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A Project Report

On

Visible Light Communication For Emergency Vehicles

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Bachelor of Engineering

In

ELECTRONICS AND COMMUNICATION ENGINEERING

(VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI)

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ABSTRACT

LiFi technology utilizes light for high speed data transmission, ideal for congested spaces. It operates through modulating LED light intensity, offering enhanced security and bandwidth. Integrated with IoT and lighting systems, LiFi promotes energy efficiency and connectivity, promising a transformative impact across multiple domains.

LiFi's potential in the healthcare and retail sectors is recognized, with ongoing exploration into its application in road safety and traffic management. Research focuses on identifying challenges and proposing novel solutions, leveraging LiFi's high speed data transmission via light to enhance communication and efficiency, and addressing critical issues in transportation systems.

The project delves into LiFi's potential for enhancing road safety and traffic management by efficiently transmitting realtime distress signals from stranded emergency vehicles to authorities. Leveraging LiFi technology ensures swift and reliable communication, enabling prompt assistance and significantly contributing to the overall safety and efficiency of transportation systems.

In summary, the use of LiFi technology for transmitting distress signals from stranded emergency vehicles shows encouraging efficiency and dependability. With its ability to reduce risks and greatly improve overall transportation management, this system is a great asset for improving traffic control and road safety.

Future tasks for LiFi encompass refining systems, aligning with vehicle to everything (V2X) communication, and integrating into fleet management solutions. Its potential applications are diverse, spanning from enhancing in-vehicle connectivity and entertainment to enabling seamless communication between vehicles, infrastructure, and pedestrians, revolutionizing transportation efficiency and safety.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULLFORM
ASCII	American Standard Code for Information Interchange
CAC	Cooperative Adaptive Cruise Control
GPS	Global Positioning System
GSM	Global System for Mobile Communication
IDE	Integrated Development Environment
IoT	Internet of Things
LED	Light Emitting Diode
Li-Fi	Light Fidelity
VLC	Visible Light Communication
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything

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CHAPTER 1

INTRODUCTION

In the rapidly evolving realm of communication technologies, Visible Light Communication (VLC) has emerged as a promising solution for various applications, ranging from indoor positioning systems to vehicular communications. VLC also known as Li-Fi, is a wireless technology that transmits data using visible light. Particularly, when integrated with emergency vehicles, VLC can offer groundbreaking advancements in ensuring safer and more efficient emergency response operations. The integration utilizes Vehicle-to-Vehicle (V2V) communication, a subset of Vehicular Ad-Hoc Networks (VANETs), to facilitate data exchange between emergency vehicles, thereby enhancing coordination and response times during critical situations.

The scope of this work primarily revolves around the application of Light Fidelity (LiFi), a VLC technology that employs light as a medium for communication, in emergency vehicles. By harnessing the power of LiFi, emergency vehicles can transmit and receive data through modulated light signals, ensuring reliable communication even in challenging environments where traditional radio frequency (RF) communication may face interference or bandwidth limitations.

The importance of this research stems from the critical need to improve the efficiency and reliability of emergency response systems. In emergency situations, timely and accurate communication between emergency vehicles can be a matter of life and death. Therefore, exploring innovative communication solutions like LiFi based V2V communication can significantly enhance the capabilities of emergency response teams, allowing them to better coordinate their actions and make informed decisions in real-time.

The work also builds upon previous studies in the field of VLC and V2V communication, aiming to address some of the existing challenges and limitations associated with these technologies. By leveraging recent advancements in LiFi technology and V2V communication protocols, this research seeks to develop a robust and scalable communication framework tailored for emergency vehicles.

Furthermore, with the ongoing advancements in LiFi technology and the increasing demand for reliable communication solutions in smart cities and intelligent transportation systems, the present developments in this area hold immense potential for revolutionizing the way emergency services operate. By integrating LiFi-based V2V communication systems into existing infrastructures, cities can pave the way for safer, more efficient, and smarter emergency response networks, setting new benchmarks for public safety and urban mobility.

1.1 Motivation for the Work

1. Enhanced Safety and Efficiency: In emergency situations, every second counts. Delays in communication or miscoordination between emergency vehicles can lead to critical consequences. By employing LiFi-based V2V communication, we aim to reduce response times, improve coordination, and ultimately enhance the safety and efficiency of emergency operations.
2. Overcoming RF Limitations: Traditional radio-frequency (RF) communication methods used in emergency vehicles can sometimes face challenges like interference, bandwidth constraints, and security vulnerabilities. LiFi offers an alternative solution that leverages the visible light spectrum, providing a more reliable and secure communication medium.
3. Scalability and Integration with Smart Cities: As cities around the world continue to evolve into smart cities, there is a growing need for intelligent transportation systems that can seamlessly integrate with other smart infrastructures. LiFi based V2V communication for emergency vehicles aligns with this vision, offering a scalable solution that can be integrated into broader smart city initiatives.
4. Environmental and Health Considerations: LiFi technology is inherently more environmentally friendly compared to RF technologies, as it utilizes LED lights that consume less energy and produce fewer electromagnetic emissions. Additionally, concerns regarding potential health risks associated with prolonged exposure to RF radiation make LiFi an appealing alternative.
5. Innovative Technological Advancements: The ongoing advancements in LiFi technology, including improvements in data transmission rates, range, and compatibility with existing infrastructures, present new opportunities for innovation in

the field of vehicular communication. Exploring the capabilities of LiFi in the context of emergency vehicles can pave the way for groundbreaking applications and solutions.

