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U-Bend Accident Prevention Through Lora Communication

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Abstract: *With the rapid development of wireless communication technologies, communication among the vehicles has become a crucial component in modern intelligent transportation systems. This paper presents a long-range, low-power communication system using LoRa (Long Range) technology to enhance road safety and vehicle coordination. The system utilizes Arduino-based controllers equipped with LoRa modules, ultrasonic sensors for obstacle detection, and emergency alert mechanisms. The objective is to provide real-time data exchange between vehicles, allowing them to react proactively to potential hazards. Ultrasonic sensors are employed on each vehicle to detect obstacles in the surroundings, while push button switches are provided for emergency situations, triggering alerts. In case of an emergency, a buzzer is activated, providing an audible warning. The data is communicated between the vehicles using the LoRa modules, allowing for real-time alerts and status updates on each vehicle's condition. The system is powered by 12V adapters and features LCD displays to show the status of each vehicle's sensors. This approach aims to improve road safety by enabling vehicles to communicate and respond proactively to obstacles and emergencies. The proposed solution addresses the limitations of conventional short-range communication technologies like Wi-Fi and Bluetooth by offering an extended transmission range with minimal power consumption. This study explores the feasibility, design, and implementation of the system, highlighting its benefits in improving vehicular safety and reducing accident risks.*

Keywords: *LoRa, V2V Communication, Arduino, Ultrasonic Sensor, Emergency Alert, Road Safety, Wireless Communication*

1. INTRODUCTION

With the increasing demand for intelligent transportation systems, Vehicle-to-Vehicle (V2V) communication is emerging as a vital technology to improve road safety, traffic efficiency, and autonomous driving. Traditional communication methods like DSRC and cellular networks often face challenges such as high latency, limited range, and infrastructure dependency. In contrast, LoRa (Long Range) technology offers low power consumption, long-range communication, and high signal reliability, making it a suitable candidate for V2V applications [4][5]. Studies have shown that LoRa can maintain robust signal performance under various vehicular speeds and mobility conditions, especially when configured with suitable parameters like spreading factor and bandwidth [1][2]. Field tests have also demonstrated LoRa's ability to support vehicle-to-roadside (V2I) communication with consistent data transmission rates even in non-line-of-sight environments [3]. Further evaluations highlight LoRa's adaptability in urban and rural mobility environments, showcasing its low-latency performance and ability to operate under varying Doppler effects and signal interference [5][6]. Integrating LoRa WAN in vehicular networks has been tested and found suitable for real-time applications, including traffic alerts, proximity warnings, and environmental sensing [3][4][7]. Our project leverages these capabilities by designing a LoRa-based V2V communication system. It facilitates real-time data exchange between vehicles, enhancing driver safety and environmental awareness. The system includes:

- Obstacle detection using ultrasonic sensors (HC-SR04) to prevent collisions [8].
- Driver fatigue monitoring through heartbeat sensing using MAX30102 [9][10].
- In-car air quality monitoring using MQ2 gas sensors for pollution detection [12].

The LoRa modulation scheme, based on Chirp Spread Spectrum (CSS), provides excellent range and resistance to noise and interference—essential for vehicular motion scenarios [6]. These benefits, along with LoRa WAN's duty cycle regulations and its ability to operate in unlicensed frequency bands, make it ideal for cost-effective and scalable deployments [7]. According to the latest developments from industry sources, LoRa continues to evolve with enhanced features and integration options for smart mobility applications [4]. By combining wireless communication with intelligent sensing, this project presents a practical and efficient solution for modern V2V systems, supporting future implementations of smart transportation and urban mobility networks.

2. LITERATURE SURVEY

LoRa WAN-based Vehicle-to-Vehicle (V2V) communication systems to enhance road safety and driving efficiency. Z. Zhang et al. (2020) proposed a LoRa WAN-based V2V communication system designed to prevent intersection collisions. The system employs a pre-crash algorithm to detect potential collisions between vehicles approaching an intersection and sends warning messages to the involved vehicles via LoRa WAN. Their findings suggest that the system can significantly reduce the frequency of intersection collisions, making it a viable solution for improving road safety. Building on this, M. F. Ahmed et al. (2021) conducted a performance assessment of LoRa WAN for V2V communication in a highway environment. Through simulation, the study analyzed the effects of transmission power, traffic density, and vehicle speed on communication latency and reliability. The results revealed that LoRa WAN maintains reliable communication even under high-speed and high-density traffic conditions, while operating at low transmission power. Similarly, Y. Han et al. (2021) examined the use of LoRa WAN-based V2V communication for cooperative driving. They proposed a system that integrates a Cooperative Adaptive Cruise Control (CACC) algorithm to reduce fuel consumption and improve traffic flow. Simulation results confirmed the system's effectiveness in enhancing traffic efficiency and lowering fuel use on highways. Collectively, these studies highlight the potential of LoRa WAN technology to support various V2V applications that contribute to safer and more efficient transportation systems.

