Chapter 1

INTRODUCTION

Vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology represent a transformative advancement in intelligent transportation systems. This technology enables vehicles to communicate wirelessly with each other and with roadside infrastructure, facilitating enhanced safety, efficiency, and convenience on the roads.[1]

V2V Communication: In V2V communication, vehicles exchange information directly with nearby vehicles within a certain range. This exchange includes data on speed, position, acceleration, and other relevant parameters. By receiving and processing this real-time data, vehicles can anticipate potential collisions, warn drivers of dangers, and optimize traffic flow.

V2R Communication: V2R communication involves vehicles communicating with roadside infrastructure such as traffic lights, signs, and sensors.[3] This interaction allows vehicles to receive important traffic-related information, such as traffic light timings, road conditions, and detour routes. V2R can also provide vehicles with updates on weather conditions, road hazards, and other critical alerts.[1]

1.1 History

The history of vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology is rooted in the development of intelligent transportation systems (ITS) aimed at enhancing road safety and efficiency. Here's an overview of key milestones in this technological evolution:

1.1.1 Early Research and Prototypes (1990s - 2000s):

The concept of V2V and V2R communication emerged in the 1990s as researchers began exploring ways to use wireless technology to improve road safety and traffic management. Various research projects and prototypes were developed to demonstrate the feasibility and benefits of wireless communication between vehicles and infrastructure.

1.1.2 IEEE 802.11 Standards (2000s):

The IEEE 802.11 standard, which defines Wi-Fi technology, started to play a significant role in the development of V2V and V2R communication systems.
In 1999, the FCC allocated the 5.9 GHz spectrum specifically for ITS applications, paving the way for dedicated short-range communications (DSRC) based on Wi-Fi standards like 802.11p.

1.1.3 First Deployments and Pilot Projects (Mid-2000s):

The United States Department of Transportation (USDOT) initiated pilot projects such as the Vehicle Infrastructure Integration (VII) program to test V2V and V2R technologies in real-world settings.
Initial deployments focused on applications like intersection collision warning, emergency vehicle signal prioritization, and traffic flow optimization.

1.1.4 Standardization Efforts (Late 2000s - 2010s):

Standardization bodies such as IEEE and SAE (Society of Automotive Engineers) played a crucial role in defining protocols and specifications for V2V and V2R communication.
IEEE 802.11p, an amendment to the Wi-Fi standard specifically for vehicular communication, was ratified in 2010, providing a standardized framework for interoperable V2V and V2R systems.

1.1.5 Government Support and Regulations (2010s - Present):

Governments around the world recognized the potential of V2V and V2R technologies in improving road safety and traffic management.
The USDOT proposed rules in 2016 to mandate V2V communication in new vehicles, highlighting the importance of these technologies for future transportation systems.

1.1.6 Advancements in Technology and Integration (Present - Future):

Recent advancements in wireless communication technologies, including the emergence of 5G networks, are expected to further enhance V2V and V2R capabilities.
Integration with emerging technologies such as artificial intelligence (AI) and autonomous vehicles will reshape the landscape of intelligent transportation systems.

1.1.7 Current Status and Future Outlook:

V2V and V2R communication using Wi-Fi technology have transitioned from research and pilot projects to being integral components of next-generation transportation systems.
Ongoing efforts focus on addressing technical challenges, standardization issues, and regulatory frameworks to facilitate widespread adoption and deployment of these technologies.

1.2 Motivation

In a country like India, accident is a major problem which must be solved using new technologies rather than traditional ways. Indian commuters travel approximately 35 km/day, out of that 75% commute using private vehicles. If the average speed is around 60 km/h then every person spends 30 minutes per day travelling. One crore people travel per day, so people spend approximately 570 years in driving per day. This is too much time spent on just driving.
77.3% accidents caused because of Human error (2018). One-fourth of the Indian drivers use phones while driving which is dangerous for everybody (survey 2015).

1.3 Objectives

- Implement V2V Communication: Develop a system where two vehicles can communicate wirelessly with each other using NRF24L01+ modules.
- Vehicle Detection: Utilize an infrared (IR) sensor to detect vehicles in front of Vehicle.
- Real-time Alert System: Create an alert system that warns Vehicle 1 when another vehicle is too close.
- User Interaction: Allow user interaction with Vehicle 2 through a 4x4 matrix keypad for sending predefined messages.

- Visual Feedback: Provide visual feedback using a 16x2 LCD display for displaying messages and system status.
- Reliable Communication: Ensure reliable and efficient communication between vehicles and roadside infrastructure.
- Scalability: Design the system to be scalable for future enhancements and integration with other vehicles and roadside units.
- Safety Enhancement: Enhance road safety by providing timely warnings to drivers about vehicles too close to their own.

1.4 Project modules

- Arduino Nano
- NRF24L01+ modules (for wireless communication)
- Infrared (IR) sensor (for vehicle detection)
- 4x4 matrix keypad (for user input)
- 16x2 LCD display (for visual feedback)
- Battery (for power supply)
- Supporting resistors, capacitors, and wiring.

1.5 Applications

- Collision Avoidance Systems
- Traffic Flow Optimization
- Emergency Vehicle Warning Systems
- Pedestrian and Cyclist Detection

1.6 Advantages

- Improved Road Safety
- Collision Avoidance
- Traffic Efficiency
- Enhanced Emergency Response
- Improved Driver Assistance
- Optimized Traffic Management

- Enhanced Connectivity
- Cost-Effective Implementation
- Scalability and Flexibility

1.7 Disadvantages

- Security Risks
- Limited Range and Coverage
- Bandwidth Limitations
- Cost and Deployment Challenges

Fig 1.1: Vehicle to Roadside Communication

SURVEY

2.1 Literature Survey

A comprehensive literature review and survey of vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology provide insights into the evolution, challenges, and applications of this transformative area of intelligent transportation systems. Here's an overview of key findings and research contributions from relevant studies:

2.1.1 Evolution of V2V and V2R Communication:

Early research in the late 1990s and early 2000s laid the groundwork for V2V and V2R communication systems, exploring concepts like cooperative collision warning and traffic management using wireless technologies.[2]

IEEE 802.11p emerged as a critical standard for DSRC (Dedicated Short-Range Communications) in the automotive context, enabling reliable and low-latency communication between vehicles and infrastructure.

2.1.2 Communication Protocols and Standards:

The NRF24L01+ Protocol is utilized for wireless communication between vehicles, employing the SPI (Serial Peripheral Interface) protocol for communication between the Arduino Nano and the NRF24L01+ modules. Operating on the 2.4 GHz frequency band, the NRF24L01+ modules offer a communication range of 50-200 feet. Ad-Hoc Networking is established, allowing vehicles and roadside units to form direct wireless networks for communication. Data exchange follows a predefined message format to ensure compatibility and interoperability between vehicles and infrastructure. Additionally, beacon signals are broadcasted by vehicles and roadside units to identify and discover neighbouring nodes within communication range. Studies evaluate the performance of these protocols under various traffic conditions, considering factors like latency, reliability, and scalability.[6]

2.1.3 Safety and Collision Avoidance:

A significant focus of research is on safety applications enabled by V2V and V2R communication. Studies explore how real-time exchange of vehicle data (e.g., speed, position, heading) can support collision avoidance systems, lane change assistance, and emergency braking.

Simulation-based analyses and field trials demonstrate the effectiveness of these safety applications in reducing accidents and improving overall road safety.

2.1.4 Traffic Management and Efficiency:

Literature often discusses the role of V2V and V2R communication in traffic management and congestion reduction. Cooperative adaptive cruise control (CACC), traffic light optimization, and dynamic route guidance are examined as key applications.

Research evaluates the impact of these technologies on traffic flow, fuel efficiency, and emissions reduction, highlighting their potential benefits for sustainable transportation.

2.1.5 Challenges and Future Directions:

Reviews of literature identify technical challenges and research gaps in V2V and V2R communication, such as spectrum utilization, security and privacy concerns, interoperability issues, and scalability of communication networks.

Future directions in research focus on integrating V2V and V2R systems with emerging technologies like artificial intelligence (AI), edge computing, and connected autonomous vehicles (CAVs) to achieve more robust and intelligent transportation ecosystems.

