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Li-Fi Driven V2v Connectivity For Real-Time Accident Avoidance

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Abstract: Traffic safety applications using vehicle-to vehicle (V2V) communication is an emerging and promising area within the ITS environment. Many of these applications require real-time communication with high reliability. Li-Fi is a wireless communication system in which light is used as a carrier signal instead of traditional radio frequency as in Wi-Fi. Li-Fi is a technology that uses light emitting diodes to transmit data wirelessly. Li-Fi is a form of Visible Light Communication (VLC). VLC uses rapid pulses of light to transmit information wirelessly that cannot be detected by the human eye. This project is determined to enhance the quality of Intelligent Transportation System (ITS) with the help of Visible light communication technology using a Li-Fi transmitter and receiver kit. The V2V communication system consisting of the Li-Fi transmitters placed on a leading vehicle and the Li-Fi receiver is placed on a following vehicle. The received data can be used for further development in vehicle control and to avoid collisions by controlling the speed of the vehicle.

Key Words: Li-Fi; VLC; vehicles

I. INTRODUCTION

Nowadays, the need of users to access Internet anywhere at any time is increasingly becoming a necessity. The exponential increase in mobile data traffic has led to the massive deployment of wireless systems. As a consequence, the limited available RF spectrum is subject to an aggressive spatial reuse and co-channel interference has become a major capacity limiting factor. Therefore, there have been many independent warnings of a looming “RF spectrum crisis” as the mobile data demands continue to increase while the network spectral efficiency saturates despite newly- introduced standards and great technological advancements in the field. It is estimated that by 2017, more than 11 exabytes of data traffic will have to be transferred through mobile networks every month. Most recently, VLC has been identified as a potential solution.

Unlike other wireless environments that are mostly stationary or with low mobility, data transmission in VANETs poses more challenges to be resolved. Since the topology is constantly changing, vehicles could move away from their home network and cause connectivity breakage. In order to cope with this problem, a vehicle connected to the wireless network should be able to move using different access points available along the road. These access points could belong to different networks or wireless technologies like Wi-Fi, WiMAX or 3G. The performances are not enough good with the traditional RF technologies. In this paper we will show how in VANETs networks a Li-Fi wireless network would complement existing heterogeneous RF wireless networks, and would provide significant spectrum relief by allowing cellular and wireless-fidelity (Wi-Fi) systems to off-load a significant portion of wireless data traffic.

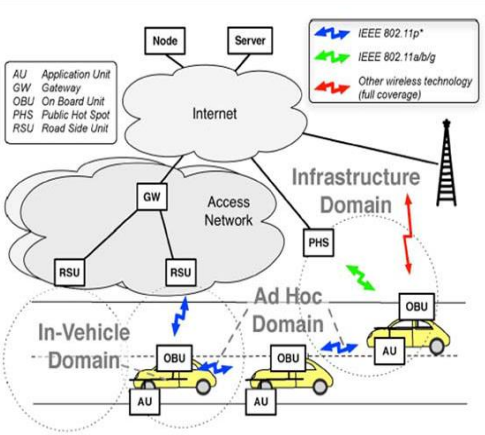

Fig 1: System architecture, currently assumed by the V2V Communication Consortium

II. WORKING PRINCIPLE

A. Working of Li-Fi System

The working principle of vehicle-to-vehicle communication using Li-Fi in this system is based on real-time detection of critical conditions and optical data transmission using visible light. Each vehicle is equipped with an Arduino Uno microcontroller, which acts as the central processing unit for reading sensor inputs and controlling communication functions. Sensors such as a flame sensor, vibration sensor, and infrared (IR) sensor are used to detect fire hazards, collisions, or proximity to other vehicles or objects. Upon detection of an abnormal event (e.g., fire or sudden impact), the Arduino processes this input and generates an alert signal. This alert data is then modulated and sent through a Li-Fi transmitter typically a high-brightness LED-embedded in the vehicle's headlight or another light source. The Li-Fi transmitter rapidly switches the LED on and off to encode the binary data corresponding to the alert, which is received by a photodiode-based Li-Fi receiver mounted on a nearby vehicle. The receiver demodulates the incoming light signal and passes the data to the receiving vehicle's Arduino Uno. The Arduino then interprets the received data and activates a notification or warning on the LCD display installed in the vehicle, alerting the driver to potential hazards or critical conditions in real time. A voltage regulator is used to ensure stable 5V power supply to the Arduino and sensors. This system enables direct, line-of-sight communication between vehicles using Li-Fi, providing low-latency alerts without relying on radio frequency communication, and enhances road safety by facilitating immediate awareness of dangerous situations.

