Design and Implementation of Vehicle To Vehicle Communication Using Li-Fi Technology

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***Abstract* - Vehicle-to-vehicle data transmission, we present initial designs and results of a small-scale prototype using light fidelity (Li-Fi) technology, a new technology that has been developing in the last few years, but still needs more systematic inquiry on its sustainability for outdoor vehicular networks. Vehicle-to-vehicle communication is the most effective solution we have used to reduce vehicle accidents. In Li-Fi technology for vehicle-to-vehicle data transmission, we use LED bulbs. In this technology, there are no protocols used. So, in Li-Fi technology complexity gets reduced. The aim of designing this system is highly reliable and gives desired data transmission between vehicle to vehicle by using a transmitter and receiver mounted on the vehicle.**

***Keywords:* Arduino UNO, Ultrasonic sensor, MEMS sensor, LDR sensor, LIFI module (Li-Fi Transmitter and Li-Fi Receiver), Buzzer, Switches, LCD, Regulated power supply.**

I. INTRODUCTION

Vehicle-to-vehicle (V2V) communication is an advanced technology designed to enhance road safety, optimize traffic flow, and enable smarter transportation systems. It allows vehicles to share critical data such as speed, location, braking status, and potential hazards in real time, reducing the risk of accidents and improving overall driving efficiency. Traditional V2V communication systems rely on radio frequency (RF)-based technologies like Dedicated Short-Range Communications (DSRC) and Cellular Vehicle-to-Everything (C-V2X). However, these methods face challenges such as limited bandwidth, interference from other wireless signals, and cybersecurity threats.

To address these limitations, this project leverages Li-Fi (Light Fidelity) technology, an emerging wireless communication method that uses visible light instead of radio waves to transmit data. Li-Fi operates through LED-based light signals, which offer several advantages, including high-speed data transfer, enhanced security, reduced electromagnetic interference, and efficient energy consumption. By incorporating Li-Fi into V2V communication, vehicles can achieve seamless data exchange while maintaining a safe and interference-free environment.

Integrating Li-Fi into V2V communication not only enhances data transmission speed and security but also minimizes latency, ensuring real-time responsiveness in critical driving situations. Unlike RF-based systems, Li-Fi is immune to radio interference, making it highly reliable in dense urban environments where multiple wireless signals compete for bandwidth. Additionally, Li-Fi-enabled V2V communication can improve night-time and low-visibility driving conditions by leveraging vehicle headlights and streetlights as data transmitters, creating a robust and intelligent transportation network. This innovative approach has the potential to revolutionize road safety, reduce traffic congestion, and pave the way for autonomous vehicle communication systems with unparalleled efficiency.
Furthermore, Li-Fi-based V2V communication can significantly enhance vehicular coordination by enabling instantaneous data exchange between multiple vehicles, reducing reaction time during emergencies. Its high-speed capabilities allow for rapid transmission of crucial information such as sudden braking, lane changes, and obstacle detection, thereby preventing collisions and ensuring smoother traffic flow.

Figure 1:

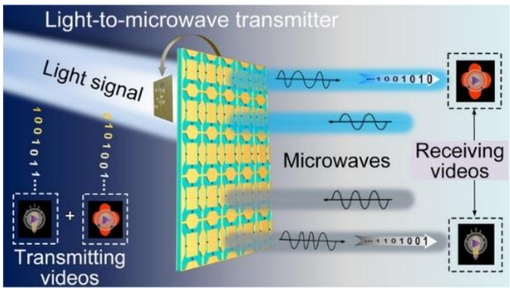
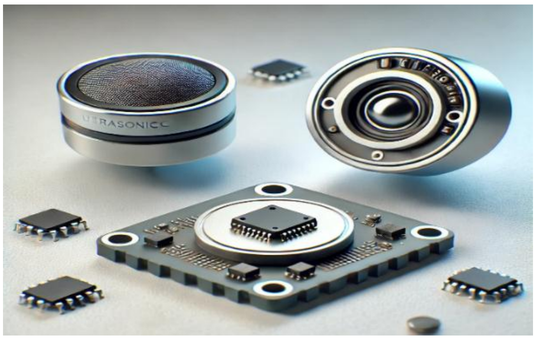


Figure 2:



This project proposes a Li-Fi-based V2V communication system that integrates essential hardware components such as Arduino microcontrollers, ultrasonic sensors, MEMS sensors, and Li-Fi modules. These components work together to detect obstacles, monitor vehicle movement, and enable real-time data sharing. Additionally, an LCD and buzzer system provide instant alerts to drivers, helping them respond quickly to potential dangers. By utilizing a cost-effective and scalable approach, this system aims to revolutionize vehicular communication, making roads safer, smarter, and more efficient.