2.1.6 Case Studies and Deployment Scenarios:

Case studies and deployment scenarios for the V2V communication system could include:

- Urban Traffic Management:
    - Scenario: Implement the system in a congested urban area with heavy traffic.
    - Case Study: Analyze how V2V communication helps in reducing traffic congestion by providing real-time alerts about nearby vehicles.
    - Deployment: Deploy the system in a fleet of vehicles within the city, including buses, taxis, and private cars.

- Highway Safety Enhancement:
    - Scenario: Deploy the system on a busy highway with high-speed traffic.
    - Case Study: Evaluate the effectiveness of V2V communication in preventing accidents by warning drivers about vehicles too close.
    - Deployment: Install the system in commercial trucks and passenger vehicles traveling on the highway.

- Emergency Vehicle Assistance:
    - Scenario: Use the system to assist emergency vehicles like ambulances and fire trucks.

- Case Study: Examine how V2V communication can clear the path for emergency vehicles and alert other drivers to give way.
- Deployment: Equip emergency vehicles with the V2V communication system to prioritize their movement on the road.

- Fleet Management:
  - Scenario: Apply the system in managing a fleet of vehicles for a delivery service.
  - Case Study: Investigate how V2V communication optimizes route planning, reduces delivery times, and improves overall efficiency.
  - Deployment: Install the system in delivery vans and trucks to coordinate their movements and deliveries.

- Public Transportation System:
  - Scenario: Implement the system in a public transportation network, such as buses and trams.
  - Case Study: Explore how V2V communication enhances passenger safety and schedule adherence.
  - Deployment: Integrate the system into buses and trams to communicate with each other and with roadside infrastructure.

2.1.7 Policy and Regulatory Considerations:

- Spectrum Allocation:
  - Regulatory bodies need to allocate and manage spectrum for V2V communication systems, ensuring minimal interference and maximum efficiency in the 2.4 GHz frequency band.

- Standardization:
  - Governments and industry organizations must establish and enforce standards for V2V communication protocols to ensure interoperability and compatibility among different vehicles and infrastructure.

- Data Privacy and Security:
  - Policies need to address data privacy concerns by defining rules for the collection, storage, and sharing of data transmitted over V2V networks.
  - Regulations should also mandate robust security measures to protect against cyber threats and unauthorized access to vehicle data.

- Safety Regulations:
  - Governments should enact regulations that mandate the use of V2V communication systems in vehicles to improve road safety.
  - Standards for vehicle-to-infrastructure (V2I) communication should also be established to ensure seamless integration with traffic management systems.

- Liability and Insurance:
  - Policies need to clarify liability issues in case of accidents or failures involving V2V communication systems.
  - Insurance regulations may need to be updated to account for the impact of V2V technology on accident rates and risk assessment.

- Certification and Testing:
  - Vehicles and V2V communication devices should undergo certification and testing processes to ensure compliance with regulatory standards.
  - Regular inspections and audits may be required to verify the functionality and performance of these systems.

- International Collaboration:
  - Governments should collaborate with international regulatory bodies to harmonize policies and standards for V2V communication systems across borders.
  - This collaboration is crucial for ensuring seamless interoperability and consistency in regulations.

- Public Awareness and Education:
  - Policies should include provisions for public awareness campaigns to educate drivers and stakeholders about the benefits and usage of V2V communication systems.
  - Training programs for technicians and engineers involved in the deployment and maintenance of these systems may also be necessary.

In conclusion, a literature review and survey of V2V and V2R communication using Wi-Fi technology offer a comprehensive understanding of the evolution, applications, challenges, and future prospects of this transformative area within intelligent transportation systems. Research contributions in this field contribute to advancing road safety, traffic efficiency, and sustainable mobility in urban and highway environments.

2.2 Market Survey

Conducting a market survey on vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology involves gathering insights into market trends, adoption rates, key players, growth drivers, challenges, and future prospects. Here's how you can structure and conduct such a survey:

2.2.1 Define Objectives:

Clarify the purpose of the survey, whether it's to understand market demand, assess competitor landscape, identify customer needs, or evaluate technology adoption.

2.2.2 Target Audience:

Define the target audience, including automotive manufacturers, technology providers, government agencies, transportation authorities, and potential end-users (e.g., fleet operators, commuters).

2.2.3 Survey Methodology:

Choose appropriate survey methods such as online questionnaires, phone interviews, or in-person surveys.

Consider using a mix of qualitative (open-ended questions, interviews) and quantitative (closed-ended questions, ratings) approaches.

2.2.4. Key Areas of Inquiry:

2.2.4.1 Market Size and Growth:

Assess the current market size and projected growth rate for V2V and V2R communication technologies.

2.2.4.2 Adoption Rates:

Understand the level of adoption among different stakeholders (OEMs, technology providers, governments) and geographic regions.

2.2.4.3 Competitive Landscape:

Identify key players, market leaders, and emerging startups in the V2V/V2R communication market.

2.2.4.4 Technology Trends:

Explore emerging technologies like 5G, LTE-V2X, and their impact on Wi-Fi-based V2V/V2R solutions.

2.2.4.5 Regulatory Environment:

Evaluate regulatory policies and mandates influencing the adoption of V2V/V2R communication.

Customer Needs and Challenges: Capture customer preferences, pain points, and barriers to adoption (e.g., cost, interoperability, security concerns).

2.2.4.6 Survey Distribution:

Use targeted distribution channels to reach the intended audience, such as industry associations, trade shows, online communities, and professional networks.

Leverage partnerships with industry stakeholders to access relevant contacts and distribute the survey effectively.

2.2.4.7 Data Analysis and Reporting:

Analyze survey responses to derive actionable insights and trends.

Prepare a detailed report summarizing survey findings, including market dynamics, competitor analysis, technology trends, and recommendations for stakeholders.

2.2.4.8 Dissemination of Results:

Share survey results with industry stakeholders, policymakers, and interested parties through reports, presentations, webinars, or white papers.

DESIGNING / ALGORITHM

3.1 Circuit designing:

The project vehicle to vehicle communication has 3 main blocks. Two vehicles communicating over WI-FI through NRF module. Vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication systems are crucial for road safety and efficiency. This report focuses on a V2V scenario involving two vehicles, Vehicle 1 and Vehicle 2. Vehicle 1 is equipped with an IR sensor detecting nearby vehicles, sending a "vehicle too close" signal via an NRF module. Both vehicles use Arduino Nano, with common components like a battery, 4x4 matrix keypad, and a 16x2 LCD display. [6]

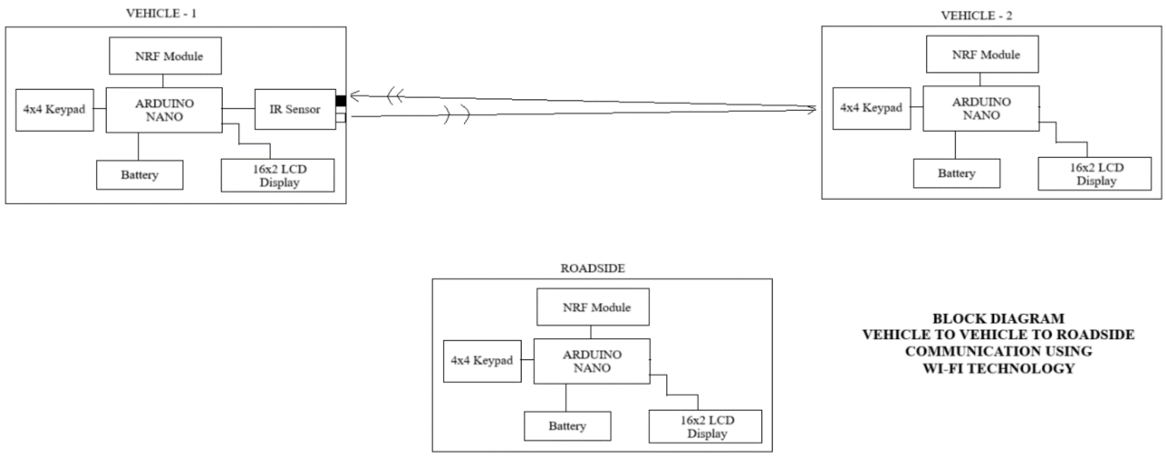

Fig 3.1: Block Diagram

3.2 Project Parts/Components:

A vehicle to vehicle to roadside communication using Arduino nano is a complex project that requires several different components to work together seamlessly. Here is a brief introduction to some of the key components used in a vehicle to vehicle project:

3.2.1 Arduino nano:

Arduino nano is heart of our project. In this Arduino nano 14 Digital I/O pins of which 6 provides PWM outputs, Analog input pins are 8, 2KB SRAM, 32KB flash memory, 1KB EEPROM memory and clock speed is 16 MHz. The Arduino Nano is a compact, versatile, and easy-to-use microcontroller board based on the ATmega328P microcontroller chip. It is part of the Arduino family of development boards, known for their simplicity and accessibility [6].