3. EXISTING SYSTEM

Current V2V communication systems primarily rely on technologies like:
Wi-Fi and DSRC (Dedicated Short-Range Communication) provide high bandwidth but have a limited range, typically less than 1 km.
Bluetooth and Zigbee have low power consumption but are highly susceptible to interference.
Cellular networks (4G/5G) provide reliable coverage but depend on infrastructure, leading to high operational costs.
The key challenges in existing systems are as follows

1. Limited Communication Range: Conventional wireless technologies have a limited communication range, making them ineffective for long-distance V2V communication.
2. High Power Consumption: High power consumption requires frequent recharging or the use of large battery packs.
3. Interference and Congestion: Dense traffic environments cause signal interference and congestion, resulting in packet loss.
4. Infrastructure Dependence: Cellular-based solutions require network towers, making them less feasible in remote areas.

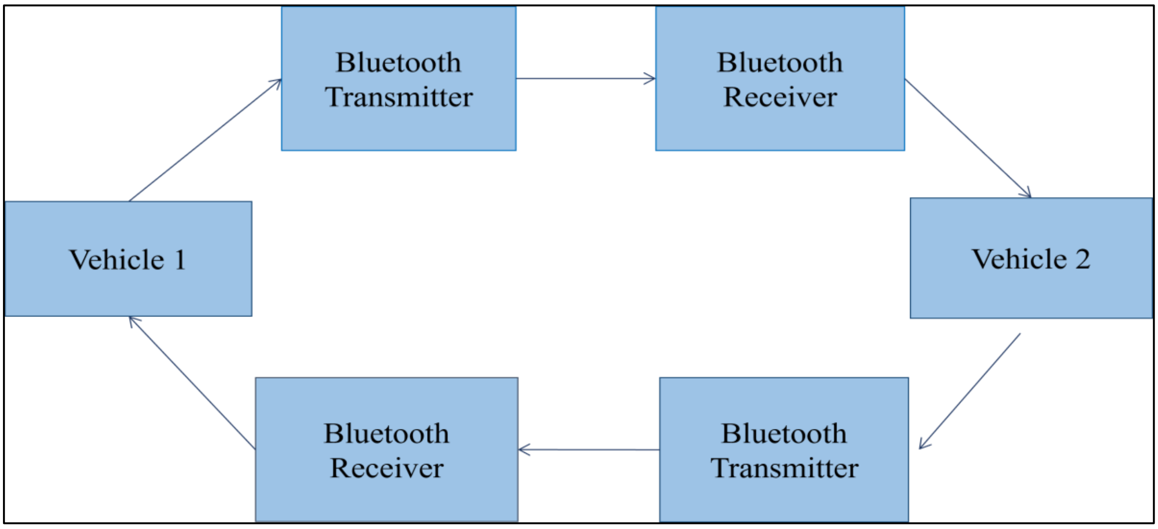

FIGURE 1. Block Diagram of Existing System

TABLE 1. Technical Characteristics of WiFi

Parameter	**Description**
Range	Up to 10 meters
Date rate	High (up to several Gbps)
Power consumption	Moderate to high

TABLE 2. Technical Characteristics of Bluetooth

Parameter	**Description**
Range	Short up to 100 meters
Date rate	Moderate (up to 2 Mbps)
Power Consumption	Low to Moderate

4. PROPOSED SYSTEM

The proposed system integrates LoRa (Long Range) communication technology for vehicle-to-vehicle (V2V) communication, enabling reliable and long-range data exchange between vehicles. Unlike traditional wireless communication methods, LoRa offers extended coverage and stability, making it ideal for real-time vehicle communication, even in remote or low-signal areas. Each vehicle in the system is equipped with an Arduino microcontroller, a LoRa module for wireless communication, ultrasonic sensors for obstacle detection, and push-button switches for emergency alerts. The ultrasonic sensors continuously monitor the surroundings for potential obstacles, while the push-button switches allow drivers to manually send emergency signals.

