# Vehicle to Vehicle communication using li-fi technology

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**Abstract -**

In the modern era of intelligent transportation systems (ITS), the role of vehicular communication has become increasingly significant in enhancing road safety, minimizing traffic congestion, and providing real-time information to both vehicles and infrastructure. Among various technologies employed for vehicular communication, Light Fidelity (Li-Fi) presents a promising and efficient solution for short-range, high-speed, and secure data transmission. This research paper explores a novel implementation of Vehicle-to-Vehicle (V2V) Communication using Li-Fi Technology, focusing on accident detection, emergency alert dissemination, and proximity-based collision avoidance systems. The objective is to harness the potential of Li-Fi to establish seamless communication between vehicles, thereby improving driver awareness and response time during critical situations.

The proposed system employs a combination of sensors integrated into an embedded system platform to detect different vehicular states and environmental conditions. The ADXL345 accelerometer is used to detect abrupt and high-impact acceleration or deceleration along the X and Y axes, which typically indicate a collision or accident scenario. Simultaneously, an ultrasonic sensor is implemented to measure the distance between vehicles, allowing for real-time proximity monitoring and collision warning in congested or low-visibility environments. A Light Dependent Resistor (LDR) is used to sense ambient light intensity, enabling adaptive alert mechanisms in dim or low-light situations. An emergency push button is incorporated to allow the driver or a passenger to manually trigger an emergency alert in case of sudden health issues, road hazards, or critical mechanical failures.

Data from these sensors is processed by a microcontroller unit, which then transmits corresponding alerts via Li-Fi—a form of visible light communication that uses light-emitting diodes (LEDs) to transmit information. The receiving vehicle, equipped with a photodiode or light sensor, captures this light signal, decodes the transmitted message, and takes appropriate action.

***Keywords:*** *Vehicle-to-Vehicle Communication, Li-Fi Technology, Accident Detection,Emergency Alerts, Proximity Sensing, ADXL345 Accelerometer,Ultrasonic Sensors,Light Fidelity*

## 1.INTRODUCTION

The rapid advancement of technology in the 21st century has catalyzed a transformative shift in transportation systems worldwide. With the exponential increase in the number of vehicles on roads, ensuring driver safety, efficient traffic management, and real-time inter-vehicular communication has become a pressing need. According to the World Health Organization (WHO), approximately 1.3 million people die each year due to road traffic crashes, and millions more sustain injuries. These statistics emphasize the urgency of implementing advanced technologies that can proactively reduce accidents, enable faster emergency responses, and enhance situational awareness among drivers. One promising approach to address this critical challenge lies in the development of Vehicle-to-Vehicle (V2V) communication systems, which allow vehicles to share information such as position, speed, direction, and hazard alerts directly with each other.

Traditionally, V2V communication has relied on radio frequency (RF)-based technologies such as Dedicated Short Range Communication (DSRC), ZigBee, and cellular networks. While effective, these technologies face several inherent challenges, including limited spectrum availability, susceptibility to electromagnetic interference, latency issues, and cybersecurity vulnerabilities. Additionally, the growing number of RF-based applications in urban areas has led to increased congestion in the wireless spectrum, which further diminishes the reliability and performance of V2V systems. As a result, researchers and engineers have been exploring alternative communication mediums that can overcome the limitations of RF technologies. One such alternative that has garnered significant attention in recent years is Light Fidelity (Li-Fi).

Li-Fi is a cutting-edge wireless communication technology that uses visible light to transmit data between devices. Introduced by Professor Harald Haas in 2011, Li-Fi is based on the principle of modulating the intensity of light emitted from Light Emitting Diodes (LEDs) at extremely high speeds—too fast to be noticed by the human eye. The data is received by photodetectors or light sensors and then decoded by the receiving device. The major advantage of Li-Fi lies in its vast bandwidth, high data transfer rate, immunity to electromagnetic interference, and enhanced security due to line-of-sight communication. These features make it highly suitable for short-range, high-speed communication in environments where traditional wireless signals are unreliable or congested.