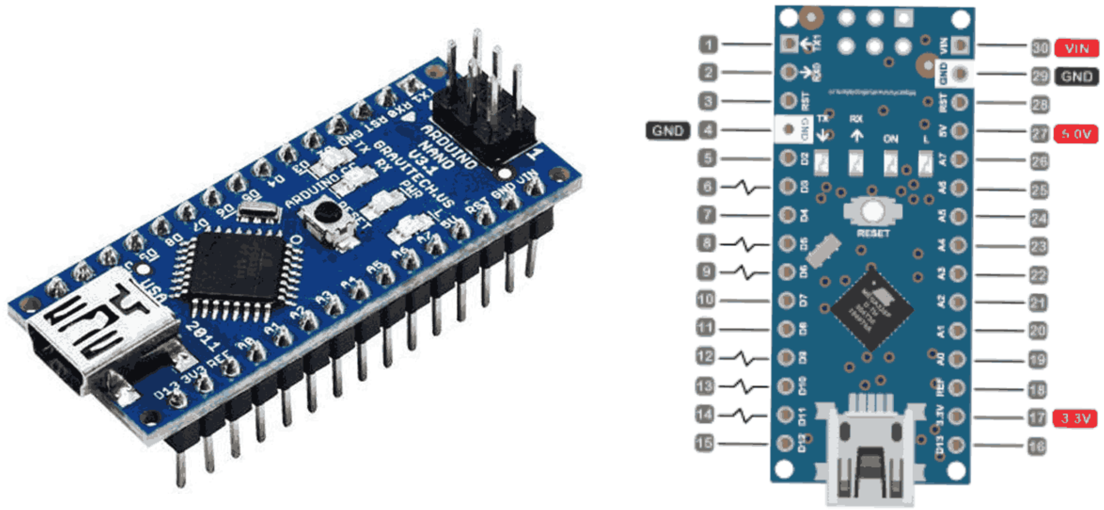

Fig 3.2: Arduino nano

Here's a brief introduction to the Arduino Nano:

3.2.1.1 Microcontroller:

The Arduino Nano is powered by the ATmega328P microcontroller, which features 32KB of flash memory for storing program code, 2KB of SRAM for data storage, and 1KB of EEPROM for non-volatile data storage.

3.2.1.2 Form Factor:

The Nano is characterized by its small size, typically around 45mm x 18mm, making it suitable for projects with space constraints or where a compact design is desired.

3.2.1.3 Connectivity:

The Nano comes equipped with a USB interface for programming and serial communication with a computer. It has digital and analog input/output pins, as well as support for I2C, SPI, and UART communication protocols, allowing it to interface with a wide range of sensors, actuators, and peripheral devices.

3.2.1.4 Programming Environment:

The Nano is programmed using the Arduino Integrated Development Environment (IDE), which provides a user-friendly interface for writing, compiling, and uploading code to the board. It supports a simplified version of the C++ programming language, making it accessible to users with varying levels of programming experience.

3.2.1.5 Expansion Options:

Despite its small size, the Nano offers a considerable number of digital and analog input/output pins, as well as support for hardware interrupts and PWM (Pulse Width Modulation) output. This allows users to interface with a wide range of sensors, actuators, displays, and other electronic components to create a diverse array of projects.

3.2.1.6 Versatility:

The Arduino Nano is suitable for a wide range of applications, including robotics, automation, IoT (Internet of Things), embedded systems, and educational projects. Its compact size, ease of use, and affordability make it a popular choice among hobbyists, students, and professionals alike.

3.2.2 NRF Module:

The NRF (Nordic Radio Frequency) module is an electronic component manufactured by Nordic Semiconductor. It is commonly used for wireless communication in various applications, including Internet of Things (IoT) devices, wireless sensor networks, remote controls, and smart home systems. [1] Here's a brief introduction to NRF modules:

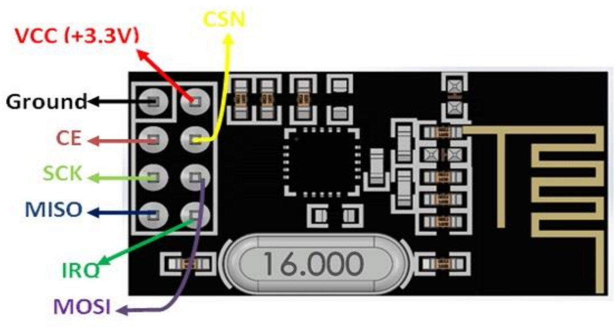

Fig 3.3: NRF module

Radio Frequency Transceiver	2.4 GHz
Operating Voltage	3.3 V
Range	50-200 ft
Protocols	SPI, NRF24L01+

Table 3.1: NRF Specifications

3.2.2.1 Wireless Communication:

NRF modules enable wireless communication between electronic devices over short distances. They utilize the 2.4 GHz ISM (Industrial, Scientific, and Medical) band and implement protocols such as Bluetooth Low Energy (BLE) and Nordic's proprietary 2.4 GHz protocol stack.

3.2.2.2 Low Power Consumption:

NRF modules are known for their low power consumption, making them suitable for battery-powered devices and energy-efficient applications. They typically feature power-saving modes, advanced sleep modes, and efficient data transmission techniques to minimize power consumption.

3.2.2.3 Range and Throughput:

NRF modules offer a balance between communication range and data throughput. Depending on the model and configuration, they can achieve communication ranges of several hundred meters in line-of-sight conditions, with data rates ranging from a few kilobits per second to several megabits per second.

3.2.2.4 Configuration and Customization:

NRF modules can be configured and customized to meet specific application requirements. Developers can adjust parameters such as transmit power, data rate, frequency channels, and packet formats using software configuration tools and programming interfaces provided by Nordic Semiconductor.

3.2.2.5 Development Ecosystem:

Nordic Semiconductor offers a comprehensive development ecosystem for NRF modules, including software development kits (SDKs), reference designs, documentation, and technical support. This ecosystem enables developers to rapidly prototype, develop, and deploy wireless applications using NRF modules.

3.2.2.6 Compatibility and Interoperability:

NRF modules are designed to be compatible with a wide range of electronic devices, microcontrollers, and development platforms. They support standard communication protocols such as SPI (Serial Peripheral Interface) and UART (Universal Asynchronous Receiver-Transmitter), allowing seamless integration with existing hardware and software systems**.**

3.2.3 LCD 16x2 display:

An LCD (Liquid Crystal Display) is a widely used electronic component that serves as a visual display for various devices, ranging from consumer electronics to industrial equipment. LCDs offer advantages such as low power consumption, compact size, and compatibility with digital interfaces. [6]

The LCD display operates based on the principle of light modulation. When voltage is applied to specific segments of the display, the liquid crystal molecules twist or align to control the passage of light through the display, resulting in the formation of characters, images, or graphics**.**

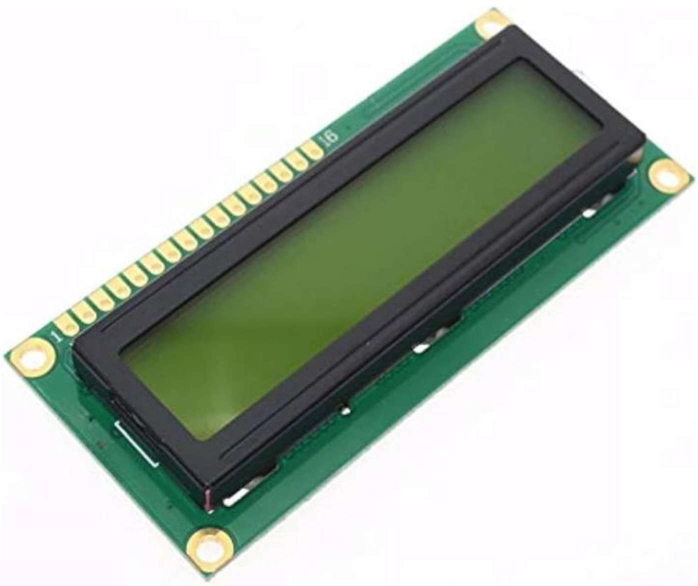

Fig 3.4: 16x2 LCD Display

3.2.3.1 Types of LCD Displays:

- **Segment LCD:**
  Used for displaying numbers, letters, and simple symbols in devices like digital watches, calculators, and appliances. Segment LCDs have predefined segments that can be activated or deactivated to form characters.

