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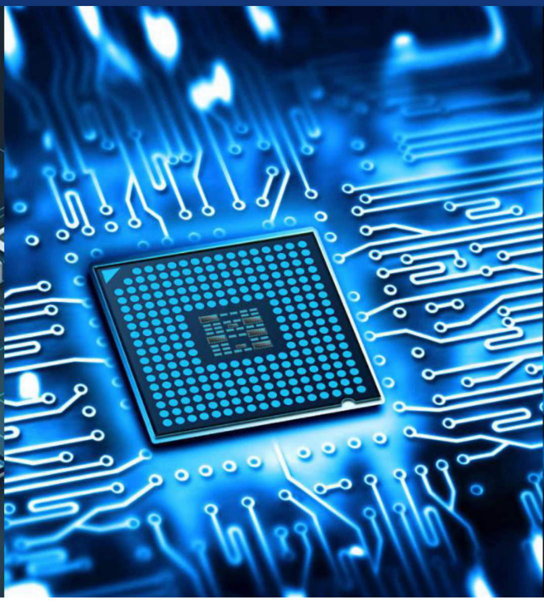


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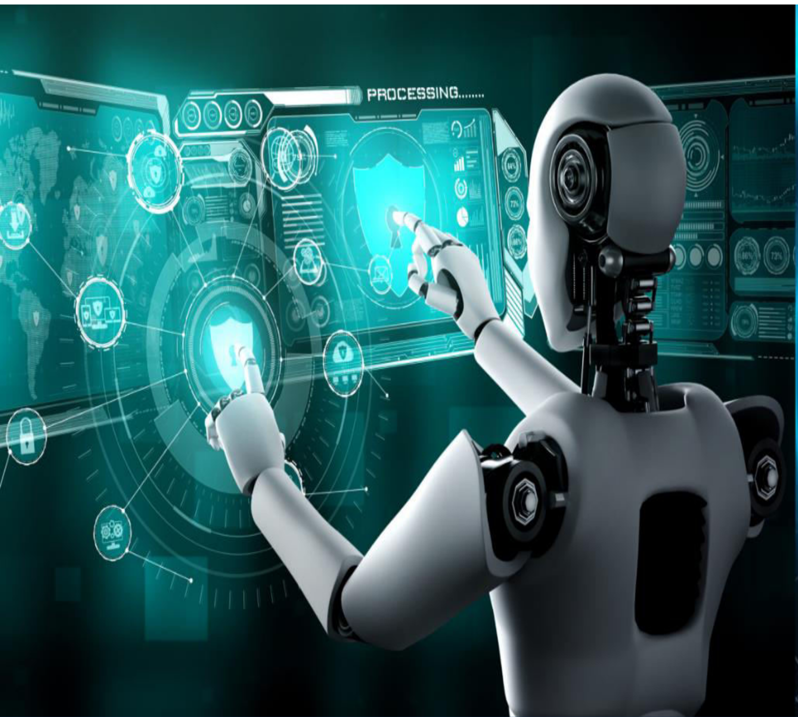