1.2 Objectives

The primary objectives of our project are

1. Seamless and Efficient Connection between Emergency Vehicles and Vehicles for Enhanced Speed and Responsiveness.
2. Enable emergency vehicles to navigate through traffic seamlessly using V2V coordination, ultimately preserving crucial seconds and saving lives.
3. Forge a network of interconnected vehicles to eliminate collisions.

1.3 Organization of the Report

Chapter 1 gives the introduction for visible light communication for emergency vehicles. It describes the motivation for the work and the objectives.

Chapter 2 gives the information on the key features of various papers in the literature review.

Chapter 3 details the wagon's working methodology and the establishment of V2V communication using the LIFI transmitter and LIFI receiver.

Chapter 4 shows the results of the successful establishment of V2V communication between the two wagons.

Chapter 5 concludes the report with a brief description of what has been accomplished in this project and gives insight into the future scope for the project.

CHAPTER 2

LITERATURE REVIEW

Sl.No	Paper Title	Author	Year	Key Points
1	Vehicle To Vehicle Communication Using LI-FI	S.Saranya,M. Sriram, K. Varadharaj and K. Yugesh	2023	The system consists of a LIFI transmitter and receiver, an Arduino UNO board, a vibration sensor, a gas sensor, an ultrasonic sensor, a PC camera, an LED bulb, a funnel, a solar panel, and light. The LED emits light, which is picked up by the solar panel, and converted into a human-readable form for data transfer.
2	Vehicle-To-Vehicle Communication Using Li-Fi Technology	S.P. Cowsigan, S. Narendhran, B. Nithisree and T.J. Jisshnu Kannan	2022	The study proposes the use of Li-Fi technology, consisting of light-emitting diode bulbs, to reduce vehicle accidents and save lives. The technology uses an ultrasonic sensor to detect the distance between the vehicles, allowing data exchange between them. The project also explores the use of LED based lighting for data

				communication, which highlights its potential for the future work and advancements.
3	LI-FI Based Vehicle To Vehicle Communication	Ishwarya.S, Christina Sugikesita.M, Deepajothi.M, Dr.R.Sabitha B	2022	The proposed system uses various sensors, including nictitation, ultrasonic, mems, and alcohol sensors, with a DC motor. The α sensor detects armature tilt, while the mems sensor detects rash driving. A reflex sensor detects rider drowsiness, alerting the driver before a mishap. The system uses a liquid display and ESP32 microcontrollers with integrated Wi-Fi and Bluetooth.
4	Vehicle To Vehicle Communication Using Li-Fi Technology	Vishal Mishra, Anand Yadav, Prabhat Singh Rawat, Md. Uzair, Ravi Shankar	2022	The system consists of a sender, receiver, and user input. The sender sends a message to a capable microcontroller, which converts it to ASCII. The message is then boosted by an NPN switching circuit, reversed by a PNP switching module, and transferred to a Syska

				LED. The message is then sent to a TTL to a USB circuit.
5	Vehicle To Vehicle Communication Using LiFi Technology	Kaarthick Saran. S, Keerthivasan. V, Parthiban. D, Pradeep. P , Dr. C. Amali	2022	Li-Fi uses visible light from overhead illumination for information transmission. It uses a VLC framework and consists of a transmitter, Arduino board, transmitter, LED bulb, photovoltaic cell, and receiver. The transmitter converts data into binary.
6	A Future way of Vehicle Communication using Li-Fi Technology	Mohd Farhan Jafri, Mohd Yusuf	2020	Headlights in vehicles transmit data, such as load, velocity, and position, to avoid accidents. Nearby vehicles have light detectors that capture this data. Li-Fi technology connects vehicles using this method, which is safer, more efficient, and faster. The data is transmitted digitally using an ADC and passed on to a controller, which adjusts the light source intensity.

7	Vehicle to Vehicle Communication using LI-FI Technology	Buvaneswari S, Tanishka Raghu, Saranraj S	2020	The system uses Li-Fi technology which includes many sensors such as MQ3, vibration sensor, ultrasonic sensor, PC camera along with an Arduino board, LED light, and a solar panel to communicate from one vehicle to another. Thus the system proposes a solution to minimize road accidents, and in the future, it can ensure safety of the drivers along with passengers
8	Traffic Management System using Vehicle to Vehicle Communication employing LI-FI and IoT	Shambhavi,Shuchi Mishra, Rada Chandresh, Md Abdullah Khan, Dr. Arvind HS	2020	A Li-Fi communicator and accident detector is a system that communicates between vehicles using components like an Arduino-Uno module, ultrasonic sensor, accelerometer, and Li-Fi transmitters and receivers. It provides details like speed, distance, orientation, and potential accidents, updating the cloud with data for collision avoidance, traffic

				management, emergency response.
9	Accident Analysis and Avoidance by V2V Communication Using LIFI Technology	S. Sivakumar, A. Alagumurugan, G. B. Baala Vignesh, S. Dhanush	2020	The system uses two Arduinomicrocontrollers as the brain, with a transmitter and receiver section. The transmitter sends stop condition information wirelessly via the Li-Fi Transmitter, while the receiver receives this information via Li-Fi Receiver. The receiver features an ultrasonic sensor for distance calculation and a crash sensor for accident detection, sharing location via GPS, and sending messages via GSM.
10	Channel Modelling and Performance Limits of Vehicular Visible Light Communication Systems	M. Karbalayghareh, F. Miramirkhani, H. B. Eldeeb, R. C. Kizilirmak, S. M. Sait and M. Uysal	2020	VLC, a promising contender for V2V communication, leverages existing LEDs in headlights and taillights to transmit data, ditching traditional radio waves. This not only avoids interference but also boasts potential for blazing-fast data transfer,

				exceeding gigabits per second. With automakers embracing LEDs, VLC seems a natural fit for future roadways, paving the way for safer and more efficient traffic flow.
11	LiFi for Vehicle-to-Vehicle Communication – A Review	Rahul George, Srikumar Vaidyanathan, Amandeep Singh Rajput , K Deepa	2019	Modulation signals control the flickering of LEDs at different frequencies to transmit data. SCM is suitable for low to moderate data rates, allowing for individual reception of multiple signals at different frequencies. Techniques include ON-OFF Keying (OOK), Pulse-amplitude modulation (PAM), and Pulse position modulation (PPM). In this project, OOK represents data as 1s and 0s through LED flickering, while VPPM provides efficient dimming support.
12	Vehicle-to-Vehicle Visible Light Communication: How to select	H. B. Eldeeb and M. Uysal	2019	The source destination uses high-beam headlights as transmitters and is equipped with four PDs.