TABLE 3. Technical Characteristics of LoRa Module

Parameter	**Description**
Range	Up to 10km
Date rate	1ow to moderate upto 50kbps
Power Consumption	5 volts

The collected data is transmitted via LoRa modules to nearby vehicles, alerting them to hazards or emergency situations in real-time. This system enhances road safety by ensuring seamless and power-efficient communication between vehicles. The low power consumption and long-range capabilities of LoRa make this solution highly effective for intelligent transportation systems, reducing the risk of collisions and improving overall traffic management.

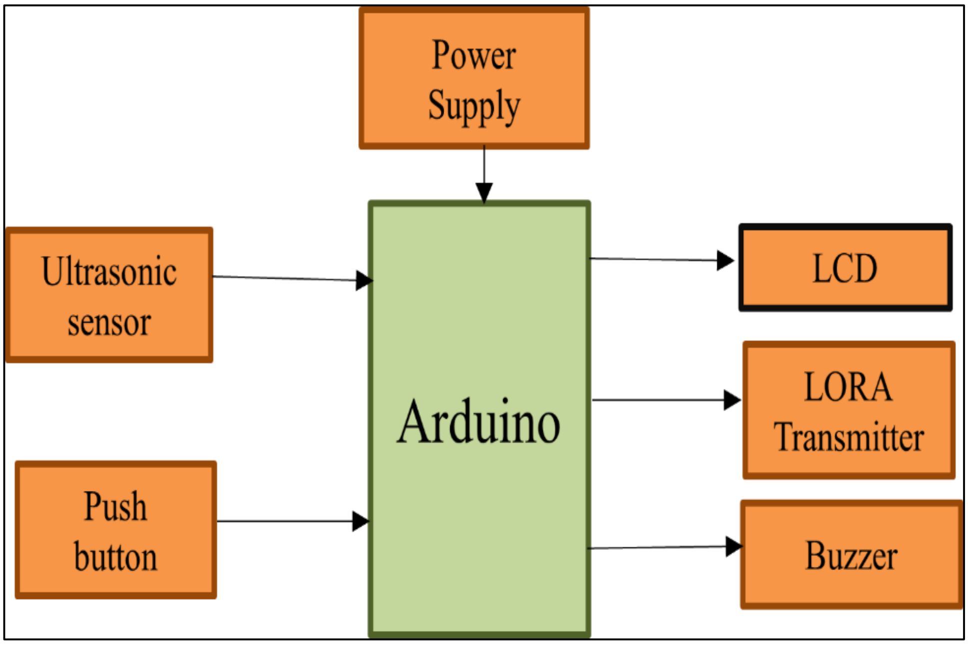

FIGURE 2. Block Diagram of Transmitter

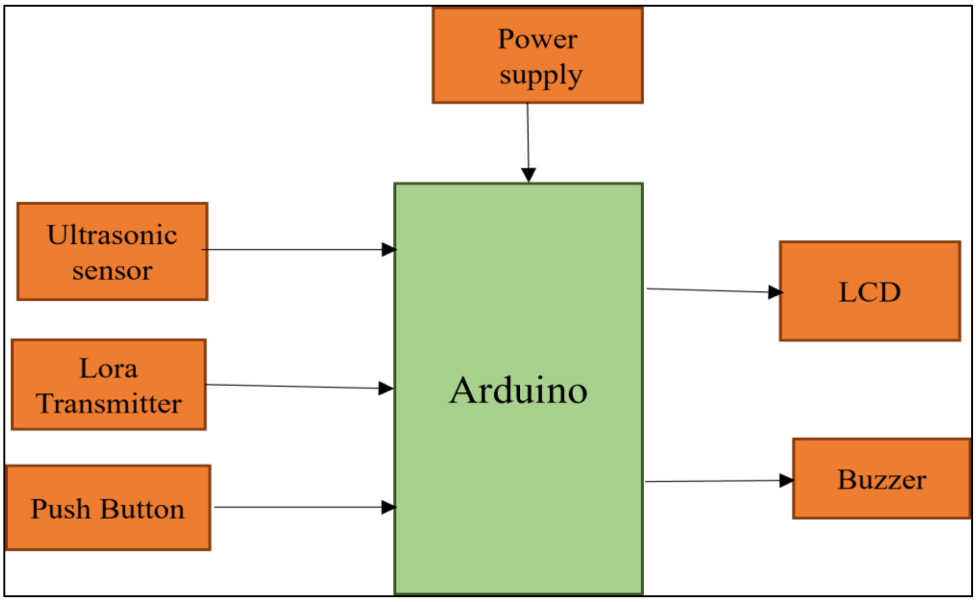

FIGURE 3. Block Diagram of Receiver

5. SYSTEM ARCHITECTURE

Arduino Uno:

The Arduino Uno is a popular open-source microcontroller board based on the ATmega328P. It is widely used for electronics projects, prototyping, and learning embedded systems. The ATmega328P is an 8-bit microcontroller operating at 5V with a clock speed of 16 MHz and a flash memory of 32 KB, of which 0.5 KB is reserved for the bootloader.

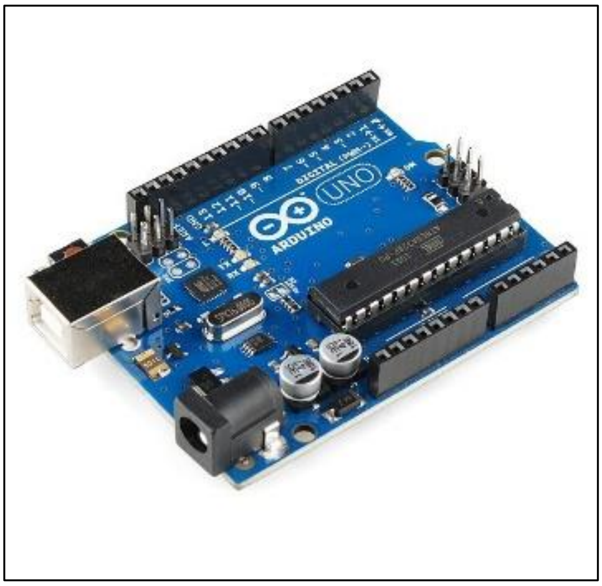

FIGURE 4. Arduino uno

Table 4: Arduino uno

Parameter	Description
Microcontroller	At mega 328P – 8 bit
Operating Voltage	5V
Frequency (Clock Speed)	16 MHz
Flash Memory	32 KB (0.5 KB is used for Bootloader)

Ultrasonic sensor:

Ultrasonic sensors measure distance using sound waves. They are accurate, reliable, and work in various conditions, making them ideal for obstacle detection, level measurement, & automation. The ultrasonic sensor detects obstacles in the vehicle's surroundings and measures the distance to nearby objects. This data is transmitted to the other vehicle to prevent collisions. The sensor operates at a voltage of 5V with a detection range of 2 cm to 400 cm, an accuracy of ±3 mm, and

an operating frequency of 40 kHz.

FIGURE 5. Ultrasonic sensor

TABLE 5. Ultrasonic sensor

Parameter	Description
Operating Voltage	5V
Detection Range	2 cm to 400 cm
Accuracy	±3 mm
Operating Frequency	40 kHz

Liquid Crystal Display (LCD):
A liquid-crystal display is a flat-panel display or other electronically modulated optical device that uses the light – modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly but instead use a backlight or reflector to produce images in color or monochrome. The LCD display shows real-time status updates, including sensor data and emergency alerts.

FIGURE 6. Liquid Crystal Display

Long Range (LoRa) Module: Long Range (LoRa) is a wireless communication technology based on Chirp Spread Spectrum (CSS), developed by Semtech. It enables long-range, low-power IoT networks using the LoRa WAN protocol, supporting smart applications in cities, homes, agriculture, metering, logistics, and more. The LoRa module enables long-range, low-power wireless communication between the two vehicles. It uses chirp spread spectrum (CSS) modulation to ensure robust communication even in noisy environments.The system has a range of up to 10 km, supports a data rate from low to moderate up to 50 kbps, and operates with a power consumption of 5V.