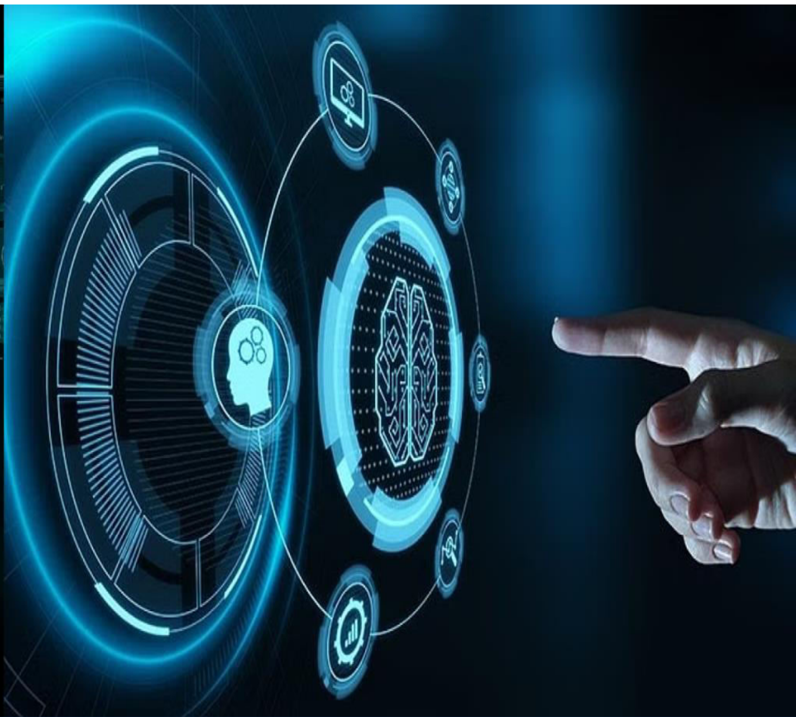

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Design and Implementation of a Li-Fi Text and Image Communication Interface using Arduino

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ABSTRACT*:* This study presents the design and implementation of a cost-effective Light Fidelity (Li-Fi) communication system utilizing readily available electronic components. The proposed system integrates a dual-core microcontroller with an LED-based transmitter and a photodiode receiver to enable data transmission through rapid modulation of visible light. Serial communication techniques are employed to ensure accurate encoding and decoding of digital signals. Experimental results demonstrate that the system achieves reliable and efficient short-range communication while maintaining low implementation cost and eliminating the need for specialized hardware. The findings highlight the suitability of Li-Fi technology for environments where conventional radio-frequency communication is limited or undesirable, such as indoor networking, underwater communication and medical applications. Overall, the developed prototype successfully demonstrates the fundamental principles of visible light communication and supports Li-Fi as a promising alternative to traditional wireless technologies like Wi-Fi.

KEYWORDS*:* Light Fidelity (Li-Fi)**,** Visible Light Communication (VLC)**,** LED-based Data Transmission**,** Photodiode Receiver System**,** Embedded Communication System.

I. INTRODUCTION

Li-Fi is a modern wireless communication technology that transmits data using visible light emitted from LEDs, offering an effective alternative to conventional radio-frequency communication systems. In Li-Fi, the intensity of the LED light is modulated at very high speeds to encode digital information. A photodiode at the receiver captures these light signals and converts them back into electrical signals, enabling fast data transfer that is invisible to the human eye. As a part of VLC, Li-Fi operates within a large, unlicensed spectrum that is significantly wider than the RF spectrum, making it suitable for high-capacity communication in crowded or bandwidth-limited environments.

The primary aim of this project is to design and implement a cost-effective Li-Fi communication system using easily available electronic components, including a dual-core microcontroller, LEDs, photodiodes and supporting circuitry. The system is developed using Arduino programming and serial communication protocols to ensure accurate and reliable transmission of data. Experimental results demonstrate that the proposed system provides stable and efficient short-range communication while maintaining low cost and minimal power consumption.

In addition to its performance, Li-Fi offers advantages such as reduced electromagnetic interference, higher data security due to confined light transmission, and flexibility for various environments. The prototype developed in this project illustrates the practical application of Li-Fi technology in indoor networking, medical facilities and underwater communication. Overall, this study demonstrates that Li-Fi is not only technically feasible but also a promising, low-cost alternative to traditional wireless technologies such as Wi-Fi, with potential for wider adoption in diverse communication scenarios.