B. Li-Fi Transmitter

The Li-Fi transmitter functions by converting digital information into modulated light signals using high-speed Light Emitting Diodes (LEDs). Initially, binary data generated from a source, such as a microcontroller or sensor module, is processed through a modulation circuit. This circuit encodes the data using modulation techniques like Pulse Width Modulation (PWM).The modulated signal is then sent to a driver circuit, which regulates the current supplied to the LED. The LED responds by rapidly switching its light intensity in accordance with the encoded signal—turning on and off or varying in brightness at very high frequencies, which are imperceptible to the human eye. This modulated light, now carrying the digital data, is emitted into the surrounding environment, typically in a line-of-sight direction. In vehicle-to-vehicle communication applications, this light can be emitted through the vehicle's headlights or dedicated LEDs, enabling real-time transmission of information such as hazard alerts or vehicle status to nearby vehicles equipped with compatible Li-Fi receivers

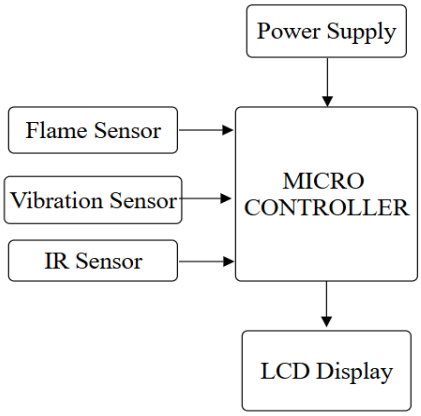

Fig 2: Li-Fi Transmitter

C. Li-Fi Receiver

The Li-Fi receiver is designed to capture and decode data transmitted via modulated light signals from a Li-Fi transmitter. It primarily consists of a photodetector—typically a photodiode or a light sensor—that converts incoming light pulses into corresponding electrical signals. When modulated light from the transmitter reaches the photodetector, variations in light intensity caused by the encoded data are translated into an analog electrical current. The ampLi-Fied signal is passed through an analog-to-digital converter (ADC), which digitizes the waveform. A demodulation circuit, often controlled by a microcontroller such as an Arduino Uno, then interprets the digital signal and reconstructs the original binary data. This information can trigger specific actions—such as displaying a warning on an LCD screen or activating a vehicle system—depending on the content of the received message. The Li-Fi receiver plays a critical role in enabling real-time, high-speed communication by accurately detecting and interpreting the modulated light, even under varying lighting conditions or mobility constraints in vehicular environments.

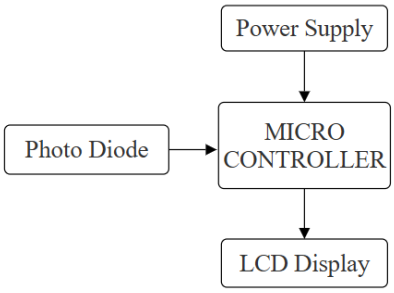

Fig 3: Li-Fi Receiver

III. EXISTING AND PROPOSED SYSTEM

A. Existing System

Easy SMS is a secure messaging system designed to ensure end-to-end encryption of SMS messages between two end users. The system operates by first establishing a symmetric shared key between two mobile stations (MS), which is then used to encrypt and decrypt messages using symmetric key cryptography. The functioning of the protocol is demonstrated through two scenarios: the SMSSec and PK-SIM protocols, both based on a client-server communication model. The SMSSec protocol is a security mechanism developed to protect SMS messages transmitted using Java's Wireless Messaging API. It employs the AES (Advanced Encryption Standard) or MAES (Modified AES) algorithm to provide robust end-to-end confidentiality, ensuring that only the intended recipient can access and interpret the message content. This effectively protects the data from interception or unauthorized access. The PK-SIM protocol extends this approach by integrating Public Key Infrastructure (PKI) capabilities into standard SIM cards. In this scenario, the SIM card is capable of generating a public-private key pair, which is used for message authentication and secure encryption. Despite its use of asymmetric cryptography for key exchange and authentication, PK-SIM also relies on AES/MAES for actual message encryption. The incorporation of strong cryptographic algorithms in both SMSSec and PK-SIM protocols significantly enhances SMS security by safeguarding sensitive information during transmission. As a result, these protocols play a crucial role in preserving user privacy and reinforcing the integrity of mobile communications in an increasingly interconnected world.