	receiver locations for optimal performance?			Three scenarios are considered: constant speed with perfect alignment, horizontal shift, and changing lanes. Ray tracing simulations are run to obtain channel impulse response (CIR) for these scenarios, calculating total received optical power and power percentage of each PD. This helps determine the essential PDs for each scenario.
13	Vehicle to Vehicle Communication using Light Fidelity	T. N. Prabhu, Adharsh M., Ashok Kumar M., Gokul Krishna M., Dhayanithi G.	2017	The top view shows the front and back vehicles, with sensors interfaced with the control unit. The front vehicle has a buzzer and LCD monitor for warning, a Photodetector for data transmission, and an Ultrasonic sensor for distance measurement. Eye-blink and alcohol sensors check driver sleepiness and intoxication, respectively. The LED transmits safety messages when alcohol. obstruction or

				sleepiness occur.
14	Vehicle-to-Vehicle and Infrastructure-to-Vehicle Communication in the Visible Range	M. A. Vieira, M. Vieira, P. Vieira, P. Louro	2017	This paper envisions a future where cars and infrastructure "talk" through light! It proposes a VLC system for road safety, where traffic lights and headlights double as data transmitters and receivers using color-shifting LEDs and silicon carbide-based processors. This allows traffic lights to signal, communicate, and even pinpoint vehicle locations, potentially paving the way for safer and smarter streets.
15	Design And Implementation of A Vehicle To Vehicle Communication System Using LiFi Technology	S.Nachimuthu, S. Pooranachandran, B. Sharomena Aarthi	2016	The infrared sensor detects objects by transmitting a narrow band infrared beam from an LED. The IR distance sensor then sends the detected information to a controller using an Arduino Pro mini microcontroller board. The controller has 14 digital input and output pins, 8 analog input pins, and 6 PWM output pins. The

				LCD displays the information, and the controller reduces the motor speed.

CHAPTER 3

METHODOLOGY

3.1 Overview of LiFi

Li-Fi or Light Fidelity is a relatively new technology that refers to the Visible Light Communication (VLC) system which uses light as a pathway for the transfer of data at high speeds. Since light is used, it offers a wide
range of frequencies and wavelengths. "Fidelity" refers to the accuracy and faithfulness of the transmission.

At its core, LiFi operates by modulating the intensity of light emitted by Light Emitting Diode (LED) bulbs at
extremely high speeds, These fluctuations in light intensity are imperceptible to the human eye but can be detected and decoded by specialized photodetectors, such as photodiodes, integrated into receiving devices.

3.1.1 Features of LiFi

1. High Speeds: LiFi can achieve data transmission rates that surpass those of traditional WiFi, reaching several gigabits per second (Gbps) under optimal conditions. This makes LiFi particularly well-suited for applications that require ultra fast data transfer, such as high-definition video streaming, virtual reality, and augmented reality.
2. Low Latency: With minimal signal propagation delays, LiFi offers low latency communication, making it ideal for real-time applications like online gaming, video conferencing, and autonomous vehicles.
3. Immunity to Electromagnetic Interference: Unlike RF signals, which can be susceptible to interference from other wireless devices or environmental factors, LiFi operates in the optical spectrum, where interference is minimal. This makes LiFi a reliable choice for communication in environments where RF interference is a concern, such as hospitals, industrial facilities, or aircraft cabins.
4. Energy Efficiency: LiFi utilizes LED bulbs for both illumination and data transmission,

offering energy efficient lighting solutions that contribute to overall sustainability efforts. By leveraging existing lighting infrastructure, LiFi deployment can be cost-effective and environmentally friendly.

5. Distance: The effective communication range of LiFi systems can vary depending on factors such as the intensity of the light source, the sensitivity of the receiver, and environmental conditions. In indoor environments, where line-of-sight communication is possible, LiFi systems can achieve ranges of up to several meters. However, the range may be limited in environments with obstacles or high ambient light levels. With advancements in receiver sensitivity and signal processing techniques, researchers have demonstrated LiFi links over distances exceeding 10 meters in laboratory settings.
6. Baud Rate: The baud rate, or symbol rate, represents the rate at which bits are transmitted per second in a communication system. LiFi technology offers extremely high baud rates, often ranging from several Mbps to several Gbps. The achievable baud rate depends on factors such as the modulation scheme, the modulation depth, and the signal-to-noise ratio of the communication channel.
7. Data Rate: The data rate of a LiFi system refers to the rate at which useful data can be transmitted over the communication link. The data rate is directly proportional to the baud rate and can reach several gigabits per second in high-speed LiFi systems. Advanced modulation schemes and signal processing techniques enable LiFi to achieve data rates that rival or exceed those of traditional radio frequency (RF) communication technologies like WiFi.
8. Channel Bandwidth: LiFi systems typically operate within the visible light spectrum, which offers a wide range of available frequencies. The channel bandwidth of LiFi systems can vary depending on factors such as the modulation scheme and the specific spectral range used for communication. In practice, LiFi systems can utilize channel bandwidths ranging from tens of megahertz (MHz) to several hundred megahertz, allowing for high-capacity data transmission.
9. Interference and Noise: LiFi systems are generally immune to electromagnetic interference (EMI) from RF sources, as they operate in the optical spectrum. However, LiFi communication may be susceptible to ambient light interference, flicker noise, and other optical impairments, especially in outdoor or highly illuminated environments.