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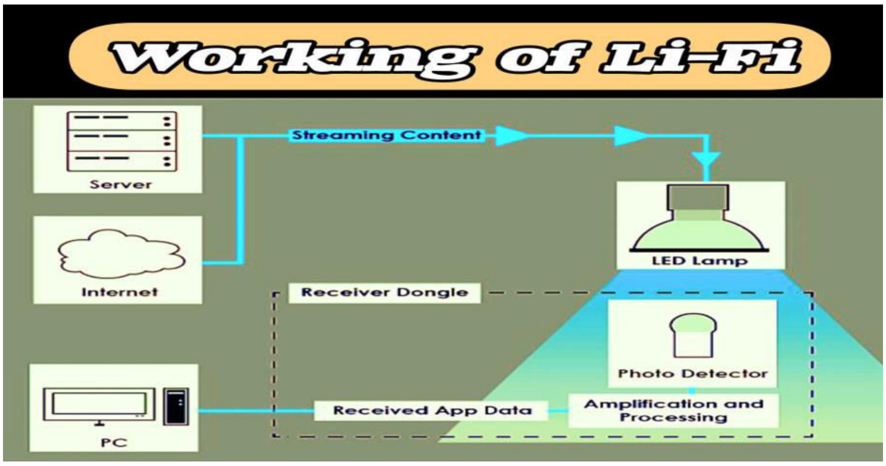

FIG:1 Working of Li-Fi Technology

OBJECTIVE: The primary objective of the Li-Fi text and image transmission project is to develop an efficient communication system that utilizes visible light as a medium for wireless data transfer. This technology aims to introduce a new class of high-intensity solid-state lighting sources that are capable of performing dual functions: illumination and data communication. By integrating LEDs with communication electronics, the system enables the transmission of digital information such as text and images through rapid modulation of light signals. Another important objective of this project is to provide a clean and energy-efficient alternative to conventional wireless communication technologies. Compared to traditional radio frequency systems, Li-Fi offers advantages such as reduced electromagnetic interference, enhanced data security and improved energy utilization. The system also benefits from the inherent characteristics of LED lighting, including long operational life, high brightness, low power consumption and the ability to support full-spectrum illumination with dimming capability. This project further aims to demonstrate the fundamental building blocks required for Li-Fi communication, including data encoding, optical transmission and signal reception. By designing and implementing a transmitter and receiver architecture capable of handling text and image data, the system highlights the practical feasibility of visible light communication in modern communication networks. Ultimately, the project contributes toward the development of advanced lighting infrastructures that combine illumination with high-speed wireless data transmission.

Motivation: The rapid growth of wireless communication has intensified the limitations of conventional radio frequency systems. RF spectrum scarcity, network congestion caused by widespread 2G–5G usage and high operational costs restrict efficient data transmission. In addition, RF communication faces security risks because signals can penetrate physical barriers, enabling potential unauthorized access. Certain environments such as hospitals, aircraft and underwater regions also limit or restrict RF usage. Furthermore, wireless infrastructure consumes substantial energy, with a large portion dedicated to cooling rather than transmission. These challenges motivate the investigation of alternative communication methods. Visible Light Communication, which utilizes LED light for data transfer, offers a secure, energy-efficient and spectrum-abundant solution for future communication systems.

II. LITERATURE SURVEY

With the rapid growth of wireless devices, radio frequency networks are becoming increasingly congested, leading to limited bandwidth and unreliable connectivity. To address this, Dr. Harald Haas, a German physicist, introduced a novel approach called "Data Through Illumination," later popularized as Li-Fi. This technology transmits data using visible light emitted from LEDs by modulating light intensity at speeds imperceptible to the human eye. Inspired by the principle of infrared remote controls, Li-Fi achieves high-speed data transfer without occupying traditional RF spectrum, producing rates exceeding 10 megabits per second in early experiments. One of its key advantages is enhanced security, as light cannot penetrate walls, preventing unauthorized access to the transmitted data. Over time, Li-Fi has been standardized under the IEEE 802.15.7 VLC framework, enabling uniform protocols for data transmission. Typically implemented with white LED bulbs, Li-Fi allows devices to serve both as illumination sources and data transmitters. By applying subtle, high-speed variations to the LED current, optical signals can carry digital

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information efficiently while maintaining normal lighting conditions, demonstrating a viable alternative to conventional wireless communication technologies.