B. Proposed System

The proposed system enables real-time, short-range communication between vehicles using Light Fidelity (Li-Fi) technology integrated with a microcontroller-based sensing and alert mechanism. The core objective of this system is to enhance road safety by allowing vehicles to exchange critical information such as fire detection, collision alerts, or proximity warnings through modulated light signals. Each vehicle is equipped with a Li-Fi transmitter and receiver, an Arduino Uno microcontroller, and a set of sensors including a flame sensor, vibration sensor, and infrared (IR) sensor. These sensors are responsible for monitoring environmental and vehicular conditions in real time. When an abnormal event such as fire, vibration due to impact, or close-range object detection occurs, the respective sensor detects the condition and sends the signal to the Arduino Uno. The microcontroller processes the input and formats it into a binary data message, which is then modulated and transmitted using the Li-Fi transmitter (high-speed LED). The transmitter modulates the LED light based on the encoded data and projects it forward (or in a specific direction depending on the vehicle configuration). A nearby vehicle equipped with a Li-Fi receiver (photodiode or light sensor) receives this light signal. The received light is converted into an electrical signal, demodulated, and decoded by the receiving Arduino.

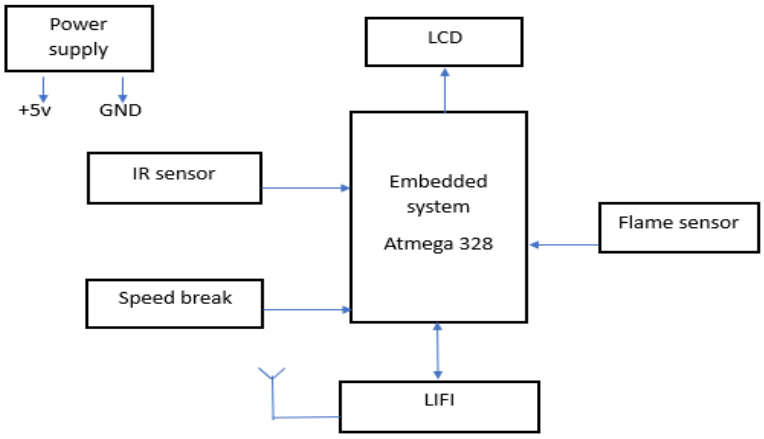

Fig 4: Block diagram for back vehicle

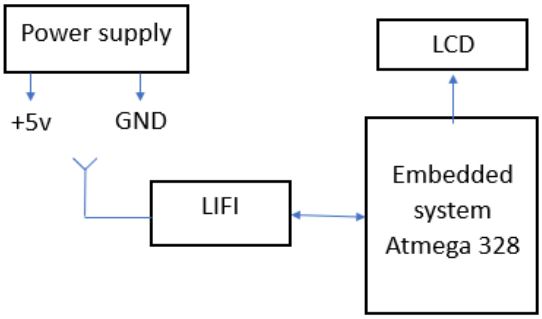

Fig 5: Block diagram for front vehicle

Once the message is decoded, the system identifies the type of alert (fire, collision, or proximity) and displays it on an LCD display installed in the vehicle's dashboard, thereby warning the driver instantly. A voltage regulator ensures that all components, including the sensors, microcontroller, and display, operate within a stable 5V supply. This optical communication system offers advantages over traditional radio-based V2V communication, such as reduced electromagnetic interference, increased bandwidth, and secure line-of-sight transmission. The integration of sensor-based alert mechanisms with Li-Fi technology provides a low-latency, cost-effective, and efficient method to improve vehicular communication and road safety.