In this research project, we propose a Vehicle-to-Vehicle communication system based on Li-Fi technology that is capable of detecting accidents, sending emergency alerts, and identifying the proximity of other vehicles in real time. The primary motivation behind this system is to enhance road safety and improve driver response time in critical situations. The system integrates a set of sensors—including an ADXL345 accelerometer, ultrasonic sensor, LDR (Light Dependent Resistor), and a manual emergency push button—into an embedded microcontroller platform. These sensors monitor various vehicular and environmental parameters such as sudden acceleration or deceleration, nearby obstacles or vehicles, ambient light intensity, and manual emergency situations. The data collected from these sensors is then transmitted via Li-Fi to surrounding vehicles, allowing them to react promptly and appropriately to potential dangers.

The accelerometer (ADXL345) plays a pivotal role in detecting collision or accident scenarios. By continuously monitoring the acceleration values on the X and Y axes, the system can identify abrupt changes in motion, which are often indicative of an accident. Upon detection, an alert message such as “ACCIDENT ALERT X” or “ACCIDENT ALERT Y” is transmitted to nearby vehicles using the Li-Fi channel. This allows following vehicles to reduce speed, change lanes, or take alternate actions to prevent secondary collisions.

Simultaneously, an ultrasonic sensor is employed to calculate the distance between the host vehicle and other nearby objects or vehicles. If the measured distance falls below a critical threshold (e.g., 9 cm), the system interprets it as a proximity hazard and transmits a “Vehicle Detected” alert. This feature is particularly useful in scenarios involving fog, blind spots, or dense traffic, where visual detection of surrounding vehicles may be compromised.

The system also incorporates an LDR sensor to assess ambient lighting conditions. In cases where the light intensity is significantly low (e.g., in tunnels or during nighttime), the system recognizes the possibility of reduced driver visibility and sends a “Light Dimmed” alert. This ensures that other vehicles are aware of the visibility constraints and can activate their lights or adjust their speed accordingly.

In addition to automatic detection, the system includes a manual emergency button that can be activated by the driver or passengers. This is particularly useful in medical emergencies, engine failures, or any unforeseen road hazard that requires immediate attention. Upon pressing the button, the system sends an “Emergency Alert” to surrounding vehicles, prompting them to offer assistance or make way for the affected vehicle.

The receiving vehicle is equipped with a compatible Li-Fi receiver, such as a photodiode, which captures the transmitted light signals and decodes them into readable data. Once the message is received, it is displayed on an LCD screen inside the vehicle, and accompanied by audible alerts via a buzzer and visual signals via LEDs. This multi-modal alert mechanism ensures that the driver is made aware of the situation through both visual and auditory cues, increasing the likelihood of timely and effective response.

The use of Li-Fi over RF offers several advantages in vehicular environments. First, since Li-Fi operates in the visible light spectrum, it does not interfere with other wireless systems like GPS, mobile networks, or Wi-Fi. Second, it provides a much higher bandwidth capacity, allowing faster and more reliable transmission of data. Third, its line-of-sight nature ensures that signals are confined within a specific path, reducing the risk of eavesdropping or signal interception. Lastly, Li-Fi is energy-efficient, as it utilizes existing LED headlights and taillights in vehicles as transmitters, thereby minimizing additional power consumption.

This system, while currently demonstrated in a prototype format, has the potential to be expanded and integrated into large-scale intelligent transportation systems. By connecting vehicles, traffic signals, and roadside units through Li-Fi networks, a fully interconnected and responsive vehicular environment can be realized. Such a system would not only improve road safety but also enhance traffic flow, reduce accidents, and pave the way for autonomous driving solutions.