- **Dot Matrix LCD:**
  Capable of displaying more complex graphics and alphanumeric characters. Dot matrix LCDs consist of a grid of pixels, with each pixel capable of independently displaying different colours or shades.

3.2.3.2 Key Features and Benefits:

- Low Power Consumption
- Thin and Lightweight
- Digital Interface Compatibility
- Wide Range of Applications

3.2.4 IR sensors:

An infrared (IR) sensor is an electronic component that detects infrared radiation (IR) emitted from objects in its field of view. These sensors are used for various applications such as proximity sensing, motion detection, temperature measurement, and remote controls. Here's a brief introduction to IR sensors:

Fig 3.5: IR Sensor

3.2.4.1 Working Principle:

IR sensors work based on the principle of detecting IR radiation emitted by objects. All objects emit IR radiation based on their temperature (according to Planck's law of black-body radiation).

IR sensors typically use a special material known as a pyroelectric material or a photodiode to detect changes in IR radiation levels. When an object comes into the sensor's range, it absorbs or reflects IR radiation, which is then detected by the sensor.

3.2.4.2 Types of IR Sensors:

- **Passive Infrared (PIR) Sensors:**
  PIR sensors detect changes in IR radiation caused by the movement of objects (typically humans or animals) within their detection range. They are commonly used for motion-activated lighting and security systems.

- **Infrared Proximity Sensors:**
  These sensors emit IR radiation and measure the intensity of the reflected radiation. The distance to the object is determined based on the intensity of the reflected IR radiation. Infrared proximity sensors are used for object detection and obstacle avoidance in robotics and automation.

- **Infrared Temperature Sensors (IR Thermometers):**
  IR thermometers measure the temperature of objects by detecting the intensity of IR radiation emitted by the object's surface. They are non-contact temperature sensors used in industrial, medical, and consumer applications.

- **IR Receiver Modules:**
  IR receiver modules are used in remote control systems to receive signals from IR remote controls. They convert modulated IR signals (transmitted by the remote) into electrical signals that can be decoded by the device.

3.2.5 Jumper wires:

Jumper wires are fundamental electronic components used in prototyping, circuit building, and breadboarding to create connections between various electronic components, such as microcontrollers, sensors, LEDs, and other devices. Here's a brief introduction to jumper wires:

Fig 3.6: Jumper wire

3.2.5.1 Purpose and Function:

Jumper wires are insulated wires with connectors or pins at both ends that facilitate easy and temporary electrical connections between components on a breadboard, PCB (Printed Circuit Board), or development board.

They are primarily used to establish electrical continuity between different points on a circuit, allowing signals, power, and data to flow between components during prototyping and testing phases.

3.2.5.2 Types of Jumper Wires:

- **Male-to-Male Jumper Wires:**
  These wires have pin headers or connectors on both ends and are used to connect female headers or pins on different electronic components, such as microcontrollers, sensors, and development boards.

- **Male-to-Female Jumper Wires:**
  One end of these wires has pin headers or connectors, while the other end has female connectors. They are used to connect male pins on one component to female headers on another component.

- **Female-to-Female Jumper Wires:**
  Both ends of these wires have female connectors. They are used to create connections between components with female headers or pins, such as connecting two separate breadboard rows or connecting a jumper to a header pin.

3.2.6 Arduino 4 x 4 matrix Keypad:

An Arduino keypad is a user interface component used with Arduino microcontrollers to input data or commands into a project. It consists of a grid of buttons arranged in rows and columns, which can be pressed to generate specific electrical signals corresponding to different keys. Here's a brief introduction to Arduino keypads:

Fig 3.7: 4x4 Matrix Keypad

3.2.6.1 Structure and Operation:

An Arduino keypad typically uses a matrix arrangement of push buttons. The buttons are organized into rows and columns, with each button at the intersection of a row and a column.

When a button is pressed, it connects the corresponding row and column, allowing current to flow through that specific button's intersection.

3.2.6.2 Types of Arduino Keypads:

- **Membrane Keypads:**
  These keypads consist of a thin membrane with printed conductive traces, covered by a flat, flexible overlay**.** Pressing a button deforms the membrane, causing the conductive traces to make contact and generate a signal.

- **Mechanical Keypads:**
  These keypads use physical buttons that make direct contact with electrical contacts when pressed. They provide tactile feedback and are more durable than membrane keypads.

3.2.6.3 Connecting to Arduino:

Arduino keypads are connected to the Arduino board through digital input/output (I/O) pins. Each row and column of the keypad is connected to a set of I/O pins on the Arduino.

To read input from the keypad, the Arduino sequentially scans each row (by setting the row pins as outputs and the column pins as inputs) and detects which button (if any) in that row is pressed.

3.2.7 Battery

The battery is a critical component in the circuit design of the vehicle-to-vehicle (V2V) communication system. It provides the necessary power to drive the Arduino Nano and other electronic components. In this system, the battery ensures uninterrupted operation, allowing the V2V communication system to function effectively.

Fig 3.8: Battery

3.3 software use:

The Arduino IDE (Integrated Development Environment) is a software platform used for programming Arduino microcontrollers. It provides a user-friendly interface for writing, compiling, and uploading code to Arduino boards. With its simplicity and extensive library support, the Arduino IDE is widely adopted in the maker and electronics communities.

In this project, we utilize the Arduino IDE to write and upload code to the Arduino Nano microcontroller. The IDE offers a straightforward environment where code can be written in C/C++ language. Once written, the code is compiled and uploaded to the Arduino Nano via a USB connection.

Additionally, the Arduino IDE includes a serial monitor tool that allows for debugging and monitoring of data sent and received by the Arduino board. This feature is particularly useful for testing and troubleshooting communication protocols, such as those used in the vehicle-to-vehicle (V2V) communication system described in this project.

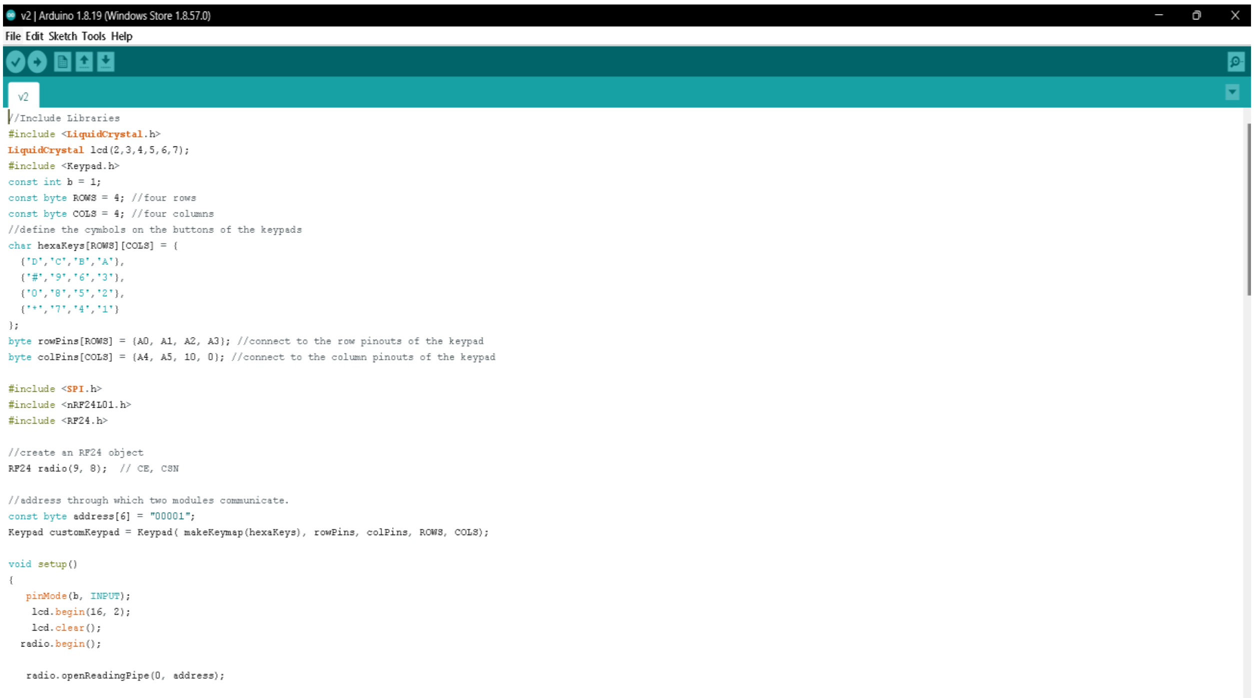

Fig 3.9: Arduino IDE

WORKING PRINCIPLE

The working principle of vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology involves establishing wireless connections between vehicles and roadside infrastructure to enable data exchange and coordination. Here's a breakdown of the working principle:

4.1 Communication Protocol:

V2V and V2R communication systems utilize SPI (Serial Peripheral Interface) protocol and operate on the 2.4 GHz frequency band, offering a communication range of 50-200 feet. This protocol is specifically designed for short-range, high-speed communication between devices. By leveraging SPI and the 2.4 GHz frequency band, these systems ensure reliable and efficient data transmission in vehicular environments.

4.2 Wireless Connectivity:

Vehicles and roadside units (RSUs) are equipped with NRF modules capable of transmitting and receiving data using the NRF24L01+ protocol. These modules establish ad-hoc wireless networks, enabling direct communication between nearby vehicles and infrastructure. [9]

4.3 Data Exchange:

Through V2V communication, vehicles become aware of the presence and status of neighbouring vehicles. They can receive and process real-time data from other vehicles to anticipate potential hazards, such as sudden braking, lane changes, or obstacles on the road.

4.4 Safety Applications:

V2V communication enables the implementation of safety applications such as collision warning systems and cooperative adaptive cruise control (CACC). Vehicles can exchange messages to warn drivers of potential collisions, support automated emergency braking, or facilitate safe merging and lane changing maneuvers.

4.5 Traffic Management:

V2R communication allows vehicles to communicate with roadside infrastructure, such as traffic lights, road signs, and traffic management systems. Vehicles can receive traffic-related information, including signal timing, road conditions, and detour routes, to optimize traffic flow and enhance efficiency.[5]

4.6 Intelligent Decision-Making:

By integrating V2V and V2R data, vehicles can make intelligent decisions to improve overall road safety and efficiency. For example, vehicles can adjust their speed and trajectory based on information received from nearby vehicles and roadside units to prevent accidents and reduce traffic congestion.

4.7 Scalability and Interoperability:

V2V and V2R communication systems are designed to be scalable and interoperable, allowing vehicles from different manufacturers and equipped with different communication technologies to communicate seamlessly. Standardization efforts ensure consistent protocols and compatibility across diverse vehicle fleets.[5]

In summary, the working principle of vehicle-to-vehicle and vehicle-to-roadside communication using Wi-Fi technology revolves around establishing reliable wireless connections, exchanging real-time data, and enabling cooperative awareness among vehicles and roadside infrastructure. These technologies play a crucial role in enhancing road safety, traffic management, and overall mobility in modern transportation systems.

OPERATING PROCEDURE

The operating procedure of vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology involves a series of steps to establish, maintain, and utilize wireless connections between vehicles and roadside infrastructure. Here's a detailed procedure outlining how V2R communication operates:

5.1 Initialization:

Vehicles and roadside units (RSUs) equipped with Wi-Fi modules and communication capabilities initialize their wireless communication systems upon.

5.2 Network Establishment:

Vehicles and RSUs form ad-hoc wireless networks using NRF24L01+ modules operating in the 2.4 GHz frequency band. Each vehicle and RSU broadcasts beacon signals to identify and discover neighbouring nodes within communication range.[7]

5.3 Data Transmission:

Vehicles continuously transmit and receive data packets containing information about their status, including speed, position, acceleration, and heading.

RSUs broadcast traffic-related data, such as traffic light timings, road conditions, and congestion alerts.

5.4 Cooperative Awareness:

Vehicles use received data from neighbouring vehicles and RSUs to build a real-time situational awareness of the surrounding traffic environment.

Cooperative awareness enables vehicles to anticipate potential hazards, detect nearby obstacles, and react to sudden changes in traffic conditions.

5.5 Safety Applications:

V2V communication supports safety applications, such as collision warning systems and emergency braking assistance.

Vehicles exchange safety messages to warn drivers of impending collisions, provide alerts for lane departures, and support cooperative maneuvers to avoid accidents.

5.6 Traffic Management:

V2R communication allows vehicles to interact with roadside infrastructure, such as traffic lights and road signs.

Vehicles receive traffic-related information from RSUs, including signal phase and timing (SPaT), intersection status, and traffic flow data to optimize driving behaviour and improve traffic efficiency.

5.7 Decentralized Decision-Making:

Vehicles autonomously make decisions based on received V2V and V2R data to enhance safety and efficiency.

Decisions may include adjusting speed, changing lanes, or modifying driving behaviour to respond to dynamic traffic conditions and avoid potential conflicts.

5.8 Interoperability and Scalability:

V2V and V2R systems are designed to be interoperable and scalable, allowing vehicles and infrastructure from different manufacturers and jurisdictions to communicate seamlessly.

Standardization efforts ensure consistent protocols, messaging formats, and interoperability across diverse communication technologies.

5.9 Continuous Monitoring and Adaptation:

Vehicles and RSUs continuously monitor the surrounding environment, adapt to changing conditions, and update communication parameters to maintain reliable wireless connections.

5.10 End-to-End Integration:

V2V and V2R communication systems integrate with other intelligent transportation systems (ITS) components, such as vehicle-to-infrastructure (V2I) systems and connected autonomous vehicles (CAVs), to create a comprehensive ecosystem for smart mobility.

In summary, the operating procedure of vehicle-to-vehicle and vehicle-to-roadside communication using Wi-Fi technology involves dynamic data exchange, cooperative awareness, and decentralized decision-making to enhance road safety, traffic management, and overall transportation efficiency. These technologies play a critical role in the evolution of intelligent transportation systems (ITS) towards safer, more connected, and sustainable mobility solutions.

RESULTS AND SNAPSHOTS

6.1 Results:

The results of vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology have demonstrated several key benefits and outcomes in the realm of intelligent transportation systems (ITS) and automotive safety. Here are some notable results and impacts of deploying Wi-Fi-based V2V/V2R communication systems:

6.1.1 Improved Road Safety:

V2V communication has shown to significantly enhance road safety by enabling real-time exchange of critical safety information between vehicles. This includes warnings about nearby vehicles, potential collisions, lane departures, and hazardous road conditions.

Studies have indicated a reduction in traffic accidents and fatalities through the use of V2V safety applications like collision avoidance systems and cooperative braking.

6.1.2 Enhanced Traffic Efficiency:

V2V and V2R communication systems contribute to optimizing traffic flow and reducing congestion by providing vehicles with up-to-date traffic information, such as traffic light timings, road closures, and alternative routes.

Cooperative adaptive cruise control (CACC) systems enabled by V2V communication help maintain safe and efficient spacing between vehicles, improving overall traffic efficiency and reducing fuel consumption.

6.1.3 Emergency Response and Assistance:

V2V communication facilitates faster emergency response by enabling vehicles to communicate distress signals or emergency alerts to nearby vehicles and roadside units. This enhances situational awareness during emergency situations and aids in coordinating response efforts.[10]

6.1.4 Automated Driving and Connectivity:

Wi-Fi-based V2V/V2R communication is a foundational technology for connected and autonomous vehicles (CAVs), enabling vehicle-to-vehicle coordination and interaction in autonomous driving scenarios.

V2V connectivity supports advanced driver-assistance systems (ADAS) and cooperative driving features, paving the way for safer and more efficient autonomous transportation systems.