C. Flow Chart

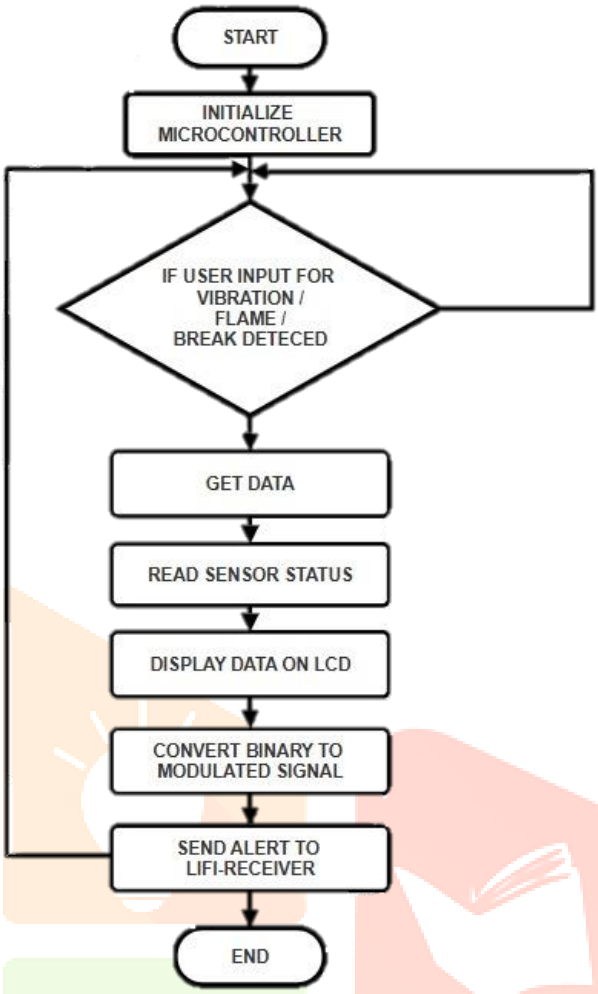

Fig 6: Flow chart for Li-Fi Transmitter

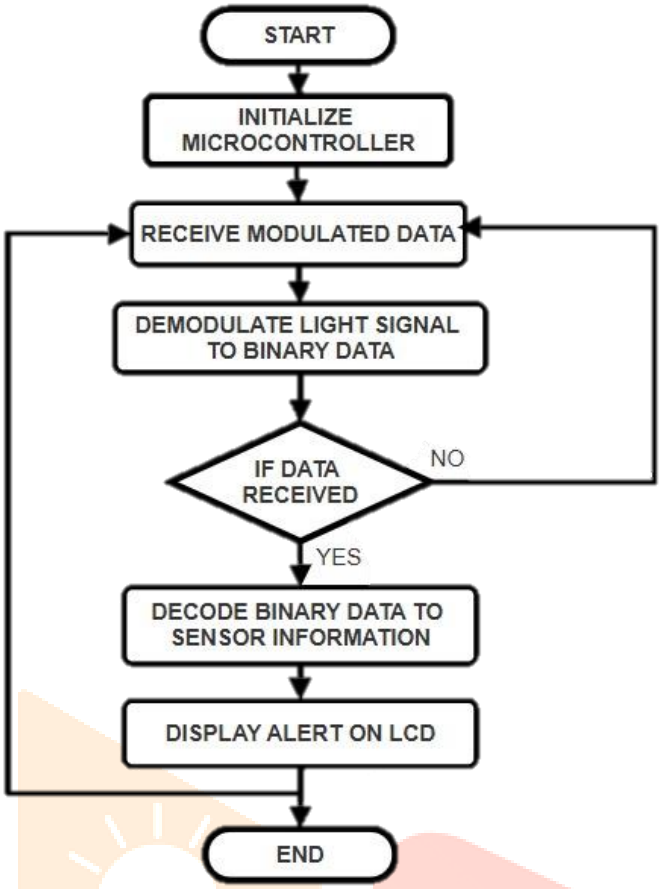

Fig 7: Flow chart for Li-Fi Receiver

IV. RESULT

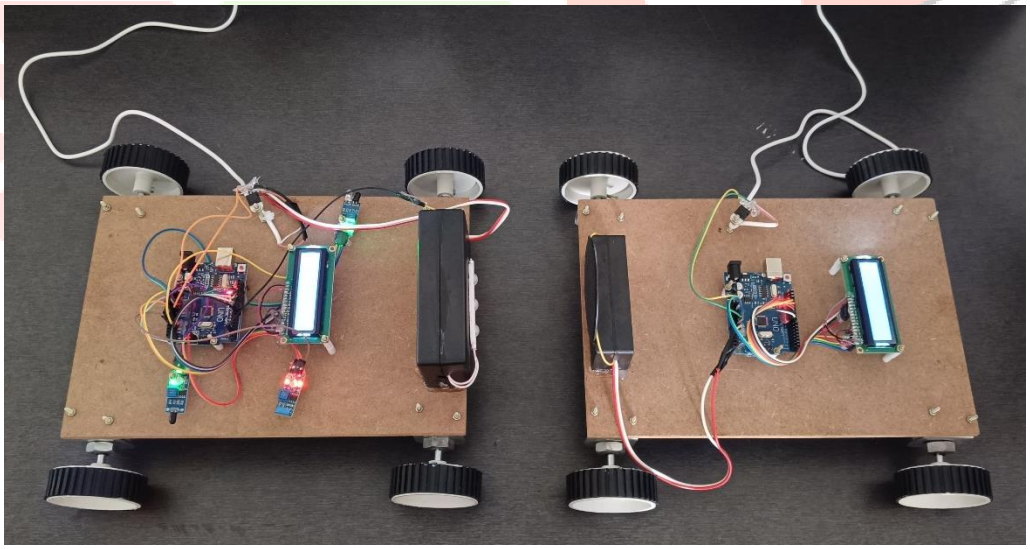

Fig 8: Full image of the proposed work

Below are the results of our project that incorporates a Flame sensor, Vibration sensor, IR sensor,

The vibration sensor is used to detect sudden impacts, such as collisions or hard bumps. When a collision occurs, the sensor senses the vibration or shock and sends a signal to the Arduino Uno. The Arduino identifies this as a collision event and encodes it into a different binary message. This message is sent to the Li-Fi LED, which turns on and off in a pattern representing this new code. The light is picked up by the receiving vehicle's photodiode, and the receiving Arduino decodes the pattern. It realizes the message means a collision has occurred in the front or nearby vehicle and displays an alert on the LCD to warn the driver to react quickly.