II. LITERATURE SURVEY

1. This study talks about the li-fi using vehicle-to-vehicle communication Li-Fi is the advanced technology of the world. This project is concise in the vehicle-to-vehicle communication to avoid accidents. We use the ultrasonic sensor, gas sensor, vibration sensor, LCD display, normal robot setup, and Li-Fi transmitter and receiver. The ultrasonic sensor is used to find the distances of the front vehicle and measure the vibration level in the vehicle the gas sensor measures the alcohol level of the driver and this data is sent through the Li-Fi transmitter to the receiver vehicle. If any abnormal condition in a front vehicle means this vehicle will stop on the second. Li-fi is connected with the UART function to the microcontroller.

2. This study talks about the Vehicle To Vehicle Communication Using Li-Fi Light Fidelity is a technology that uses virtual communication which was developed in the last few years and it requires investigations for its sustainability. V2V communication is the most powerful approach used to minimize vehicle collisions. In reality, the use of (LEDs) removes the requirement for compound wireless networks and rules. Some of the case studies imitating V2V communication are discussed here. Our project develops a smart vehicle communication system using Li-Fi technology that gives protection against vehicular collisions on the road. We focus on the safety of the people and about less damage to the vehicles. The headlights of the car which consist of LEDs act as transmitters and help communicate with the solar panel acting as a receiver.

3. This study talks about vehicle-to-vehicle data transfer and communication using LI-FI technology The concept of Vehicle-to-vehicle data transmission refers to the communication between two vehicles that ensures the safety and security of the vehicle occupants. In this project, we present the designs and results of a prototype using the light fidelity (Li-Fi) technology, which is the latest technology that was developed in the last few years, and needs some systematic inquiry on its sustainability for use in the vehicles. Vehicle-to-vehicle communication is the most effective solution that is available in order to reduce road accidents. The proposed use of this Li-Fi technology comprises mainly the light-emitting diode (LED) bulbs as the means of connectivity that function by sending data through the light spectrum as an optical wireless medium for signal propagation. The usage of this light-emitting diode (LED) eliminates the need for complex wireless networks and protocols. The designed system ensures reliable communication between the vehicles so that accidents can be reduced to a greater extent

4. This study talks about the Inter-Vehicle Communication System Using Li-Fi Technology to improve the safety of the car passenger and driver, cooperation driving is proposed, and it will help to improve efficiency by enabling vehicles to communicate by sending and receiving emergency or help-related messages with each other. Inter-vehicle communication is an effective method in which communication takes place between the vehicles by which one can maintain a safe distance between the vehicles to prevent accidents. It transmits various messages such as rash driving, fuel leakage, etc. In Li-Fi technology, for communication between two vehicles, data is transmitted using an LED panel and at the receiving end, we use a photo-detector or receive the data. In this application, no need to use any protocol therefore it reduces the complexity.

5. This study talks about Vehicle To Vehicle Using Li-Fi Technology, Vehicle Vehicle communication is one of the upcoming prominent technologies, that aims to provide more road safety measures by providing important data and information about the vehicles. Introducing Li-Fi technology in the V2V communication enhances the overall performance of the system. The Li-Fi technology helps the V2V communication system to transmit data through a wireless medium at a higher data rate. In Li-Fi, the signal is transmitted from an LED, and the data is received by the photodetector. In this project, a prototype V2V communication Li-Fi system is designed to avoid road accidents and traffic congestion. The transmitter of the proposed system consists of a Li-Fi transmitter module to convert the input data into a modulated light signal. The receiver of the proposed system consists of a Li-Fi receiver module which decodes the modulated light signal. The decoded data is displayed in the LCD. The data shared between the two vehicles are speed, temperature, and steering angle. These parameters are important to avoid major accidents. Li-Fi technology is used over other transmission techniques because it is suitable for real-time applications.

III. EXISTING WORK

In the current scenario, traffic management and vehicle communication systems face several limitations that lead to inefficiency, accidents, and fuel wastage. Presently, traffic updates rely heavily on manual reporting by affected drivers, leading to delays in receiving real-time information. This lack of instant communication results in vehicles waiting unnecessarily at traffic signals, leading to fuel wastage and increased pollution.