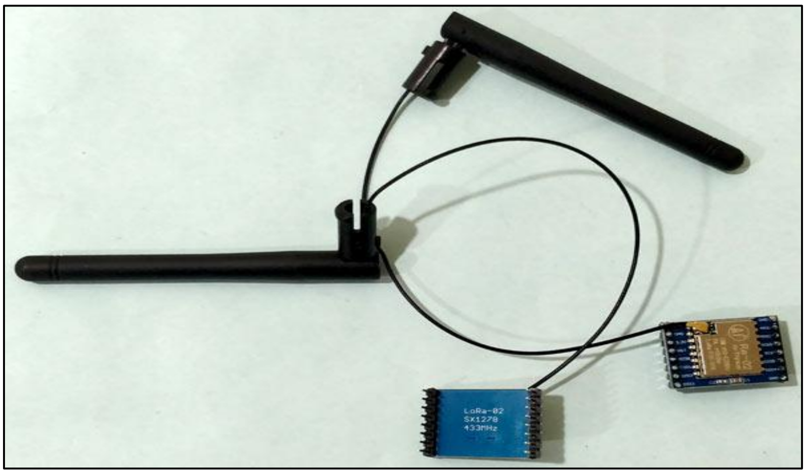

FIGURE 7. LoRa Connected with Antenna

TABLE 6. Technical characteristics of LoRa

Parameter	Description
Range	Up to 10 km
Date rate	1ow to moderate upto 50 kbps
Power Consumption	5 volts (v)

Push Button:

A push button switch is an electrical component that momentarily closes a circuit when pressed, allowing current flow. When released, it opens the circuit, stopping the flow. It is widely used in electronics, machinery, and appliances for turning devices on or off.

FIGURE 8. Push Button

Buzzer:

A buzzer is an electroacoustic device that produces sound when powered. It uses a coil and magnet to vibrate a diaphragm, creating sound waves.

FIGURE 9. Buzzer

Communication Mechanism

Each vehicle continuously monitors its surroundings using ultrasonic sensors. When an obstacle is detected, the information is transmitted via LoRa to nearby vehicles, triggering an alert on their displays and activating the buzzer if necessary. The system also allows manual emergency alerts via push buttons, ensuring quick response in critical situations.