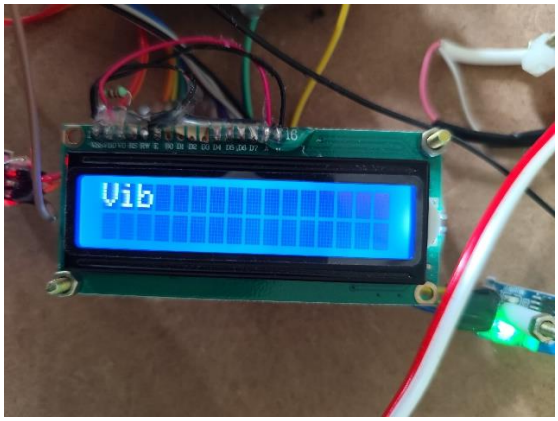

Fig 9: Monitor showing result of vibration sensor

The flame sensor is used to detect the presence of fire or a high-temperature flame near the vehicle. It continuously monitors for infrared light emitted by a flame. When a flame is detected, the sensor sends a signal to the Arduino Uno. The Arduino recognizes that this signal means a fire is present and creates a binary message to represent a fire alert. This binary message is then sent to the LED, which blinks rapidly in a pattern that matches the binary code. This modulated light travels to the next vehicle, where a photodiode receives it. The receiving Arduino reads the light signal, decodes it, and understands that it's a fire alert. It then displays a warning message on the LCD screen to alert the driver immediately.