III. PROBLEM STATEMENT

In modern wireless communication, short-range data transfer primarily relies on radio frequency technologies such as Wi-Fi and Bluetooth. While these methods are widely used, they have significant limitations that hinder performance and security. RF signals can penetrate walls, making them vulnerable to unauthorized access and compromising data security. The limited bandwidth of the radio spectrum restricts the amount of data that can be transmitted simultaneously, reducing communication efficiency. Prolonged exposure to RF waves also raises concerns about potential health effects, including electromagnetic sensitivity. Additionally, RF-based communication is often restricted in sensitive environments, such as hospitals, airplanes and nuclear facilities, due to interference with critical electronic systems. High power consumption and inefficient energy usage further reduce practicality in large-scale or portable applications. These challenges highlight the need for a more secure, efficient and safe alternative. This project addresses these limitations by implementing a Li-Fi system using Arduino, enabling reliable text and image transmission through visible light communication.

IV. PROPOSED MODEL

The proposed system utilizes Li-Fi technology for transmitting both text and images through visible light, offering a secure and high-speed alternative to traditional RF-based wireless communication. In this approach, an LED light source serves as the transmitter and a photodiode acts as the receiver. Data from an Arduino microcontroller is first converted into digital signals. For text communication, each character is translated into binary code, while image data is serialized into a sequence of binary packets suitable for transmission. These digital signals modulate the intensity of the LED, producing rapid fluctuations in light output that are imperceptible to the human eye. The photodiode receiver captures these light variations and converts them back into electrical signals, which the Arduino processes to reconstruct the original text or image.

To increase data capacity and speed, multiple LEDs can be used in parallel, allowing simultaneous transmission of different data streams. This system supports line-of-sight communication, enhancing security since the light cannot pass through walls, thereby minimizing the risk of interception. Compared to RF communication, the Li-Fi system consumes less power, making it suitable for energy-efficient and portable applications. Furthermore, it avoids the electromagnetic interference associated with radio waves, enabling deployment in sensitive environments such as hospitals, airplanes and industrial facilities. By integrating Arduino microcontrollers, the system offers flexibility, low cost and easy scalability. Overall, this model demonstrates a practical and efficient solution for reliable text and image communication using visible light, highlighting the potential of Li-Fi for next-generation wireless communication technologies.

V. SYSTEM DESIGN AND WORKING

POWER SUPPLY SECTION:

FIG1: **power supply section**

The power section supplies regulated energy to all modules in the Li-Fi text and image transmission system. A 12V adapter serves as the primary external power source for the circuit. This input voltage is applied to a buck converter to efficiently step down the voltage level. The converter regulates the output to a stable 5V DC supply. This regulated 5V output powers the transmitter and receiver circuitry, ensuring reliable system operation.

TRANSMITTER SECTION:

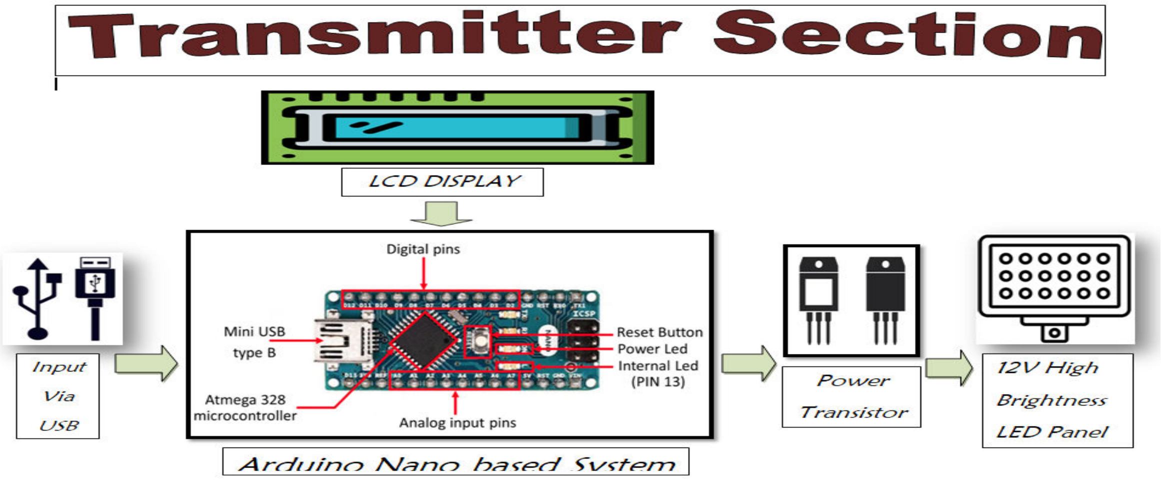

FIG: 3 Transmitter Section

The transmitter section of the Li-Fi text and image transmission system is responsible for converting user input data into optical signals for wireless communication through light. In the initial stage, a keyboard connected through a PS/2 interface provides alphanumeric input to the microcontroller. The keyboard communicates directly with the AT89S52 microcontroller, which is based on the 8051 architecture and operates as the primary control unit of the transmitter module. This microcontroller processes the incoming data and manages serial communication for further transmission.

To ensure accurate timing and reliable execution of instructions, the microcontroller is driven by an external crystal oscillator operating at a frequency of 11.0592MHz. Two 27pF capacitors are connected with the crystal to stabilize the oscillation and maintain a consistent clock signal. A stable power supply is also essential for proper functioning of the circuit. A 9V DC battery provides the input power, which is regulated to 5V using the 7805 voltage regulator IC. Additionally, a reset circuit consisting of a 10µF capacitor and a 10kΩ resistor is incorporated to initialize the microcontroller during startup or unexpected interruptions.

When a key is pressed on the keyboard, the corresponding ASCII code is transmitted to the microcontroller. The controller converts this ASCII data into binary format for digital processing. These binary signals are then forwarded to a transistor-based amplification stage composed of an NPN transistor and a PNP transistor. Together, these transistors operate as a push-pull driver configuration that strengthens the signal before it is applied to the light source.

The amplified signal controls the switching of an LED torch used as the optical transmitter. In this process, the LED turns ON when the binary value is '1' and turns OFF when the value is '0'. The rapid switching of the LED produces light pulses that represent the transmitted digital data. These pulses occur at a speed beyond human visual perception, enabling efficient and continuous data transfer.

In extended implementations, a computer running communication software such as CoolTerm can also provide input data in the form of text or images. The data is converted into ASCII codes and transmitted to a microcontroller through serial communication. The controller then converts the data into binary form and drives LEDs accordingly, enabling the transmission of digital information using visible light in a Li-Fi communication system.

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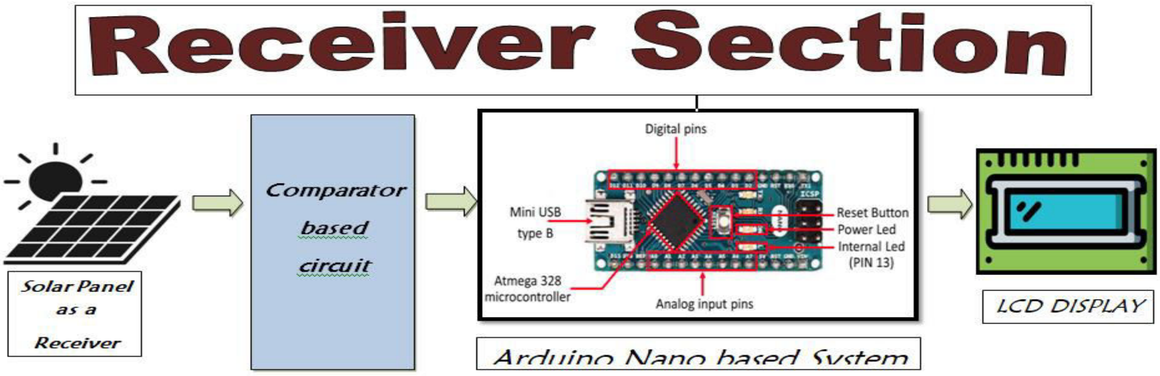