Additionally, there is no automated accident detection system in place. When an accident occurs, the information takes too long to reach other vehicles and emergency responders, increasing risks on the road. Furthermore, long-distance communication between vehicles is absent, meaning that drivers are not alerted about roadblocks, hazards, or sudden braking ahead, which often leads to collisions.

Another critical drawback is the lack of distance monitoring between vehicles. Without an automated system to measure and maintain safe following distances, rear-end collisions become more frequent. Lastly, there is no buzzer alert system in most vehicles to immediately warn drivers about potential dangers, delaying their reaction time in critical situations

DISADVANTAGES

- Manual Traffic Updates – Traffic updates rely on manual monitoring, causing delays and inefficiencies in real-time information sharing.
- Fuel Wastage Due to Inefficient Traffic Management – Poor traffic management leads to unnecessary fuel consumption due to idling, frequent stops, and congestion.
- No Automated Accident Detection System – The absence of an automated accident detection system delays emergency response and increases the risk of fatalities.
- No Long-Distance Communication Between Vehicles – Vehicles lack a system to share real-time traffic or hazard information over long distances, increasing accident risks.
- No Distance Monitoring Between Vehicles – Without an automated system to monitor the distance between vehicles, the chances of collisions and sudden braking incidents rise.
- No Buzzer Alert System for Immediate Warnings – The absence of an alert system prevents timely warnings for drivers, reducing road safety and increasing accident risks.

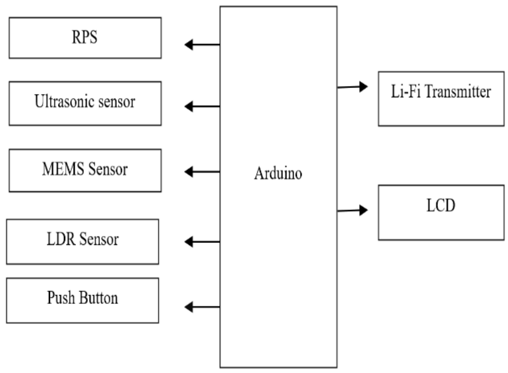
IV. PROPOSED SYSTEM

The proposed Li-Fi-based Vehicle-to-Vehicle (V2V) Communication System is designed to overcome the drawbacks of the existing traffic management and accident prevention systems. This project utilizes Li-Fi (Light Fidelity) technology, enabling vehicles to exchange real-time data using visible light communication (VLC) instead of traditional radio waves. By integrating ultrasonic sensors, MEMS sensors, Li-Fi modules, and an Arduino microcontroller, the system ensures instant hazard detection, safe distance monitoring, and efficient traffic management.

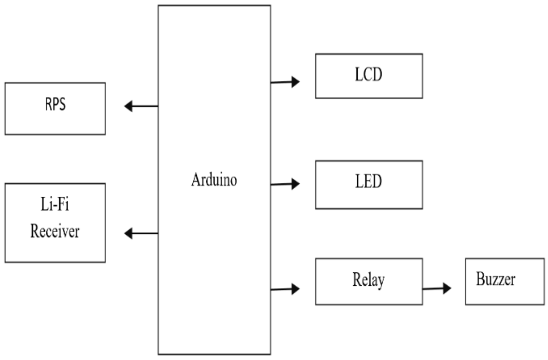
When a vehicle detects an obstacle, sudden braking, or an accident, the system immediately transmits a warning signal to nearby vehicles using Li-Fi transmitters and receivers. A buzzer and LCD display provide real-time alerts to drivers, allowing them to take preventive actions and avoid collisions. This cost-effective, interference-free, and high-speed communication system significantly improves road safety and transportation efficiency.

Additionally, the Li-Fi-based V2V communication system enhances data security and reliability by eliminating the risks associated with radio frequency interference and cyber threats. Since Li-Fi operates through line-of-sight communication, it minimizes signal congestion in high-traffic areas while ensuring seamless data transmission between vehicles. The integration of sensors and microcontrollers further optimizes response times, enabling vehicles to react swiftly to dynamic road conditions. By fostering a smarter and more connected transportation ecosystem, this system not only reduces accident rates but also contributes to the development of future autonomous vehicle networks.

Block Diagram of Transmitter:



Block Diagram of Receiver:



Key Components of the Proposed System

1. Arduino Microcontroller
- Acts as the central processing unit, controlling the sensors and communication modules.
- Process input data and trigger alerts when hazards are detected.

2. Li-Fi Transmitter & Receiver
- Li-Fi Transmitter (LED): Encodes and sends data as light pulses to nearby vehicles.
- Li-Fi Receiver (LDR/Photodiode): Captures light pulses and converts them into digital signals.
- Enables high-speed, interference-free communication between vehicles.