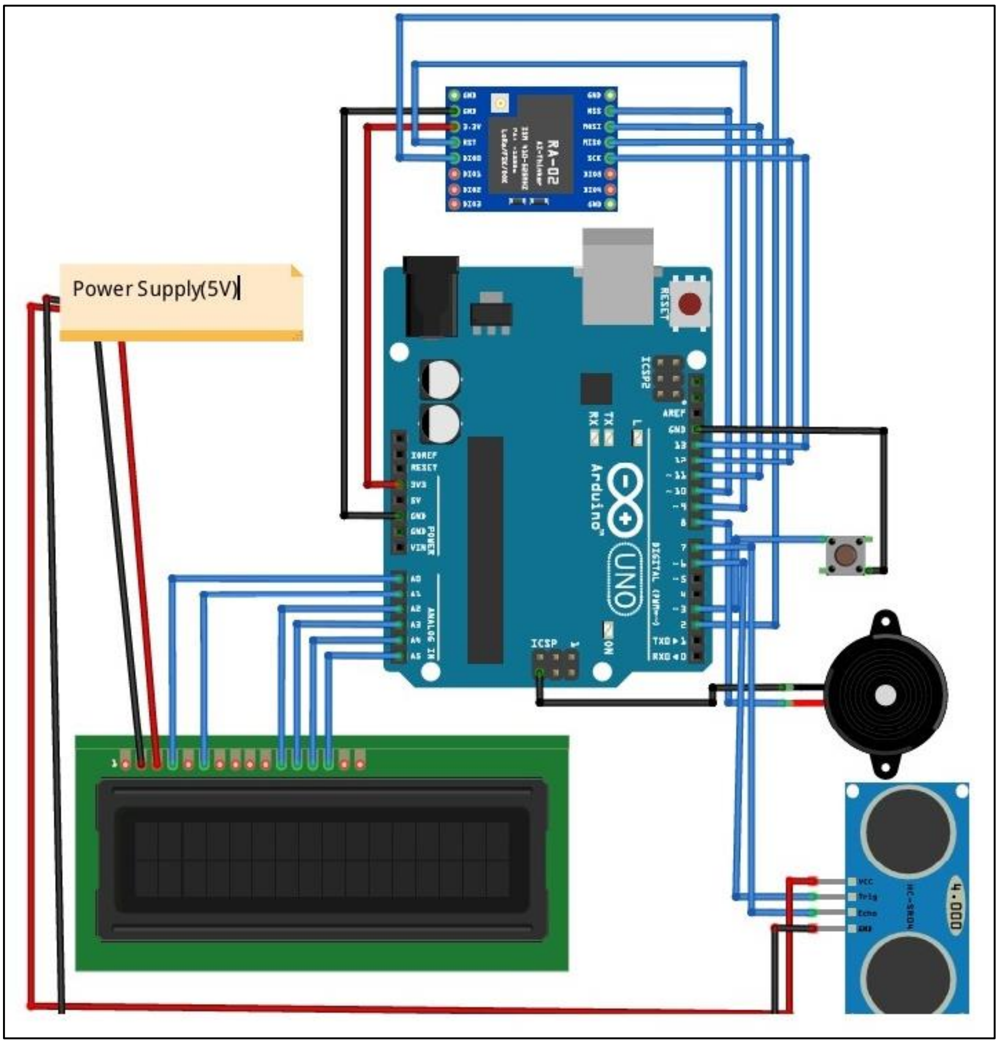

FIGURE 10. Circuit Diagram

6. IMPLEMENTATION AND RESULTS

Hardware Setup

The experimental setup includes two Arduino-based V2V communication nodes, each consisting of:

- Arduino Uno
- LoRa SX1278 Module
- HC-SR04 Ultrasonic Sensor
- 16x2 LCD Display
- Buzzer and Push Button

The components were interconnected as per the designed circuit and programmed using the Arduino IDE with embedded C.

Hardware Setup

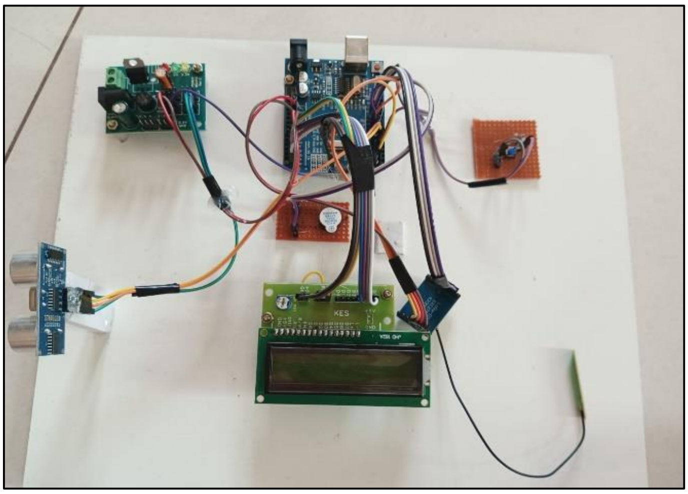

FIGURE 11. Hardware Setup of Vehicle 1

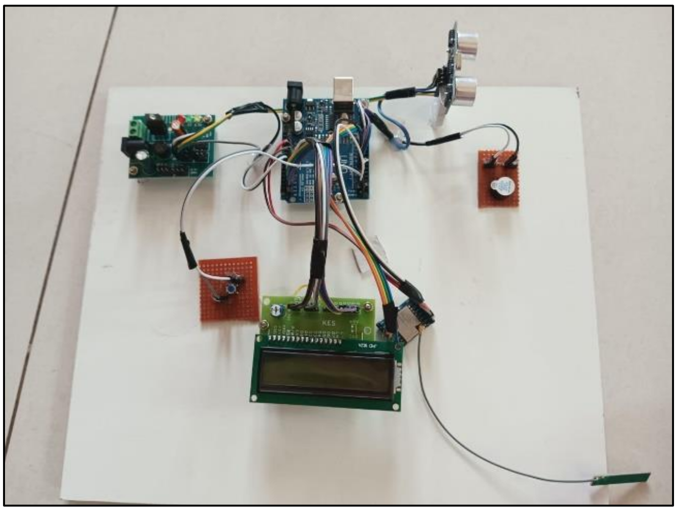

FIGURE 12. Hardware Setup of Vehicle 2

Performance Analysis

The system was tested under various conditions, including urban and suburban environments. Key performance metrics included:

1. **Communication Range:** The system maintained reliable data transmission over distances up to 3 km in urban areas and 12 km in open environments.
2. **Power Efficiency:** The LoRa module consumed less than 15mA during transmission, ensuring extended battery life.