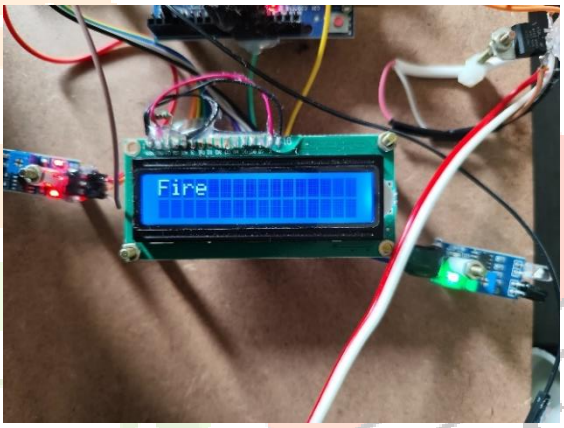

Fig 10: Monitor showing result Flame sensor

The infrared (IR) sensor is used to detect objects or vehicles that are too close, helping prevent possible accidents due to reduced distance. The IR sensor constantly checks for objects within a certain range. If it detects something too close, it sends a signal to the Arduino. The Arduino processes this and generates a third unique binary code to indicate a proximity warning. This code is sent using the Li-Fi LED as a blinking light signal. The receiving vehicle’s light sensor captures the signal, and the receiving Arduino decodes it as a proximity alert. It then displays a message like on the LCD screen to inform the driver to slow down or take caution.

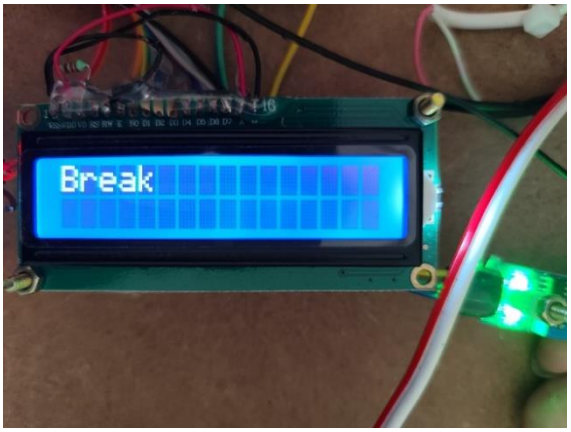

Fig 11: Monitor showing result IR sensor

V. Conclusion and Future scope

A. Conclusion

The most powerful approach that has been used to minimize vehicle injuries is vehicle-to-vehicle contact. Vehicle to Vehicle communication is the communication methodology which implies the network-based topology. The Buzzer indicator in a vehicle with Li-Fi technology. Li-Fi includes the use of the spectrum of visible light as a contact medium. Highspeed data transfer, secure, efficient and environmentally friendly, is provided by Li-Fi technology. In this project, we present the designs and prototype of a device for vehicle-to-vehicle communication (v2v) using Light Fidelity (li-fi) technology, known as Visible Light Communication (VLC), which is here used for vehicle data communication. The proposed device also involves the prevention of turning point incidents with sensors. This proposed method meets and ensures the comfort and safety for the vehicles by preventing major accidents. This proposed project is an application of vehicle to vehicle and no infrastructure is required. Since this project does not require any protocols or any architecture which is network based, this is more robust. This proposed project makes use of various sensors namely accelerometer, ultra-sonic sensor, speed sensor and transfers the data collected from these sensors between vehicles. Services such as warning about an accident, traffic jams information or messages about a rescue vehicle which is approaching. Additional information such as whether information and voice commands can also be given. Moreover, the main key part in this proposed system is the use of Light Fidelity (Li-Fi) to transmit the data. The use of Li-Fi ensures and guarantee the speed of the communication and also go green to the environment

B. Future Scope

Vehicle-to-Vehicle (V2V) communication is set to transform modern transportation by enabling intelligent, real-time interactions between vehicles. The integration of advanced technologies such as Li-Fi, 5G, edge computing, and AI will significantly improve data speed, reduce latency, and support autonomous driving. As Li-Fi-based systems evolve, they will offer high-speed, interference-free communication that complements RF systems, particularly in congested areas. To extend coverage over long distances, future V2V networks will incorporate hybrid models combining Li-Fi for short-range and 5G or satellite links for long-range communication. Enhanced security through blockchain and post-quantum encryption will ensure safe transmission of critical alerts like collisions or road hazards. Combined with Vehicle-to-Infrastructure (V2I) and V2X systems, V2V will be essential in building smart, connected cities. Ultimately, as regulatory adoption increases, V2V is expected to become a standard safety feature, supporting safer, more efficient, and sustainable transport systems.

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