3. Ultrasonic Sensor
- Measures the distance between vehicles to prevent collisions.
- Sends alerts when vehicles get too close, reducing rear-end accidents.

4. MEMS Sensor (Micro-Electro-Mechanical System)
- Detects sudden acceleration, braking, and vehicle tilts.
- Helps in accident detection and sends signals to alert nearby vehicles.

5. LCD Display:
Shows real-time information like accident warnings, distance alerts, and system status.

6. Buzzer System
Provides audio alerts to immediately warn drivers of potential hazards.

7. Power Supply Unit
Provides the necessary power to operate the Arduino, sensors, and Li-Fi modules

ADVANTAGES

- Li-Fi enables instant data exchange, eliminating the dependency on manual traffic updates.
- MEMS and ultrasonic sensors detect accidents and sudden braking instantly, alerting nearby vehicles and emergency responders in real time.
- Vehicles can transmit warnings over long distances without interference, improving hazard awareness and collision avoidance.
- Ultrasonic sensors continuously measure the distance between vehicles, preventing rear-end collisions and reckless driving.
- Drivers receive real-time alerts through audio buzzers and visual LCD signals, ensuring faster responses to potential dangers.
- Li-Fi technology provides faster data transfer than RF-based systems, eliminating interference issues caused by traditional radio waves.

V. DESIGN METHODOLOGY

The system facilitates data exchange between vehicles using Li-Fi technology for real-time hazard alerts. It comprises a transmitter (Vehicle-A) that collects sensor data (distance, braking, accident detection) and transmits encoded light pulses via an LED. The receiver (Vehicle-B) captures these signals using an LDR, decodes them with an Arduino, and triggers alerts through an LCD and buzzer.

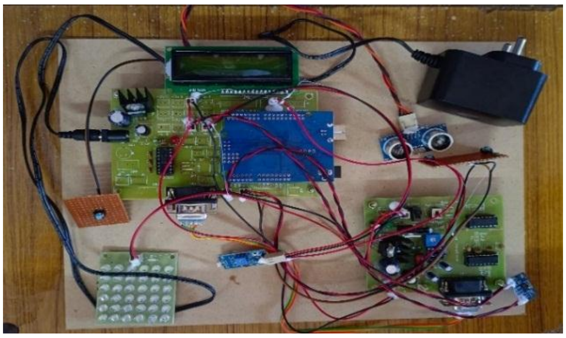
Hardware includes an Arduino for control, Li-Fi modules for communication, ultrasonic sensors for distance measurement, MEMS sensors for accident detection, an LCD and buzzer for alerts, and a regulated power supply.

Communication protocol follows data collection, signal encoding, transmission, reception, and alert activation to ensure accurate and interference-free operation.

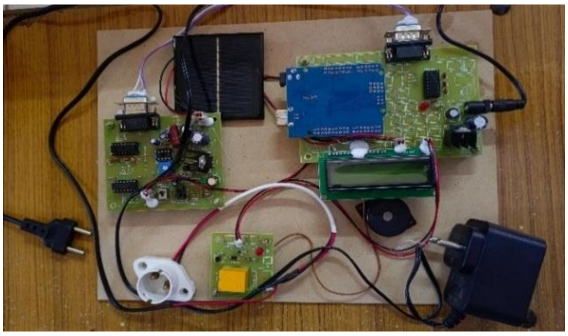
Software development in Arduino IDE (Embedded C) enables sensor data processing, hazard detection, Li-Fi transmission, and real-time warnings.

Testing & optimization involve validating Li-Fi range, sensor accuracy, real-time simulations, and optimizing signal strength, power efficiency, and response time for reliable deployment.

Li-fi Transmitter:



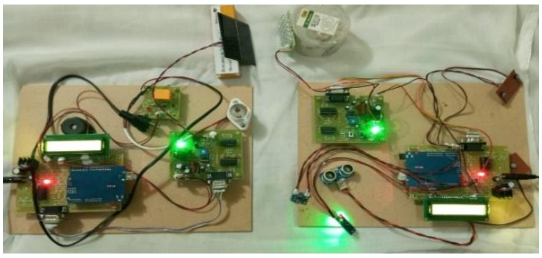
Li-fi receiver:



VI. RESULTS

The Li-Fi-based Vehicle-to-Vehicle (V2V) Communication System was successfully implemented and tested, showcasing efficient real-time data exchange, accident detection, and driver alert mechanisms. The system utilized Li-Fi technology to transmit data between vehicles, ensuring high-speed, interference-free communication without relying on traditional radio waves. The ultrasonic sensor accurately measured the distance between vehicles, triggering alerts when unsafe proximity was detected, while the MEMS sensor effectively identified sudden braking, tilting, and collisions, allowing for instant hazard warnings. The buzzer and LCD system provided immediate audio and visual alerts, ensuring that drivers received timely notifications to prevent accidents. Compared to conventional RF-based systems, Li-Fi offered faster data transfer, minimal interference, and reduced reliance on network connectivity, making it a reliable alternative for vehicular communication.