10. Signal processing techniques, such as adaptive equalization and error correction coding, are employed to mitigate the effects of interference and noise on LiFi links.
11. Scalability and Compatibility: LiFi technology is inherently scalable and compatible with existing lighting infrastructure, making it well-suited for deployment in various indoor and outdoor environments. LiFi systems can be seamlessly integrated with LED lighting fixtures, enabling cost-effective deployment and rapid adoption in commercial, residential, and industrial settings.

3.1.2 Advantages in Transmission and Reception

Transmission:

1. High-Speed Data Transfer: LiFi enables extremely high-speed data transmission, reaching rates of several gigabits per second (Gbps). This rapid data transfer capability is particularly beneficial for applications requiring large file transfers, such as video streaming, file sharing, and cloud computing.
2. Bandwidth Availability: Unlike traditional radio frequency (RF) communication, which operates within crowded frequency bands, LiFi utilizes the vast spectrum of visible light. This abundance of available bandwidth allows for simultaneous transmission of multiple data streams without the risk of congestion or interference, enhancing overall network capacity and performance.
3. Low Latency: LiFi systems offer low latency communication, minimizing the delay between data transmission and reception. This low latency is critical for real-time applications like online gaming, video conferencing, and autonomous vehicles, where even slight delays can have significant consequences.
4. Directional Transmission: Light waves emitted by LED bulbs can be precisely directed and focused, allowing for highly directional transmission of data. This directional transmission minimizes signal spillage and enhances security by confining the communication range to specific areas or devices, reducing the risk of interception by unauthorized parties.

Reception:

1. Sensitive Photodetection: LiFi receivers, equipped with specialized photodetectors such as photodiodes, are highly sensitive to variations in light intensity. These photodetectors can accurately detect and decode modulated light signals, even at extremely high speeds, enabling reliable reception of data transmitted via LiFi.
2. Adaptive Signal Processing: LiFi receivers often employ sophisticated signal processing algorithms to extract useful information from received light signals. These algorithms can compensate for factors such as ambient light interference, flicker noise, and multipath propagation, ensuring robust reception performance in diverse environmental conditions.
3. Error Correction and Resilience: LiFi systems incorporate error correction techniques and redundancy schemes to mitigate the effects of signal attenuation, distortion, and interference. By detecting and correcting errors in received data packets, LiFi receivers can maintain data integrity and reliability, even in challenging transmission environments.
4. Beamforming and Spatial Diversity: Advanced LiFi receivers may implement beamforming and spatial diversity techniques to improve signal reception quality. By intelligently combining signals received from multiple light sources or antennas, LiFi receivers can enhance signal-to-noise ratio, increase coverage range, and mitigate the effects of fading and shadowing.

LiFi technology offers a robust and versatile solution for both data transmission and reception, leveraging the unique properties of visible light to achieve highspeed, reliable, and secure wireless communication. LiFi's transmission and reception capabilities make it a compelling choice for a wide range of communication.