In summary, this research paper presents a practical and innovative approach to V2V communication using Li-Fi technology. By combining sensor data with visible light communication, the system enables real-time exchange of critical information between vehicles. This facilitates quicker reaction to road hazards, prevents accidents, and ensures safer journeys. With further research and development, this system could become an integral part of future smart transportation networks, contributing significantly to the realization of safer, smarter, and more efficient roadways.

## 2. HARDWARE REQUIREMENTS

### 1.Microcontroller (Arduino UNO)

- **Description**: Acts as the central processing unit of the system.
- **Function**: Collects sensor data, processes it, and controls communication and output devices.
- **Features**: ATmega328P microcontroller, 14 digital I/O pins, 6 analog input pins, operates at 16 MHz.
- **Reason for Use**: Easy programming, wide community support, and compatibility with multiple sensors and modules.

### 2. Li-Fi Transmitter (LED Light Source)

- **Description**: High-brightness white LED used to transmit data through modulated light signals.
- **Function**: Sends digital signals in the form of light pulses to nearby vehicles.
- **Features**: Fast switching LED, capable of high-speed data transmission.
- **Reason for Use**: Utilizes vehicle headlights or an external LED light source to enable Li-Fi communication.

### 3. Li-Fi Receiver (Photodiode or Solar Panel)

- **Description**: Light sensor used to receive modulated light signals.
- **Function**: Detects the Li-Fi signal and converts it into electrical signals for decoding.
- **Features**: High sensitivity to light intensity changes, fast response time.
- **Reason for Use**: Essential for capturing transmitted messages through visible light.

### 4. ADXL345 Accelerometer Sensor

- **Description**: A 3-axis digital accelerometer.
- **Function**: Detects sudden changes in vehicle acceleration (X and Y axes) to identify potential accidents.
- **Features**: SPI/I2C interface, measures acceleration from -16g to +16g.
- **Reason for Use**: Accurate motion detection and compact design.

### 5. Ultrasonic Sensor (HC-SR04)

- **Description**: Measures distance to nearby vehicles or obstacles using ultrasonic waves.
- **Function**: Detects proximity of vehicles and sends a warning when within a dangerous range.
- **Features**: Range of 2 cm to 400 cm, accuracy of ~3 mm.
- **Reason for Use**: Effective non-contact distance sensing.

### 6. LDR (Light Dependent Resistor)

- **Description**: Sensor that changes resistance based on ambient light intensity.
- **Function**: Detects low-light conditions (e.g., night, tunnel) to generate visibility-related alerts.
- **Features**: Analog output based on light levels.
- **Reason for Use**: Simple and cost-effective light detection.

### 7. Push Button (Emergency Alert Trigger)

- **Description**: Tactile switch manually pressed by the driver/passenger in case of emergencies.
- **Function**: Sends a manual emergency alert to nearby vehicles.
- **Features**: Normally open (NO) configuration.
- **Reason for Use**: Allows user-initiated alert transmission.

### 8. LCD Display (16x2)

- **Description**: Alphanumeric display with 16 characters per line and 2 lines.
- **Function**: Displays received messages and system alerts.
- **Features**: Operates on 5V, uses I2C or direct pin connection.
- **Reason for Use**: Provides clear, readable message output to the driver.

### 9. Buzzer

- **Description**: Audio output component.
- **Function**: Emits a sound when a critical alert is received (accident, proximity, or emergency).
- **Features**: Operates at 5V DC.
- **Reason for Use**: Provides real-time audible warning to attract the driver's attention.

### 10. LED Indicators (Red, Green, Yellow)

- **Description**: Visual indicators for different alerts.
- **Function**: Glows in different colors based on the type of alert received.
- **Features**: Low current consumption, bright illumination.
- **Reason for Use**: Offers visual feedback for alert conditions.

**11. Resistors, Breadboard, and Jumper Wires**

- **Description**: Passive components and wiring essentials.
- **Function**: Circuit connections and voltage regulation (for sensors and indicators).
- **Reason for Use**: Ensures stable and flexible prototyping and testing.