Transmission of Data between transmitter and receiver



Despite the system's success, certain challenges and limitations were identified. The line-of-sight dependency of Li-Fi meant that communication could be obstructed by physical barriers, potentially affecting data transmission in complex traffic environments. Additionally, external environmental factors such as bright sunlight, fog, or rain could impact signal strength, requiring further optimization for reliable performance under varying conditions. While the current implementation was designed for communication between two vehicles, expanding the system to support multi-vehicle networks could enhance its effectiveness in real-world scenarios. Overall, the project successfully addressed critical gaps in existing V2V communication technologies, providing a cost-effective, scalable, and intelligent solution for road safety and traffic efficiency. Future advancements could focus on improving signal reliability, integrating additional sensors, and optimizing Li-Fi for large-scale deployment in smart transportation systems.

VII. CONCLUSION

The Li-Fi-based Vehicle-to-Vehicle (V2V)

Communication System was successfully implemented to enhance road safety, accident prevention, and real-time vehicle communication.. The integration of ultrasonic sensors for distance monitoring and MEMS sensors for accident detection allows for real-time hazard warnings, significantly reducing the risk of collisions. Additionally, the buzzer and LCD display provide instant audio and visual alerts, improving driver response time. Unlike traditional RF-based communication, Li-Fi offers a cost-effective, secure, and energy-efficient alternative, free from network congestion issues. However, challenges sas line-of-sight dependency and environmental interference require further research for large-scale implementation. Future advancements can focus on multi-vehicle connectivity, AI-based predictive alerts, and improved Li-Fi signal reliability, making this system a crucial step toward smart, safe, and intelligent transportation networks.

VIII. REFERENCES

[1] W.-L. Jin, "SPIVC: A Smartphone-based inter-vehicle communication system," Proceedings of Transportation Research Board Annual Meeting, 2012.

[2] Boukerche et al., "Vehicular Ad Hoc Networks: a new challenge for localization-based systems," Computer Communications, ScienceDirect, 2008.

[3] T.H.M.A.Y.K.K.K. Isamu Takai, "Optical Vehicle-to-Vehicle Communication System Using LED Transmitter and Camera Receiver," IEEE Photonics Journal, Vol. 6, No. 5, October 2014, pp. 7902513-7902513.

[4] H. Elgala, R. Mesleh, and H. Haas, "Indoor Broadcasting via White LEDs and OFDM," IEEE Trans. on Consumer Electronics, Vol. 55, No. 3, Aug. 2009, pp. 1127 1134.

[5] W. Jia-yuan, Z. Nian-yu, W. Dong, I. Kentaro, I. Zensei and N. Yoshinori, "Experimental study on visible light communication based on LED," The Journal of China Universities of Posts and Telecommunications, Vol. 19, No. 2, October 2012, pp. 197-200.

[6] Qasim, S. M., Hranilovic, S., & Haas, H. (2016). Connectivity analysis of visible light communication networks for vehicular applications. IEEE Transactions on Vehicular Technology, 65(9), 7571-7583.

[7] H. Elgala, R. Mesleh, H. Haas and B. Pricope, "OFDM Visible Light Wireless Communication Based on White LEDs," In the Vehicular Technology Conference Proceeding, 22-25 April, 2007, pp. 2185-2189.

[8] N. Lourenco et. al, "Visible Light Communication System for Outdoor Applications," In the 8th International Symposium on Communication Systems, Networks and Digital Signal Processing, 18-20 July 2012, pp. 1-6.

[9] Li, Y., & Li, W. (2016). Vehicle-to-vehicle communication using visible light: A survey. IEEE Access, 4, 4662-4678.

[10] Research Board Annual Meeting, 2012. [2] A. Boukerche et al., "Vehicular Ad Hoc Networks: a new challenge for localization-based systems," Computer Communications, ScienceDirect, 2008, pp. 1-12.