3.2 Circuit Design

3.2.1 Working of the wagon

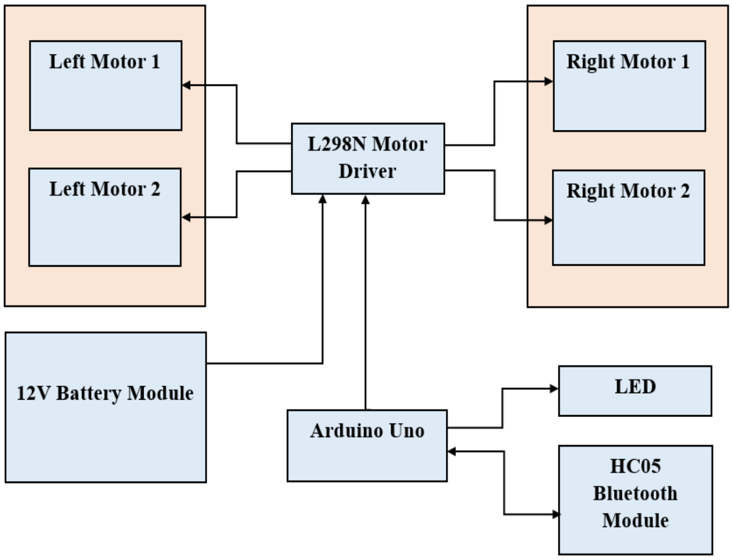

Figure 3.1 Block Diagram of the wagon

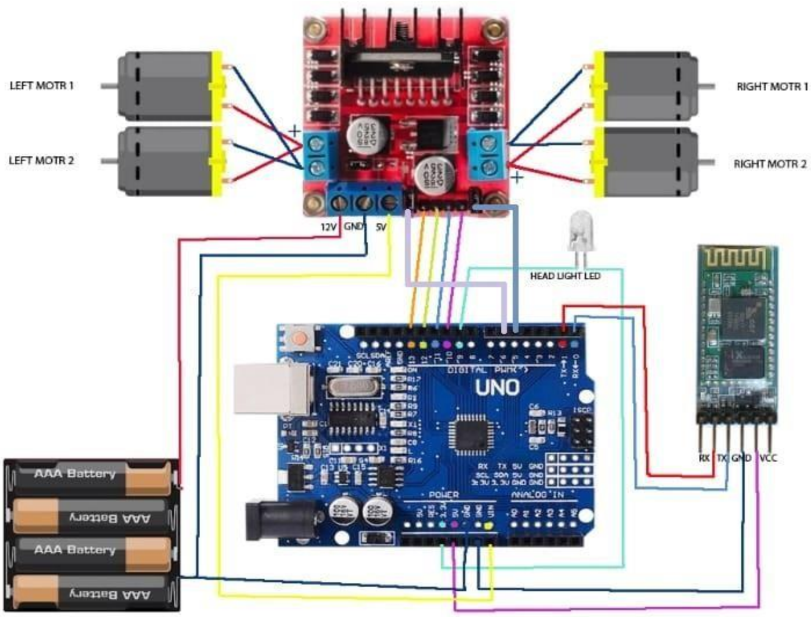

Figure 3.2 Circuit Diagram of the wagon

The wagon consists of four BO motors that are attached to the plank. The four tires are connected to the BO motors, The L298N motor driver is linked to the BO motors. The motor driver is attached to the 9V battery. The Arduino UNO is linked to the motor driver. The Arduino UNO is linked to the LED lights. The Arduino UNO is linked to the Bluetooth HC05 module.The mobile device serves as a remote control for operating the wagon through the Bluetooth HC05 module. The Bluetooth Host Controller, version 5, is denoted by the Bluetooth HC05. For quicker connectivity, the module takes advantage of Bluetooth 2.0 and Enhanced Data Rate. Within the module, there are two modes.

1. Master mode: The module can initiate connections with other Bluetooth devices.

2.Slave mode: The module can be connected to, by other Bluetooth devices.

The module uses UART for serial communication.

Pins of Bluetooth HC05 are:

Key/En: The pin specifies the mode. The mode can either be command mode or data mode.

The command mode is used to configure the module and the data mode is for the transmission or reception of data. By default the mode is set to data mode. For data mode, the baud rate is 9600. We are focused on the data mode for our project.

Vcc and ground: Used for power connections.Txd and Rxd: Used for serial communication. State: The pin specifies the module state.

The GFSK modulation technique is used by the Bluetooth HC05.The module adheres to IEEE 802.15.1 standards. The Bluetooth HC05 module has a range of roughly 10 meters. The frequency range is 2.4GHz ISM band. The voltage range is 3.3V to 5V DC. The current range is less than 50 mA.

The L298N motor driver is connected to the Arduino UNO.

The following is L298N in its entirety:

L: Indicates that the item is a member of the STMicroelectronics integrated circuit family

298: Denotes the particular model or version in the L2xx family.

N: Denotes the sort of package or variation in the series.

The motor driver employs an H-Bridge design to regulate the motor's direction based on the current flow. The voltage rating is up to 35V. The current rating is 2A per motor.

The pins 10 and 11 of Arduino UNO are connected to the right motors through the motor driver. Pins 12 and 13 of Arduino UNO are connected to the left motors through the motor driver. To move forward, pins 11,13 are set to HIGH. To move in reverse, pins 10,12 are set to HIGH. To turn right, pin 11 is set to HIGH. To turn left, pin 13 is set to HIGH. To stop, pins 10,11,12,13 are set to LOW. The LED is connected to pin 9 of the Arduino UNO.

The four BO motors are connected to the four tires and the L298N motor driver. BO motors stands for battery operated gear motors. BO motors are a combination of an electric motor and a gear motor for more efficient power transmission systems. The no-load speed is 300RPM +/- 10RPM.The voltage range is from 3V to 12V.

State of Pin Number 10	State of Pin Number 11	State of Pin Number 12	State of Pin Number 13	Orientation in which the tires are moving.
LOW	HIGH	LOW	HIGH	Forward
HIGH	LOW	HIGH	LOW	Backward
LOW	HIGH	LOW	LOW	Right
LOW	LOW	LOW	HIGH	Left
LOW	LOW	LOW	LOW	Stop