**12. Power Supply (5V USB or Battery)**

- **Description**: Provides electrical power to the entire system.
- **Function**: Powers all components of the V2V communication system.
- **Options**: USB power from laptop or 9V battery with voltage regulator.
- **Reason for Use**: Ensures mobility and portability of the system.

## 3. Implementation

The implementation of the Vehicle-to-Vehicle (V2V) Communication System using Li-Fi Technology involves integrating sensors, a microcontroller, and a Li-Fi communication module to establish an effective, short-range communication network between vehicles. This system is designed to transmit critical alerts—such as accident notifications, proximity warnings, and emergency requests—to nearby vehicles using visible light as the communication medium.

### 3.1 Hardware Integration

**1. Arduino UNO (Microcontroller)**

- Acts as the brain of the system.
- Responsible for processing sensor data, decision-making, and controlling input/output devices.
- Each sensor and output device is connected to a specific digital or analog I/O pin

**2. ADXL345 Accelerometer (Accident Detection)**

- Function: Detects sudden changes in acceleration (crashes or impacts).
- Connection:
- Uses I2C communication.
- Connect VCC → 3.3V, GND → GND, SDA → A4, SCL → A5 on Arduino UNO.
- Integration:
- Continuously monitored via code.
- If acceleration exceeds a defined threshold, an "accident" is detected.

**3. Ultrasonic Sensor (Proximity Detection) – HC-SR04**

- Function: Measures distance between vehicles to avoid collisions.
- Connection:
- VCC → 5V, GND → GND, TRIG → Digital Pin 9, ECHO → Digital Pin 10.
- Integration:
- Sends ultrasonic pulses and calculates the time of echo return to determine distance.
- If the distance is below a critical level, a proximity alert is generated.

**4. LDR (Light Dependent Resistor)** – Low Visibility Detection

- Function: Detects ambient light to identify low visibility conditions.
- Connection:
- Connected in a voltage divider circuit with a resistor.
- Output of the divider goes to Analog Pin A0.
- Integration:
- Arduino reads analog values and compares them to a threshold.
- Low light conditions trigger a "Night Alert" or "Low Visibility" warning.

**5. Push Button (Emergency Alert)**

- Function: Allows manual transmission of emergency messages.
- Connection:
- One terminal to Digital Pin 2, other terminal to GND.
- Use internal pull-up resistor or external 10K pull-down resistor.
- Integration:
- When pressed, Arduino detects LOW signal and sends predefined emergency message.

**6. Li-Fi Transmitter (High-Intensity White LED)**

- Function: Transmits modulated light signals containing data.
- Connection:
- Anode → Digital Pin 6 (via 220Ω resistor), Cathode → GND.
- Integration:
- Arduino sends binary data as high/low signals, modulating the LED accordingly.
- Light pulses carry data to the receiver.

**7. Li-Fi Receiver (Photodiode or Solar Panel)**

- Function: Receives light signals and converts them into electrical signals.
- Connection (Photodiode):
- Connected in a reverse-biased configuration.
- Output connected to Analog Pin A1 or via op-amp to amplify signal.
- Integration:
- Arduino reads analog voltages and interprets high/low transitions.
- Decoded into readable messages.

**8. LCD Display (16x2)**

- Function: Displays received messages to the driver.
- Connection:
- Connected using 4-bit mode or via I2C module.
- For 4-bit: RS → D7, EN → D8, D4-D7 → D9-D12.
- For I2C: SDA → A4, SCL → A5.
- Integration:
- Arduino sends string data to display alerts like "Accident Alert!" or "Low Visibility Ahead".

**9. Buzzer and Indicator LEDs**

- Function: Provide audio and visual alert to the driver.
- Connections:
- Buzzer → Digital Pin 3, Red/Yellow/Blue LEDs → Pins 4, 5, 6 (with 220Ω resistors).
- Integration:
- Controlled through digital HIGH/LOW logic.
- Activated when respective message is received.