7. CONCLUSION

The project demonstrates that leveraging LoRa technology for V2V communication can significantly enhance vehicle safety and situational awareness. By integrating various sensors with a low-power Arduino platform and employing LoRa's robust chirp spread spectrum modulation, the system reliably exchanges critical data between vehicles over long distances. Field tests and literature evidence support that---with careful configuration of modulation parameters---the impact of mobility and Doppler effects can be mitigated, making LoRa a cost-effective solution for real-time vehicular communication networks. Future work should aim to further optimize data throughput and integrate additional sensor modalities to expand the system's applicability in smart transportation scenarios.

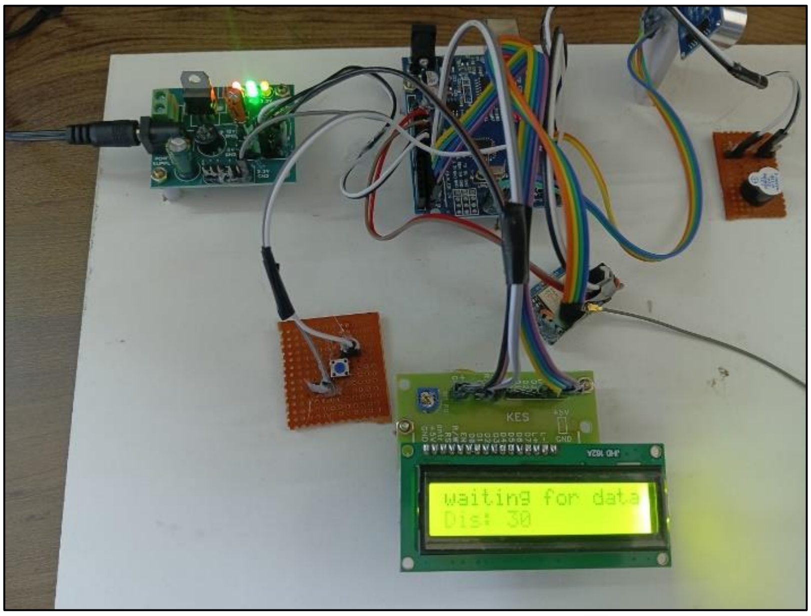

FIGURE 13. Calculating distance

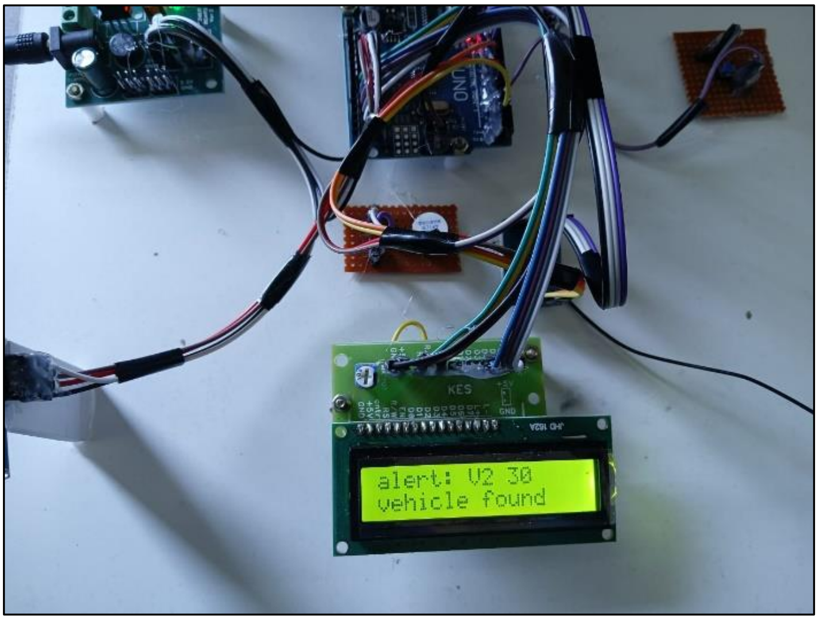

FIGURE 14. Data Received

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