Table 3.1 Wagon Orientation

3.2.2 LiFi Transmission and Reception

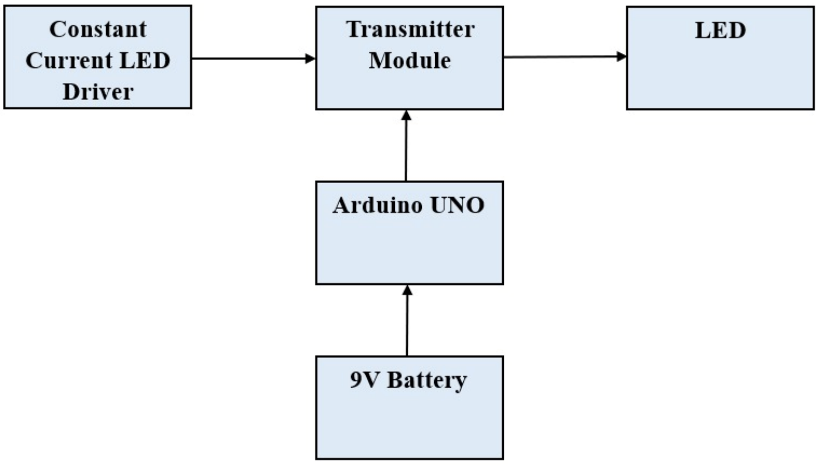

Figure 3.3 Block Diagram of LiFi Transmission

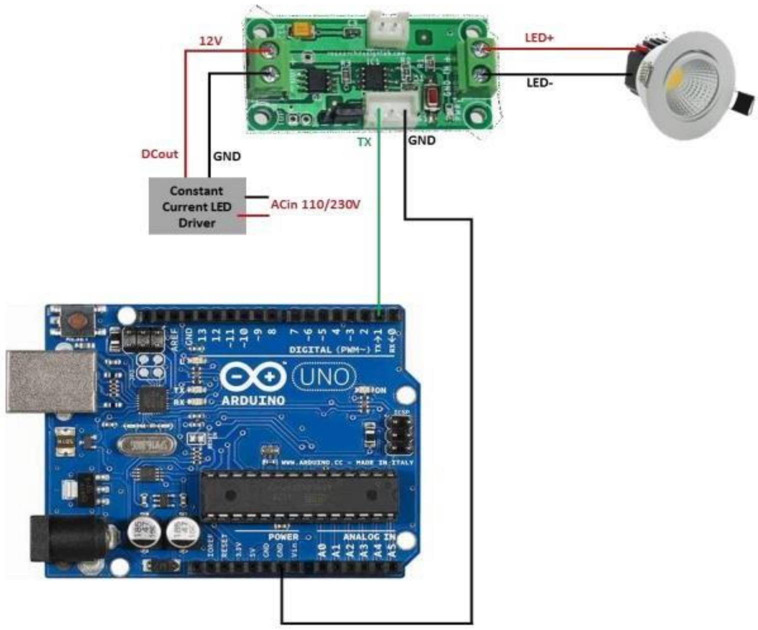

Figure 3.4 Circuit Diagram of the LiFi Transmitter

The central component of the system is the Li-Fi transmitter module, which encodes data into modulated light signals for wireless transmission. It gathers data from the Arduino UNO and uses it to modulate an LED light source's intensity. The encoded data is transmitted to other vehicles that have Li-Fi receivers by means of a modulated light signal.

The LiFi transmitter's magic lies in how it transforms data into light pulses. Here's the breakdown: First, we provide external power to the LED driver circuit through the Vin connection. This driveracts as a translator, regulating the power to match the specific needs for our chosen LED. It takesthe digital data we want to transmit and uses it to rapidly switch the LED on and off, or vary its intensity. These rapid light flickers are invisible to human eyes, but they encode the data onto thelight pulses. This way, the data gets a piggyback ride on the light waves, ready to be captured by the LiFi receiver module.

The transmitter module acts like a two-way switch with a jumper or switch to control its function. Setting the jumper to Low (L) or "CONFIG mode" is like putting it in setup mode. This mode allows you to adjust settings or prepare the transmitter for operation. We might notice the LED dimming down in this mode. Once you're done with configuration, switching the jumper to High (H) or "RUN mode" flips the transmitter to its regular gear.

To switch the transmitter to RUN mode, start by locating the designated jumper or switch on the LiFi transmitter module that is responsible for mode selection. Once we have identified the jumper,double check its current position. If it's already set to High (H) or the designated position for RUNmode, we can proceed directly to the next step. However, if it's in the Low (L) position or the designated position for CONFIG mode, carefully move the jumper to High (H) or the designated position for RUN mode. Upon making this adjustment, observe the LED intensity of the transmitter. It should return to its normal operating brightness, indicating that the transmitter is now in RUN mode and ready for data transmission.

To facilitate data transmission through LiFi technology, a combination of software and hardware setup is necessary. Firstly, we require both a LiFi transmitter module and a LiFi receiver module, which is typically connected to our computer via USB or other interfaces to enable data transfer.

These modules serve as the conduits through which digital data is converted into light signals for transmission and vice versa. Additionally, specialized LiFi communication software is essential for managing the process of data conversion and facilitating communication between our computer and the LiFi modules. The serial window acts as a user-friendly interface where we can input the data we wish to transmit, allowing for efficient communication between the computer and the LiFi modules.