6.1.5 Standardization and Regulatory Advancements:

Regulatory bodies and government agencies have recognized the potential benefits of V2V/V2R technologies and have initiated policies and mandates to promote their deployment and integration into future transportation infrastructure. Standardizations and regulatory advancements in V2V communication systems include:

- IEEE 802.11p (WAVE):
    - Standardized by the Institute of Electrical and Electronics Engineers (IEEE), 802.11p specifies the use of the 5.9 GHz frequency band for V2V and V2I communication.
    - Regulatory advancements include spectrum allocation and management to support 802.11p, ensuring interference-free communication.

- NHTSA Mandates:
    - The U.S. National Highway Traffic Safety Administration (NHTSA) has proposed mandates for V2V communication in vehicles to improve road safety.
    - Regulatory advancements involve setting timelines and requirements for automakers to implement V2V technology in new vehicles.

- EU Cooperative ITS Directive:
    - The European Union has issued directives for Cooperative Intelligent Transport Systems (C-ITS), promoting the deployment of V2V and V2I communication technologies.
    - Regulatory advancements include defining interoperability standards and requirements for C-ITS deployment across EU member states.

- ISO/SAE 21434:
    - ISO/SAE 21434 is a joint standard for cybersecurity of automotive systems, including V2V communication.

    - Regulatory advancements involve integrating cybersecurity requirements into vehicle regulations to address cyber threats in V2V communication systems.

- Global Harmonization:
    - International organizations such as the United Nations Economic Commission for Europe (UNECE) work towards global harmonization of regulations for V2V communication.
    - Regulatory advancements focus on aligning standards and requirements across different regions to facilitate cross-border deployment of V2V systems.

- FCC Regulations:
    - The U.S. Federal Communications Commission (FCC) regulates the use of radio frequencies, including those used by V2V communication devices.
    - Regulatory advancements involve updating FCC rules to support V2V technologies and ensure spectrum availability for their operation.

- Privacy and Data Protection:
    - Regulatory advancements include the development of privacy and data protection regulations specific to V2V communication.
    - Standards such as ISO 27001 address cybersecurity and data privacy concerns in V2V systems.

- Testing and Certification:
    - Regulatory advancements involve establishing testing and certification processes for V2V communication devices to ensure compliance with standards and regulations.
    - Organizations like ETSI (European Telecommunications Standards Institute) provide certification schemes for V2V equipment.

These standardizations and regulatory advancements are essential for promoting the widespread adoption of V2V communication systems and ensuring their safe and interoperable operation on a global scale.

6.1.6 Challenges and Future Directions:

While Wi-Fi-based V2V/V2R communication offers significant advantages, challenges remain, including spectrum allocation, cybersecurity, interoperability, and scalability in dense urban environments.

Future directions involve integrating V2V/V2R systems with emerging technologies like 5G networks, edge computing, and artificial intelligence (AI) to further enhance the capabilities and reliability of intelligent transportation systems.[8]

In summary, the results of vehicle-to-vehicle and vehicle-to-roadside communication using Wi-Fi technology demonstrate tangible benefits in terms of improved road safety, enhanced traffic efficiency, and support for emerging mobility paradigms such as connected and autonomous vehicles. Continued research, development, and deployment efforts are key to realizing the full potential of Wi-Fi-based V2V/V2R communication in shaping the future of transportation.

6.2 V2V Communication for Autonomous Vehicles:

Autonomous vehicles rely on sensors like radar, cameras, and lidar to provide them with a comprehensive view of their surroundings. However, transportation experts emphasize that vehicles equipped with V2V technology could gain additional insights into hazards that may not be immediately visible to these sensors. This information is transmitted in updates ten times per second, enhancing the vehicles' situational awareness. Despite these promising advancements, there is a lack of consensus and prioritization for V2V technology within certain sectors of the federal government. A significant issue revolves around the 5.9-gigahertz spectrum, which serves as the foundation for V2V communications. Originally reserved for intelligent transportation applications, this spectrum remains largely untapped, sparking debates and conflicts in Washington over its usage. [5]

6.3 Snapshots:

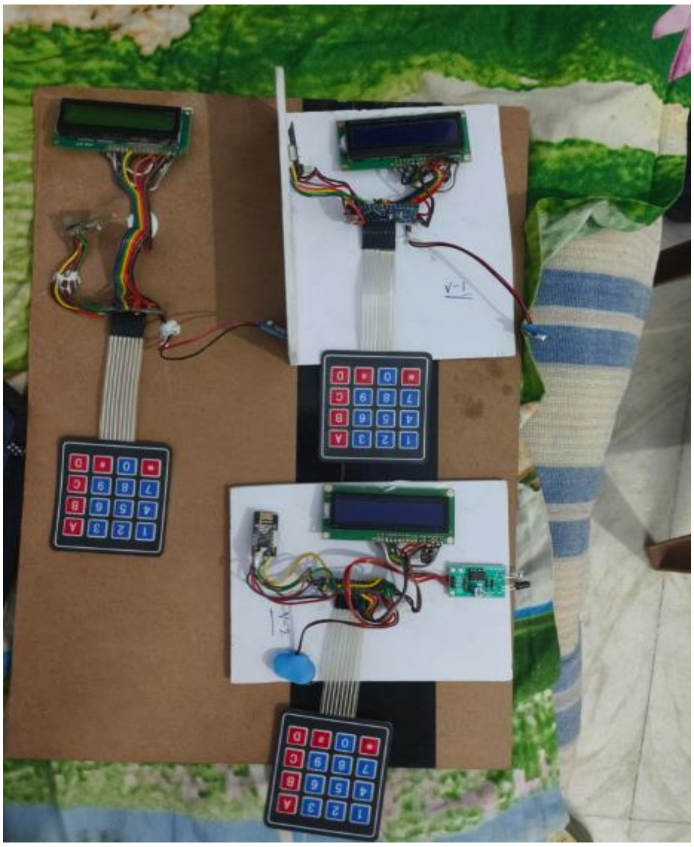

Fig 6.1: Top View

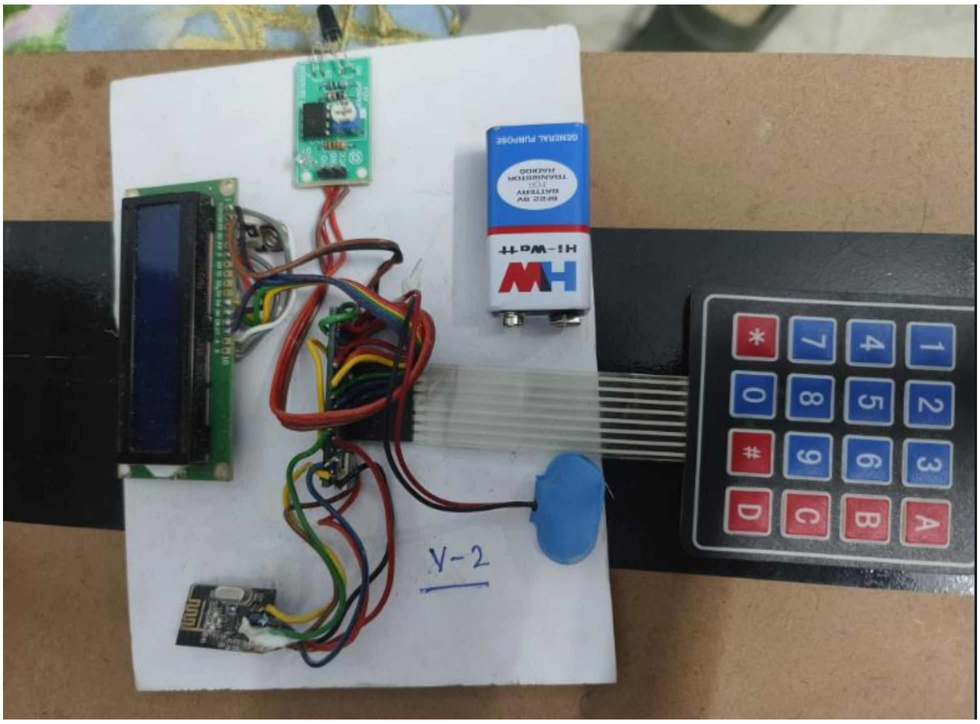

Fig 6.2: Vehicle

CONCLUSION

In conclusion, vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication using Wi-Fi technology represents a transformative approach to enhancing road safety, traffic efficiency, and mobility within intelligent transportation systems (ITS). The deployment and utilization of Wi-Fi-based communication systems have yielded several key insights and outcomes:

7.1 Improved Road Safety:

V2V communication enables vehicles to exchange real-time safety information, including collision warnings, lane departure alerts, and hazardous road conditions. This contributes to a significant reduction in traffic accidents and fatalities, enhancing overall road safety.