**10. Power Supply**

- Function: Provides stable 5V power to all components.
- Options:
- USB power from laptop or 9V battery via barrel jack.
- Optionally, use a regulated 7805 voltage regulator for external battery packs.

**3.2 Software Development**

**1. Software Architecture**

- The program is structured into multiple blocks:
- Initialization Block
- Sensor Data Acquisition Block
- Decision-Making Block
- Message Encoding & Transmission (Li-Fi)
- Message Reception & Decoding (Li-Fi)
- User Interface & Alert Display

**2.Error Handling and Noise Filtering**

- Debouncing push button inputs.
- Thresholding for analog sensors to ignore minor fluctuations.
- Timeouts to handle loss of Li-Fi signal.
- Checksums (optional) can be added for message verification.

**3. Modularity and Reusability**

- Functions are modular and reusable.
- Can easily add new sensors or alerts by adding a new function and trigger logic.

**4. Future Improvements**

- Timing synchronization between transmitter and receiver.
- Manchester encoding for more robust Li-Fi data transmission.
- Interrupt-based detection for faster and more responsive message decoding.
- Integration with GPS and vehicle ID for location-based alerts.

## 4. Real Time Implementation

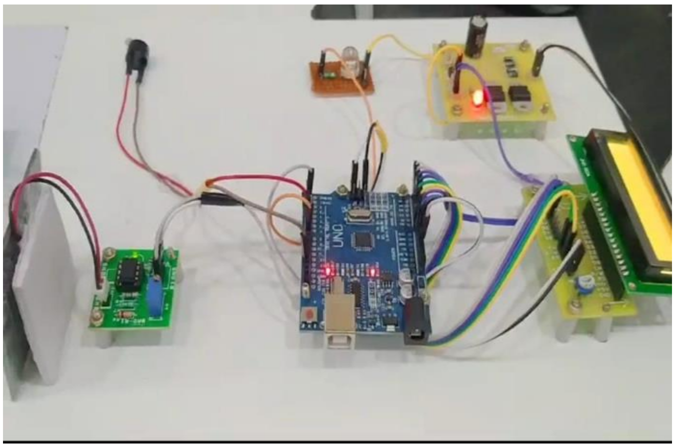

**Fig -1**: Hardware Implementation

The real-time implementation of the Vehicle-to-Vehicle (V2V) communication system using Li-Fi technology plays a critical role in demonstrating the viability, accuracy, and effectiveness of this system in real-world traffic scenarios. The implementation was conducted in a controlled lab environment and field-tested on small-scale vehicle prototypes to replicate real-world communication between moving vehicles.

This section describes the practical deployment of the system components, sensor integration, signal transmission through Li-Fi, and real-time alert generation on receiver vehicles.

**1. Test Setup Overview**

- To validate the concept, two small-scale car prototypes (Vehicle A and Vehicle B) were prepared:
- Vehicle A: Equipped with sensors (ADXL345, ultrasonic sensor, LDR), an Arduino UNO, a push button for manual emergency trigger, and an LED-based Li-Fi transmitter.
- Vehicle B: Equipped with a photodiode-based Li-Fi receiver, Arduino UNO, LCD for message display, buzzer for alerts, and an indicator LED.
- These vehicles were placed on a platform with mobility to simulate movement, proximity, and different lighting conditions.

**2. Scenario-Based Testing**

- To simulate real-world use cases, multiple scenarios were tested:

- Scenario 1: Accident Detection
- A sudden jerk was simulated on Vehicle A (tilt or shock on the ADXL345 accelerometer).
- The system detected the anomaly and triggered the message "ACCIDENT DETECTED".
- The message was converted into a binary pattern and transmitted using the LED (Li-Fi).
- Vehicle B's photodiode detected the blinking pattern, decoded the signal, and displayed the alert on the LCD with a buzzer notification.
- Scenario 2: Proximity Warning
- Vehicles were moved closer to each other.
- The ultrasonic sensor in Vehicle A detected the distance was less than 30 cm.
- A proximity alert message "VEHICLE TOO CLOSE" was transmitted.
- Vehicle B received and displayed the alert in real-time.
- Scenario 3: Low Visibility Ahead
- A dim environment was created using a cover over the LDR sensor.
- The LDR value dropped below a predefined threshold.
- The message "LOW VISIBILITY" was sent to Vehicle B via Li-Fi.
- The alert was shown on the LCD of Vehicle B.
- Scenario 4: Emergency Message
- A driver in Vehicle A pressed the emergency push button.
- The message "EMERGENCY - STOP" was instantly transmitted via the Li-Fi system.
- Vehicle B received the signal and displayed the emergency alert with a buzzer and red LED notification.

**3. Communication Timing**

- The average time for message transmission and reception was recorded.
- For short messages (8–16 bytes), the delay was less than 1 second, making it nearly real-time.
- Timing accuracy was improved using:
- Consistent delay() intervals in transmission
- Threshold-based detection in reception
- Start and stop bits in the data to define message boundaries

**4. Transmission Range and Environment Conditions**

- The effective range for Li-Fi communication was up to 1.5 meters with clear line-of-sight.
- Ambient lighting had minimal impact due to:
- Proper photodiode calibration
- Use of visible LED (white or blue) with high intensity
- Communication failed in:
- Strong sunlight directly hitting the receiver
- High-speed movement without sufficient LED blink synchronization.

**5. User Feedback Simulation**

- To validate the system's usefulness, test users operating Vehicle B noted:
- Quick and understandable messages
- Effective visual and audio alerts
- Easy-to-identify emergency situations

**6. Limitations Observed**

- Line-of-sight dependency of Li-Fi limits flexibility in certain traffic conditions.
- Interference due to ambient lighting needed calibration.
- Real-time implementation on full-scale vehicles would require stronger LEDs and focused light transmission (like IR with lenses).

**7. Real-Time Use Case Expansion**

- Though implemented on prototypes, the system can be scaled to:
- Two-wheelers and cars for peer-to-peer alerts.
- Emergency vehicles broadcasting approach alerts.
- Integration with streetlights for V2I (Vehicle-to-Infrastructure) communication.

## 5. Simulations

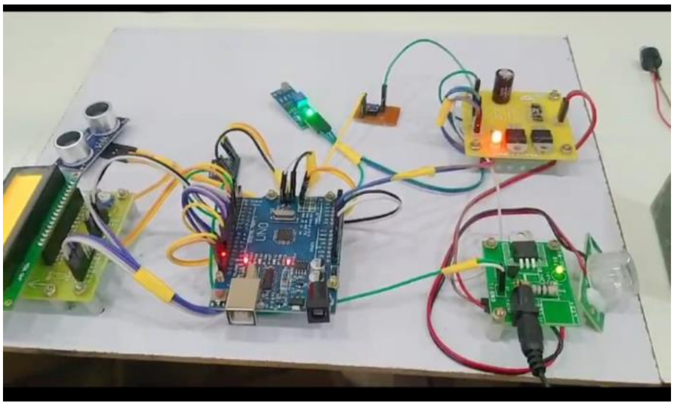

**Fig -2**: Result

## 7. ADVANTAGES

**1.High-Speed Data Transmission**

- Li-Fi enables high-speed data communication using visible light.
- Data transfer rates are significantly faster than traditional RF-based methods under optimal conditions.
- This allows for near real-time alerts between vehicles, crucial for preventing accidents.

**2. Enhanced Road Safety**

- Immediate communication of accident alerts, proximity warnings, and emergency messages helps drivers take timely preventive actions.
- Reduces reaction time and increases situational awareness, contributing to safer roads.

**3. Reduced RF Interference**

- Li-Fi does not interfere with RF systems such as Wi-Fi, Bluetooth, or mobile networks.
- This is particularly beneficial in areas with high RF congestion (e.g., cities, tunnels, or traffic-congested highways).