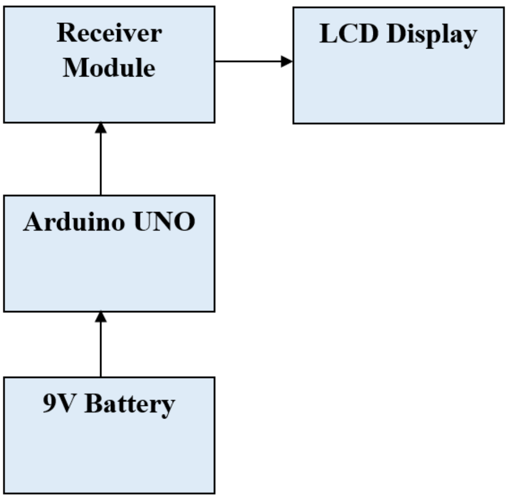

Figure 3.5 Block Diagram of the LiFi Reception

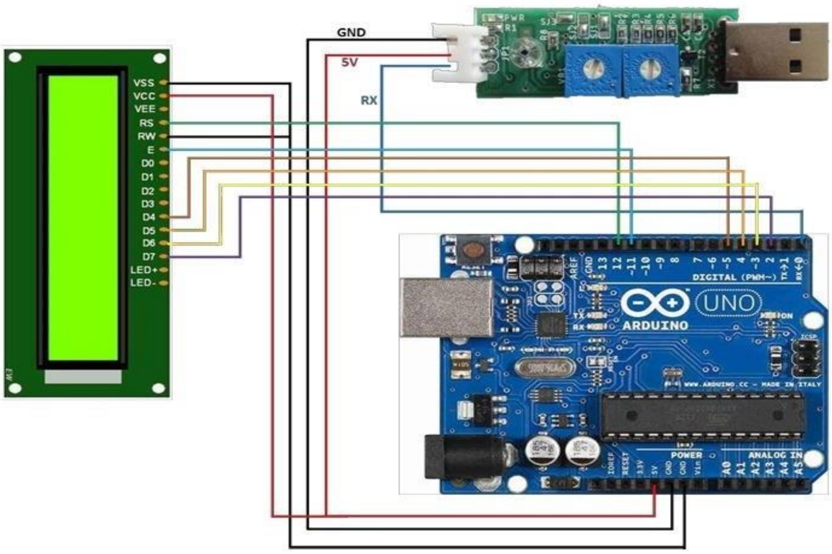

Figure 3.6 Circuit Diagram of the LiFi Receiver

The modulated light signal sent by a Li-Fi transmitter is decoded and used by a Li-Fi receiver, which is made up of multiple parts. The Receiver module sits within the line of sight of the transmitter's LED, acting like a data catcher. Its secret weapon is a photodetector, often a photodiode, which can convert the light pulses back into electrical signals. The receiver's built-in circuitry then takes center stage. It analyzes these electrical signals, focusing on the variations in light intensity. By decoding these variations, the circuitry essentially cracks the code and retrieves the original digital information you transmitted.

For successful Li-Fi communication, a clear line of sight is essential. The instructions mention keeping the "photo sensor open" on the receiver. This means ensuring there are no objects blocking the path between the transmitter's LED and the receiver's photodetector. The photodetector is the receiver's eyes – it needs a clean view of the light pulses to capture the data. Additionally, focusing the transmitter's LED beam directly onto the photodetector is crucial. Just like focusing a flashlightfor better visibility, a precise focus ensures the receiver gets the strongest light signal, maximizingdata reception and enabling efficient transmission.

To effectively focus the LED on the receiver module, begin by physically aligning the transmitter module so that its LED is directly aimed towards the receiver module's photodetector. This alignment should ensure that a straight line can be imagined between the center of the LED and the centre of the photodetector, minimizing any potential obstructions along this path. Maintainingan appropriate distance is crucial; being too far can weaken the light signal, while being too closemay result in saturation. Finally, visually confirm that there are no obstacles obstructing the line of sight between the transmitter's LED and the receiver's photodetector, as even minor obstructions can significantly impact the efficiency of data transmission.

The process of data transmission through Li-Fi technology involves several sequential steps. Initially, in the software's serial window, the user inputs the desired data to be transmitted, which typically includes text, numbers, or files in digital format. Subsequently, the Li-Fi communication software undertakes the task of converting this digital data into a format suitable for Li-Fi transmission. This conversion process often employs modulation techniques, where the data is encoded onto the light pulses emitted by the transmitter's LED.

Once the data is encoded, the Li-Fi transmitter module, under the software's control, modulates the LED's light intensity or flickering pattern according to the encoded data. Concurrently, the receiver module, positioned within the line of sight of the transmitter, captures these modulated light pulses. Upon reception, the Li-Fi receiver module transmits the captured light pulses back to the computer through its USB or designated interface. The software then decodes the received light information back into its original digital format.

Finally, the Li-Fi communication software may display the received and decoded data in a separate window or section of the interface, allowing users to verify the success of the data transmission process.

CHAPTER 4

RESULTS AND DISCUSSION

In the implementation of Vehicle-to-Vehicle (V2V) communication using LiFi technology, one wagon is equipped with a LiFi transmitter module, while the other wagon is equipped with a LiFi receiver module.

Figure 4.1 V2V Communication Establishment

The successful implementation of Vehicle-to-Vehicle (V2V) communication using LiFi technology, illustrated in Figure 4.1, showcased efficient data transmission and reception between two equipped wagons. The wagon equipped with the LiFi transmitter module effectively encoded digital data into modulated light signals, leveraging the vehicle's LED lights as the medium for transmission. Conversely, the wagon equipped with the LiFi receiver module adeptly captured and decoded the modulated light signals emitted by the transmitting wagon, establishing a robust V2V communication link between the vehicles.

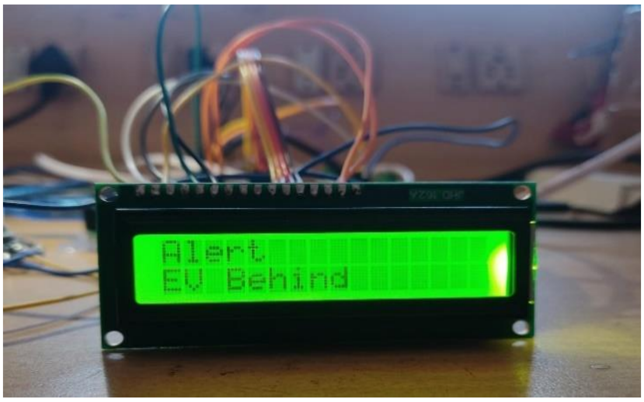

Figure 4.2 Output

Upon decoding the transmitted data, the LiFi receiver module processed and interpreted the information, notably identifying the message "Alert EV Behind." This critical message was promptly displayed on the LCD screen installed within the receiving wagon, as depicted in Figure 4.2. The successful interpretation and display of this message underscore the effectiveness of LiFi technology in facilitating real-time communication and enhancing situational awareness between vehicles on the road.

The results obtained from the V2V communication implementation using LiFi technology highlight its potential as a transformative solution for intelligent transportation systems. By harnessing modulated light signals for data transmission, LiFi offers numerous advantages over traditional RF-based communication systems, including higher data rates, lower latency, and enhanced security.

The immunity of LiFi technology to electromagnetic interference is particularly advantageous in congested urban environments or areas with high electromagnetic activity, mitigating disruptions that may affect RF-based communication systems. Furthermore, LiFi's ability to provide precise and directional communication reduces the risk of interference from neighboring vehicles, thereby bolstering the reliability of V2V communication links.