7.2 Enhanced Traffic Efficiency:

V2V and V2R systems optimize traffic flow by providing vehicles with dynamic traffic information, such as traffic light timings and alternative routes. Cooperative driving features, facilitated by Wi-Fi communication, reduce congestion and improve fuel efficiency.

7.3 Emergency Response and Assistance:

Wi-Fi-enabled V2V communication supports faster emergency response by allowing vehicles to broadcast distress signals and emergency alerts. This aids in improving situational awareness during critical incidents and enhances coordination among emergency responders.**[10]**

7.4 Integration with Autonomous Vehicles:

V2V connectivity is foundational for the development and deployment of connected and autonomous vehicles (CAVs). Wi-Fi-based communication systems enable cooperative driving features, such as cooperative adaptive cruise control (CACC), contributing to safer and more efficient autonomous transportation.

7.5 Real-World Deployments and Success Stories:

Numerous real-world deployments and pilot projects have demonstrated the feasibility and effectiveness of Wi-Fi-based V2V/V2R communication across diverse urban and highway environments. These deployments serve as success stories showcasing the scalability and interoperability of V2V/V2R technologies.

7.6 Regulatory and Standardization Efforts:

The advancement of standards such as IEEE 802.11p/WAVE has facilitated the widespread adoption of Wi-Fi-based V2V/V2R communication. Regulatory initiatives and policies promote the integration of V2V/V2R technologies into future transportation infrastructure.

7.7 Future Directions and Challenges:

Despite the successes, challenges remain, including spectrum allocation, cybersecurity concerns, interoperability, and scalability in complex urban environments. Future directions involve integrating V2V/V2R systems with emerging technologies like 5G networks and AI-driven mobility solutions.[5]

In summary, vehicle-to-vehicle and vehicle-to-roadside communication using Wi-Fi technology holds immense promise in revolutionizing the transportation landscape. The ongoing development and deployment of Wi-Fi-based V2V/V2R communication systems underscore their pivotal role in advancing road safety, traffic management, and mobility solutions for smart cities and future mobility ecosystems. Continued research, innovation, and collaboration among industry stakeholders, regulatory bodies, and academia are essential for realizing the full potential of Wi-Fi-enabled V2V/V2R communication in shaping the future of transportation.

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APPENDIX

Arduino codes:

- **Vehicle 1:**

```
//Include Libraries
#include <LiquidCrystal.h>
LiquidCrystal lcd(2,3,4,5,6,7);
#include <Keypad.h>
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
//define the cymbols on the buttons of the keypads
char hexaKeys[ROWS][COLS] = {
  {'D','C','B','A'},
  {'#','9','6','3'},
  {'0','8','5','2'},
  {'*','7','4','1'}
};
byte rowPins[ROWS] = {A0, A1, A2, A3}; //connect to the row pinouts of the keypad
byte colPins[COLS] = {A4, A5, 10, 0}; //connect to the column pinouts of the keypad

#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

//create an RF24 object
RF24 radio(9, 8);  // CE, CSN

//address through which two modules communicate.
const byte address[6] = "00001";
Keypad customKeypad = Keypad( makeKeymap(hexaKeys), rowPins, colPins,
ROWS, COLS);

void setup()
{
   lcd.begin(16, 2);
   lcd.clear();
  radio.begin();

   radio.openReadingPipe(0, address);

  //Set module as receiver
  radio.startListening();
```

```
  //Set module as transmitter
  //radio.stopListening();
  // Serial.begin(9600);
}
void loop()
{
  /*
  //Send message to receiver
  const char text[] = "Hello World";
  radio.write(&text, sizeof(text));
  */

   if (radio.available())
  {
    lcd.clear();
    char text[32] = {0};
    radio.read(&text, sizeof(text));
    lcd.print(text);
  }
  char customKey = customKeypad.getKey();

  if (customKey){
    //lcd.print(customKey);
    if(customKey=='1')
    {
      radio.stopListening();
       radio.openWritingPipe(address);
      lcd.print("hello");
        const char text[] = "Hello from V-1";
  radio.write(&text, sizeof(text));
      delay(2000);
      lcd.clear();
      lcd.print("message sent");
      delay(2000);
      lcd.clear();
      radio.startListening();
    }

      if(customKey=='2')
    {
      radio.stopListening();
       radio.openWritingPipe(address);
      lcd.print("need help");
        const char text[] = "Need help V-1";
```

```
  radio.write(&text, sizeof(text));
     delay(2000);
     lcd.clear();
     lcd.print("message sent");
     delay(2000);
     lcd.clear();
     radio.startListening();
    }
  }

// delay(1000);
}
```

- **Vehicle 2:**

```
//Include Libraries
#include <LiquidCrystal.h>
LiquidCrystal lcd(2,3,4,5,6,7);
#include <Keypad.h>
const int b = 1;
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
//define the cymbols on the buttons of the keypads
char hexaKeys[ROWS][COLS] = {
  {'D','C','B','A'},
  {'#','9','6','3'},
  {'0','8','5','2'},
  {'*','7','4','1'}
};
byte rowPins[ROWS] = {A0, A1, A2, A3}; //connect to the row pinouts of the
keypad
byte colPins[COLS] = {A4, A5, 10, 0}; //connect to the column pinouts of the
keypad

#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

//create an RF24 object
RF24 radio(9, 8);  // CE, CSN

//address through which two modules communicate.
const byte address[6] = "00001";
```

```
Keypad customKeypad = Keypad( makeKeymap(hexaKeys), rowPins, colPins,
ROWS, COLS);

void setup()
{
   pinMode(b, INPUT);
    lcd.begin(16, 2);
    lcd.clear();
  radio.begin();

   radio.openReadingPipe(0, address);

  //Set module as receiver
  radio.startListening();
  //Set module as transmitter
  //radio.stopListening();
  // Serial.begin(9600);
}
void loop()
{
  /*
  //Send message to receiver
  const char text[] = "Hello World";
  radio.write(&text, sizeof(text));
  */

   if (radio.available())
  {
    lcd.clear();
    char text[32] = {0};
    radio.read(&text, sizeof(text));
    lcd.print(text);
  }
  char customKey = customKeypad.getKey();

  if (customKey){
    //lcd.print(customKey);
    if(customKey=='1')
    {
      radio.stopListening();
       radio.openWritingPipe(address);
      lcd.print("hello");
        const char text[] = "Hello from V-2";
  radio.write(&text, sizeof(text));
```

```
    delay(2000);
    lcd.clear();
    lcd.print("message sent");
    delay(2000);
    lcd.clear();
    radio.startListening();
  }

    if(customKey=='2')
  {
    radio.stopListening();
     radio.openWritingPipe(address);
    lcd.print("need help");
      const char text[] = "Need help V-2";
radio.write(&text, sizeof(text));
    delay(2000);
    lcd.clear();
    lcd.print("message sent");
    delay(2000);
    lcd.clear();
    radio.startListening();
  }

  if(customKey=='8')
  {
    radio.stopListening();
     radio.openWritingPipe(address);
    lcd.print("abc");
      const char text[] = "abc";
radio.write(&text, sizeof(text));
    delay(2000);
    lcd.clear();
    lcd.print("message sent");
    delay(2000);
    lcd.clear();
    radio.startListening();
  }
}
if(digitalRead(b==HIGH))
{
 radio.stopListening();
     radio.openWritingPipe(address);
    lcd.print("vehicle too close");
      const char text[] = "vehicle too close";
```

```
  radio.write(&text, sizeof(text));
    delay(2000);
    lcd.clear();
    lcd.print("message sent");
    delay(2000);
    lcd.clear();
    radio.startListening();
  }
// delay(1000);
}
```