FIG: 4 Receiver Section

RECEIVER SECTION:

The receiver section of the Li-Fi text and image transmission system is responsible for detecting optical signals and converting them back into readable digital data. The main sensing component used in this stage is a photodiode, which captures the light pulses emitted by the LED transmitter. When the modulated light from the transmitter reaches the photodiode, it converts the variations in light intensity into corresponding electrical signals. These electrical signals represent the binary data transmitted through visible light.

The electrical output generated by the photodiode is passed to a transistor stage that helps in signal conditioning and amplification. A PNP transistor is used to interpret the voltage changes produced by the photodiode. The transistor switches between ON and OFF states based on the received signal. When the photodiode detects the absence or presence of light pulses, the transistor responds accordingly, producing a sequence of digital levels representing binary values.

The processed signal is then provided to the AT89S52 microcontroller, which acts as the main processing unit in the receiver section. The microcontroller operates using an external crystal oscillator with a frequency of 11.0592MHz to ensure accurate timing and synchronization during data decoding. Two 27pF capacitors are connected to stabilize the oscillator frequency and maintain consistent clock operation. The system is powered using a 9V battery supply, which is regulated to a stable 5V using the 7805 voltage regulator IC to meet the operating requirements of the microcontroller and associated components.

A reset circuit consisting of a 10µF capacitor and a push-button switch is incorporated to allow automatic and manual system initialization. After receiving the binary signal from the transistor stage, the microcontroller decodes the sequence of ones and zeros and reconstructs the original ASCII data. This decoded information corresponds to the text or image data transmitted by the Li-Fi transmitter.

Finally, the reconstructed data is sent to a display unit such as a 16×2 LCD or graphical display module interfaced with the microcontroller. The display presents the received information in a human-readable format, enabling real-time visualization of the transmitted text or image data. Through this process, the receiver section effectively completes the visible light communication link by transforming optical signals back into digital information.

VI. OBSERVATIONS

- **Transmission Distance**: The experimental setup demonstrated that Li-Fi communication operates effectively only within a certain distance range. Reliable data transfer was observed when the LED transmitter and photodiode receiver were positioned between approximately 7cm and 75cm under proper alignment conditions.
- **Line-of-Sight Requirement:** The system requires a clear line of sight between the transmitter LED and the photodiode receiver. Any physical obstruction between these components interrupts the light path and prevents proper signal detection, resulting in temporary or complete loss of communication.

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- **Effect of Distance on Signal Strength:** As the separation between the LED light source and the receiver increased, the intensity of the detected optical signal decreased gradually. Reduced signal strength at larger distances affected the reliability and clarity of the received digital data.
- **Role of LED as Transmission Medium:** The LED functions as the primary medium for transmitting information in the Li-Fi system. By rapidly switching between ON and OFF states according to binary data, the LED converts digital signals into modulated light pulses for wireless communication.
- **Photodiode Signal Detection:** The photodiode effectively senses the rapid variations in light intensity produced by the LED transmitter. It converts these optical signals into corresponding electrical signals, which are then processed by the microcontroller for accurate decoding of transmitted information.
- **Influence of Ambient Lighting:** Ambient lighting conditions slightly affect the sensitivity of the photodiode receiver. However, the communication link remains stable when the transmitted LED signal is sufficiently stronger than the surrounding light intensity present in the environment.
- **Microcontroller Data Processing:** The microcontroller plays a critical role in decoding the received binary signals into meaningful information. It processes the electrical signals generated by the photodiode and converts them into ASCII format for further display and interpretation.
- **Temperature Operating Range:** The Li-Fi communication system maintained stable operation within a temperature range of 0°C to 70°C. Within this range, the performance of electronic components and signal transmission remained consistent without noticeable degradation.
- **Real-Time Data Visualization:** The decoded information from the receiver microcontroller was successfully displayed on the LCD module. This allowed real-time visualization of the transmitted text data, confirming that the communication link between transmitter and receiver was functioning properly.
- **Power Supply Stability:** A regulated 5V power supply ensured proper operation of the microcontroller and associated electronic components. Stable voltage levels helped maintain consistent signal processing and prevented fluctuations that could negatively affect system performance..