Moreover, the successful integration of LiFi technology into V2V communication systems complements existing communication protocols such as Dedicated Short-Range Communication and Cellular Vehicle-to-Everything. This multi-modal approach to V2V communication not only improves system reliability but also ensures continuous connectivity between vehicles. Furthermore, scalability considerations are essential to accommodate the increasing number of connected vehicles and the growing demand for data exchange in future transportation networks. Standardization efforts will play a pivotal role in defining common protocols and frameworks, facilitating seamless integration and interoperability across different LiFi-enabled V2V communication systems.

In conclusion, the successful demonstration of V2V communication using LiFi technology represents a significant milestone in the advancement of intelligent transportation systems. With continued innovation and collaboration, LiFi holds the potential to revolutionize road safety, reduce traffic congestion, and enhance mobility for generations to come.

CHAPTER 5

CONCLUSION

The integration of Visible Light Communication (VLC) for emergency vehicles using Vehicle-to-Vehicle (V2V) communication through LiFi presents a groundbreaking solution to enhance emergency response systems. Through LiFi technology, emergency vehicles can overcome the limitations of traditional radio frequency (RF) communication, enabling faster, more reliable, and secure data transmission.

LiFi offers significant advantages such as high-speed data transfer, low latency, and immunity to electromagnetic interference. These features facilitate real-time coordination between emergency vehicles, optimizing response times and resource utilization during critical situations.

Moreover, LiFi's inherent security and environmental benefits make it a compelling choice for emergency communication systems. By leveraging light as a communication medium, LiFi ensures secure data transmission while minimizing electromagnetic emissions and energy consumption.

The adoption of LiFi-based V2V communication for emergency vehicles represents a significant advancement in public safety and emergency response capabilities. By embracing innovative technologies like LiFi, cities can create safer, more resilient communities and improve the effectiveness of emergency services.

In essence, LiFi technology holds the potential to revolutionize emergency communication systems, offering a reliable and efficient solution to address the evolving challenges of emergency response in modern urban environments.

CHAPTER 6

FUTURE DIRECTIONS AND IMPLICATIONS

In the near future, the scope of Visible Light Communication (VLC) for emergency vehicles using LiFi enabled Vehicle to Vehicle (V2V) communication appears poised for transformative advancements in emergency response systems. Future research efforts are likely to concentrate on refining LiFi communication protocols tailored specifically for emergency vehicles. This involves optimizing modulation schemes, error correction techniques, and network management algorithms to enhance reliability, scalability, and real time performance. Additionally, integrating LiFi based V2V communication with evolving smart city initiatives presents a significant opportunity. By leveraging data from sensors, traffic lights, and road signage, LiFi could enhance situational awareness and optimize emergency response routes on the fly.

Furthermore, the advent of autonomous vehicle technology introduces new possibilities for LiFi enabled emergency response systems. Future implementations might involve autonomous emergency vehicles equipped with LiFi communication capabilities, enabling seamless coordination with both human driven and other autonomous vehicles during emergencies. As LiFi technology matures, establishing international standards and regulatory frameworks will be essential to ensure interoperability, security, and compliance. Commercialization and widespread deployment of LiFi based V2V communication solutions for emergency vehicles are foreseeable, facilitated by partnerships with industry stakeholders, government agencies, and emergency services. Beyond emergency response, LiFi technology holds promise for addressing various societal challenges and enhancing quality of life across diverse applications and industries.

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APPENDIX

LIST OF COMPONENTS USED FOR THE PROJECT

SL.NO	COMPONENT	VALUE	DETAILS
1	Arduino UNO	4	The Arduino Uno features an ATmega328P microcontroller, 14 digital I/O pins, USB interface for programming, power supply options, reset button, LEDs, crystal oscillator, and headers/connectors for easy interfacing with external components.
2	Transmitter module	1	The LiFi transmitter module comprises a microcontroller, modulation scheme, optical components, power supply, and control interface for encoding digital data into modulated light signals for transmission.
3	Constant Current LED Driver	1	A constant current LED driver regulates the current flowing through an LED to maintain a consistent light output, ensuring stable illumination and prolonging LED lifespan.
4	Receiver module	1	The receiver module in LiFi communication captures modulated light signals, decodes the encoded data, and interfaces with a microcontroller to interpret and utilize the received information for various applications.
5	LED	1	In LiFi, LEDs function as the primary light source for data transmission, rapidly modulating light to encode digital

			information for high-speed wireless communication.
6	LCD	1	An LCD (Liquid Crystal Display) is a flat, thin display screen that utilizes liquid crystal molecules to modulate light transmission, enabling the display of text, images, or graphics with high clarity and resolution.
7	BO Motors	8	Brushed DC motors in wagons are often used to drive the wheels, providing rotational motion when powered by a battery and controlled by the receiver, offering simplicity and affordability in remote-controlled vehicle propulsion.
8	HC05 Bluetooth module	2	The L298N motor driver is often utilized in wagons to regulate the speed and direction of the motors that drive the vehicle's wheels, allowing for precise control and maneuverability through the transmitter.
9	L298N Motor Driver	2	The HC-05 Bluetooth module in an wagon enables wireless communication between the wagon and a smartphone or remote controller, facilitating remote operation and control via Bluetooth technology.
10	12V Battery Module	2	The 12V battery module in an wagon provides the necessary power supply to drive the motors, electronics, and other components of the vehicle, ensuring

			optimal performance and runtime during operation.

LIST OF SOFTWARE TOOLS USED FOR THE PROJECT

SL.NO.	SOFTWARE	VERSION/ DETAILS
1	Arduino IDE	The Arduino IDE is a software platform used for writing, compiling, and uploading code to Arduino microcontroller boards, simplifying the process of programming for embedded systems development.