- **Roadside:**

```
//Include Libraries
#include <LiquidCrystal.h>
LiquidCrystal lcd(2,3,4,5,6,7);
#include <Keypad.h>
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
//define the cymbols on the buttons of the keypads
char hexaKeys[ROWS][COLS] = {
  {'D','C','B','A'},
  {'#','9','6','3'},
  {'0','8','5','2'},
  {'*','7','4','1'}
};
byte rowPins[ROWS] = {A0, A1, A2, A3}; //connect to the row pinouts of the
keypad
byte colPins[COLS] = {A4, A5, 10, 0}; //connect to the column pinouts of the
keypad

#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

//create an RF24 object
RF24 radio(9, 8);  // CE, CSN

//address through which two modules communicate.
const byte address[6] = "00001";
Keypad customKeypad = Keypad( makeKeymap(hexaKeys), rowPins, colPins,
ROWS, COLS);

void setup()
```

```
{
    lcd.begin(16, 2);
    lcd.clear();
  radio.begin();

   radio.openReadingPipe(0, address);

  //Set module as receiver
  radio.startListening();
  //Set module as transmitter
  //radio.stopListening();
  // Serial.begin(9600);
}
void loop()
{
  /*
  //Send message to receiver
  const char text[] = "Hello World";
  radio.write(&text, sizeof(text));
  */

   if (radio.available())
  {
    lcd.clear();
    char text[32] = {0};
    radio.read(&text, sizeof(text));
    lcd.print(text);
  }
  char customKey = customKeypad.getKey();

  if (customKey){
    //lcd.print(customKey);
    if(customKey=='1')
    {
      radio.stopListening();
       radio.openWritingPipe(address);
      lcd.print("hello");
        const char text[] = "Hello from R";
  radio.write(&text, sizeof(text));
      delay(2000);
      lcd.clear();
      lcd.print("message sent");
      delay(2000);
      lcd.clear();
```

```
    radio.startListening();
   }

    if(customKey=='2')
   {
    radio.stopListening();
     radio.openWritingPipe(address);
    lcd.print("stop V-1");
      const char text[] = "Stop V-1";
 radio.write(&text, sizeof(text));
    delay(2000);
    lcd.clear();
    lcd.print("message sent");
    delay(2000);
    lcd.clear();
    radio.startListening();
   }

    if(customKey=='3')
   {
    radio.stopListening();
     radio.openWritingPipe(address);
    lcd.print("stop V-2");
      const char text[] = "Stop V-2";
 radio.write(&text, sizeof(text));
    delay(2000);
    lcd.clear();
    lcd.print("message sent");
    delay(2000);
    lcd.clear();
    radio.startListening();
   }
 }
//  delay(1000);
}
```

3. Bill of material

S. No.	Name of Component	Number	Price (Rs)
01	Arduino Nano	3	1107
02	NRF module	3	600
03	IR sensor	1	85
04	LCD Display	3	600
05	4x4 Matrix Arduino Keypad	3	375
06	Connecting wire	-	100
07	Battery	3	30

Table 01: Bill of material

4. Data Sheet

4.1 Arduino NANO:

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source (6-12V).5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: Ground pins.
Reset	Reset	Reset the microcontroller
Analog Pins	A0-A7	Used to measure analog voltage in the range of 0-5V
Input/Output Pins	Digital Pins D0 - D13	Can be used as input or output pins. 0V (low) and 5V (high)
Serial	Rx, Tx	Used to receive and transmit TTL serial data.
External Interrupts	2,3	To trigger an interrupt.
PWM	3,5,6,9,11	Provides 8-bit PWM output
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication
Inbuilt LED	13	To turn on the inbuilt LED.

IIC	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide a reference voltage for input voltage.

Table: 4.1.1: PIN Specifications of Arduino NANO

4.1.1 Arduino Nano Technical Specifications:

Microcontroller	ATmega328P – 8-bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage for Vin pin	7-12V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (2 KB is used for Bootloader)

SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz
Communication	IIC, SPI, USART

Table:4.1.2: ARDUINO NANO SPECIFICATIONS

Features

- **ATmega328** Microcontroller
  - High-performance low-power 8-bit processor
  - Achieve up to 16 MIPS for 16 MHz clock frequency
  - 32 kB of which 2 KB used by bootloader
  - 2 kB internal SRAM
  - 1 kB EEPROM
  - 32 x 8 General Purpose Working Registers
  - Real Time Counter with Separate Oscillator
  - Six PWM Channels
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
- **Power**
  - Mini-B USB connection
  - 7-15V unregulated external power supply (pin 30)
  - 5V regulated external power supply (pin 27)
- **Sleep Modes**
  - Idle
  - ADC Noise Reduction
  - Power-save
  - Power-down
  - Standby
  - Extended Standby
- **I/O**
  - 20 Digital
  - 8 Analog
  - 6 PWM Output

4.2 NRF Module:

nRF24L01+

Single Chip 2.4GHz Transceiver

Preliminary Product Specification v1.0

Key Features

- Worldwide 2.4GHz ISM band operation
- 250kbps, 1Mbps and 2Mbps on air data rates
- Ultra low power operation
- 11.3mA TX at 0dBm output power
- 13.5mA RX at 2Mbps air data rate
- 900nA in power down
- 26µA in standby-I
- On chip voltage regulator
- 1.9 to 3.6V supply range
- Enhanced ShockBurst™
- Automatic packet handling
- Auto packet transaction handling
- 6 data pipe MultiCeiver™
- Drop-in compatibility with nRF24L01
- On-air compatible in 250kbps and 1Mbps with nRF2401A, nRF2402, nRF24E1 and nRF24E2
- Low cost BOM
- ±60ppm 16MHz crystal
- 5V tolerant inputs
- Compact 20-pin 4x4mm QFN package

Applications

- Wireless PC Peripherals
- Mouse, keyboards and remotes
- 3-in-1 desktop bundles
- Advanced Media center remote controls
- VoIP headsets
- Game controllers
- Sports watches and sensors
- RF remote controls for consumer electronics
- Home and commercial automation
- Ultra low power sensor networks
- Active RFID
- Asset tracking systems
- Toys

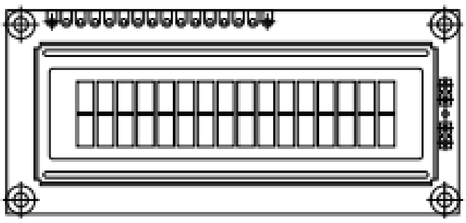
4.3 LCD Display:

LCD-016N002B-CFH-ET

www.vishay.com

Vishay

16 x 2 Character LCD



FEATURES

- Type: Character
- Display format: 16 x 2 characters
- Built-in controller: ST 7066 (or equivalent)
- Duty cycle: 1/16
- 5 x 8 dots includes cursor
- + 5 V power supply
- LED can be driven by pin 1, pin 2, or A and K
- N.V. optional for + 3 V power supply
- Optional: Smaller character size (2.95 mm x 4.35 mm)
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

MECHANICAL DATA		
ITEM	STANDARD VALUE	UNIT
Module Dimension	80.0 x 36.0 x 13.2 (max.)	mm
Viewing Area	66.0 x 16.0	
Dot Size	0.55 x 0.65	
Dot Pitch	0.60 x 0.70	
Mounting Hole	75.0 x 31.0	
Character Size	2.95 x 5.55	

ABSOLUTE MAXIMUM RATINGS					
ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	V_{DD} to V_{SS}	- 0.3	-	13	V
Input Voltage	V_I	V_{SS}	-	V_{DD}	

Note

- V_{SS} = 0 V, V_{DD} = 5.0 V

ELECTRICAL CHARACTERISTICS						
ITEM	SYMBOL	CONDITION	STANDARD VALUE			UNIT
			MIN.	TYP.	MAX.	
Input Voltage	V_{DD}	V_{DD} = + 5 V	4.5	5.0	5.5	V
Supply Current	I_{DD}	V_{DD} = + 5 V	1.0	1.2	1.5	mA
Recommended LC Driving Voltage for Normal Temperature Version Module	V_{DD} to V_0	- 20 °C	-	-	5.2	V
		0 °C	-	-	-	
		25 °C	-	3.7	-	
		50 °C	-	-	-	
		70 °C	3.1	-	-	
LED Forward Voltage	V_F	25 °C	-	4.2	4.6	V
LED Forward Current - Array	I_F	25 °C	-	100	-	mA
LED Forward Current - Edge			-	20	40	
EL Power Supply Current	I_{EL}	V_{EL} = 110 V_{AC}, 400 Hz	-	-	5.0	mA

DISPLAY CHARACTER ADDRESS CODE

Display Position

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
DD RAM Address	40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F