VII. RESULT

The experimental implementation of the Li-Fi text and image transmission system demonstrated the feasibility of using visible light as a medium for wireless data communication. In this project, alphanumeric data was successfully transmitted using an LED source controlled by a microcontroller and received through a photodiode-based detection circuit. The transmitter converted input data into binary signals, which were represented by rapid LED switching. The receiver detected these optical pulses and reconstructed the original information, displaying it on the connected output module. The results confirmed that LEDs integrated with microcontroller control can effectively function as both illumination sources and communication transmitters.

The system also showed that communication performance depends strongly on the presence of a clear optical path between the transmitter and receiver. Data transmission occurred reliably when the emitted light was directly incident on the photodiode. However, the introduction of physical obstructions between the LED and the receiver interrupted the communication link. This characteristic highlights both a limitation and an advantage of Li-Fi technology, as the confined transmission path improves security by preventing signal leakage beyond the illuminated area.

During experimentation, certain factors such as ambient lighting, sensor sensitivity and alignment between the transmitter and receiver influenced the signal quality. External light sources and improper positioning introduced noise that affected the clarity of received signals. Despite these challenges, the system successfully demonstrated real-time optical data transmission. The results indicate that with improved sensor sensitivity and better noise reduction techniques, Li-Fi technology can provide an efficient and secure alternative for high-speed wireless communication.

VIII. CONCLUSION

The Li-Fi text and image transmission project demonstrates the feasibility of using visible light communication (VLC) as a secure, high-speed and energy-efficient wireless communication method. Utilizing LEDs controlled by a microcontroller, the system successfully transmitted numeric, alphanumeric and image data over a direct line-of-sight optical link. The project highlights the potential for everyday lighting to serve as both illumination and data transmission sources, offering a cleaner, safer and more sustainable communication alternative. Li-Fi technology

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provides significant advantages, including high bandwidth, immunity to radio-frequency interference and suitability for electromagnetic-sensitive environments such as aircraft, hospitals and industrial facilities. While challenges remain, including alignment sensitivity, ambient light interference, limited range and direct line-of-sight requirements, continued research can enhance performance. Future developments may integrate transmitter and receiver modules into compact transceivers, improving efficiency and enabling simultaneous transmission and reception. Overall, Li-Fi represents a promising supplement to conventional Wi-Fi, with the potential to revolutionize wireless communication networks.

IX. FUTURE SCOPE

Li-Fi technology provides a cost-effective and high-speed alternative to Wi-Fi, potentially up to ten times cheaper. It is ideal for electromagnetic-sensitive environments, such as aircraft and nuclear facilities, as light-based communication causes no interference. The system offers enhanced security because light cannot penetrate walls, reducing the risk of unauthorized access. With a visible light spectrum approximately 10,000 times larger than radio frequencies, Li-Fi supports higher data capacities, with current speeds up to 3.5Gbps. Furthermore, the system can be extended to transmit audio alongside data, making it suitable for versatile, secure and high-speed wireless communication applications.

X. ACKNOWLEDGEMENT

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