**4. Secure and Directional Communication**

- Since Li-Fi uses light for transmission, it requires line-of-sight and is contained within the beam.
- This makes communication more secure and difficult to intercept from unintended receivers, ensuring that messages are shared only between intended vehicles.

**5. Cost-Effective Hardware**

- The system is built using low-cost components such as LEDs, photodiodes, and Arduino boards.
- Affordable for mass production and integration in existing vehicle systems without requiring expensive network infrastructure

**6. Real-Time Response with Low Latency**

- Li-Fi enables quick message transmission with very low latency, suitable for time-sensitive situations like:
- Sudden braking
- Vehicle rollover or collision
- Emergency driver warnings

**7. Environmentally Friendly**

- Li-Fi uses LED light, which consumes less power compared to RF antennas.
- Dual-purpose use: existing vehicle headlights or taillights can serve as Li-Fi transmitters with minimal power overhead.

**8. Effective in Electromagnetically Sensitive Areas**

- Useful in places where RF communication is restricted (e.g., hospitals, airplanes, nuclear facilities).
- Offers a safe alternative for intelligent transport communication in these environments.

**9. Seamless Integration with Smart Vehicles**

- Li-Fi communication systems can be easily integrated with ADAS (Advanced Driver-Assistance Systems), IoT modules, and sensor networks.
- Supports a modular architecture allowing future upgrades and AI-based decision-making.

**10. Scalability for Smart City Applications**

- The proposed Li-Fi V2V system can be extended to:
- Vehicle-to-Infrastructure (V2I) communication (e.g., traffic lights, smart signboards)
- Emergency vehicle priority systems
- Smart parking and fleet management systems

**11. Minimal Spectrum Licensing**

- Since Li-Fi uses the visible light spectrum, there's no need for costly spectrum licenses.
- Frees up crowded RF spectrum for other communication services.

**12. Versatility in Usage**

- Beyond V2V communication, the same system can be used for:
- Real-time updates to digital dashboards
- Communication in mining vehicles, warehouse robots, or military convoys
- Communication between autonomous cars

## 8. CONCLUSION

The advent of intelligent transportation systems has revolutionized how vehicles operate and interact with one another on the road. As safety and efficiency have become paramount concerns in modern traffic environments, technologies like Vehicle-to-Vehicle (V2V) Communication offer a promising avenue to reduce accidents, improve response times, and enable smoother vehicular movement. This research presents an innovative approach by implementing Li-Fi (Light Fidelity) technology as the communication backbone for V2V systems.

Li-Fi, a visible light communication system, harnesses the power of LED light to transmit data between vehicles at high speeds and with minimal latency. Unlike traditional communication systems such as RF, Wi-Fi, or Bluetooth, which may suffer from congestion, interference, or limited bandwidth, Li-Fi provides a secure, high-bandwidth alternative that works effectively within the line-of-sight range.

Nonetheless, while the advantages of Li-Fi are numerous, certain limitations must be acknowledged. Since Li-Fi requires a line-of-sight for effective communication, obstructions such as large vehicles, environmental fog, or dirty lenses can degrade performance. However, these limitations can be mitigated through hybrid systems that combine Li-Fi with backup RF or cellular technologies to maintain continuous data exchange.

Overall, the implementation of Vehicle-to-Vehicle Communication using Li-Fi offers a novel, energy-efficient, and cost-effective solution for addressing the growing challenges of traffic safety and road awareness. As cities move towards the adoption of smart mobility ecosystems, such innovations will be instrumental in building safer roads, reducing accident rates, and ultimately saving lives.

This research not only validates the feasibility of using visible light for vehicular communication but also encourages future exploration into its integration with autonomous vehicles, traffic control systems, and smart city infrastructures. By bridging the gap between concept and practical application, this project marks a step forward in the evolution of safer, smarter, and more connected transportation systems.

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