IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 1, January 2026

DOI: 10.17148/IJARCCE.2026.15103

TEXT, AUDIO AND IMAGE TRANSMISSION USING LIGHT-FIDELITY [Li-Fi] TECHNOLOGY

Mahadev Gouravvagol[1], Punithkumar N[2], Srinivasa K Y[3], Rishab Palrecha[4],

Dr. K. Somashekar[5]

Student, ECE, SJB Institute of Technology, Bengaluru, India[1-4]

Professor, ECE, SJB Institute of Technology, Bengaluru, India[5]

Abstract: The exponential growth of wireless data traffic and the increasing limitations of radio frequency (RF) spectrum have driven the need for alternative high-bandwidth and interference-free communication technologies. Light-Fidelity (Li-Fi), a subset of Visible Light Communication (VLC), has emerged as a promising solution by utilizing light-emitting diodes (LEDs) for high-speed wireless data transmission. This paper presents the design and implementation of a Li-Fi-based system capable of transmitting text, audio, and image data using intensity modulation of visible light. The proposed system employs microcontroller-based encoding at the transmitter to modulate LED light signals according to the input data, while a photodetector-based receiver decodes the transmitted information using signal conditioning and amplification circuits. Text data is transmitted using serial communication protocols, audio signals are conveyed through real-time analog modulation, and image data is transferred as sequential binary streams and reconstructed at the receiver end. Experimental results demonstrate reliable short-range indoor communication with minimal electromagnetic interference and improved data security compared to conventional RF-based systems. The study validates Li-Fi as a cost-effective, energy-efficient, and secure wireless communication technology suitable for multimedia data transmission in environments where RF communication is constrained. The proposed system highlights the potential of Li-Fi for future applications in smart indoor communication, healthcare, educational institutions, and secure data transmission systems.

Keywords: Li-Fi Technology, Optical Wireless Communication, LED Modulation, ESP32, Text Transmission, Audio Transmission, Image Transmission.

I. INTRODUCTION

The rapid growth of wireless communication has led to increased congestion in the radio frequency spectrum. Technologies such as Wi-Fi and Bluetooth rely heavily on RF signals, which face challenges including limited bandwidth, electromagnetic interference, and security concerns. To overcome these limitations, Light-Fidelity (Li-Fi) has emerged as a promising alternative that uses visible light for data transmission. Li-Fi operates by modulating the intensity of an LED at very high speeds to transmit digital information. At the receiver side, a photodiode or solar panel detects these variations and converts them back into electrical signals. Since visible light cannot penetrate walls, Li-Fi offers enhanced data security compared to RF-based systems.This project focuses on implementing a Li-Fi communication system capable of transmitting text, audio, and image data using a single optical link. The system demonstrates how different types of data can be encoded, transmitted, and decoded using simple modulation techniques and embedded controllers.

1.1 Motivation of Work

The increasing demand for secure, high-speed, and interference-free wireless communication motivates the exploration of Li-Fi technology. RF-based communication is restricted in environments such as hospitals, aircraft, and defence facilities where electromagnetic interference can be harmful. Li-Fi offers a safe alternative as it uses visible light, which does not cause electromagnetic interference.Additionally, with the widespread use of LED lighting, Li-Fi can utilize existing infrastructure for both illumination and communication. This project aims to demonstrate a low-cost and practical implementation of Li-Fi for multimedia data transmission, making it suitable for educational and research purposes.

1.2 Objectives of Work

1. To design a Li-Fi based communication system using LED and photodetector.

DOI: 10.17148/IJARCCE.2026.15103

2. To transmit predefined text messages using optical modulation.
3. To implement audio transmission through Li-Fi using analog signal modulation.
4. To transmit image data using serial communication over visible light.
5. To analyze system performance in terms of clarity, reliability, and response time.

1.2 LITERATURE REVIEW

1. Li-Fi Communication for Transmitting Data, Audio and Image Information (Sindhu, 2020)

Sindhu presents an early prototype Li-Fi communication system capable of transmitting text, audio, and image data using visible light as the medium. The study uses UART serial communication to send serial data streams via LED and photodiode link and discusses system operation in comparison to conventional Wi-Fi. It confirms that LED modulation can support multiple data types with a simplified hardware setup, laying the groundwork for multimedia Li-Fi communication systems.

2. Li-Fi: A Revolution in Wireless Networking (Materials Today Proceedings, 2020)

This paper outlines foundational principles of Li-Fi and visible light communication (VLC), notably explaining data transmission techniques using intensity modulation and direct detection (IM/DD) with LEDs. Although more general in scope, the study covers the theoretical framework that enables text, audio, and image transfer over Li-Fi links and highlights its advantages in environments crowded with RF signals.

3. Embedded Li-Fi Systems Using Arduino and ESP Microcontrollers (Rao et al., 2020)

Rao et al. explore the implementation of Li-Fi communication systems using low-cost microcontrollers such as Arduino and ESP modules. Their work demonstrates that these controllers can efficiently handle data encoding, LED modulation, and serial data decoding at the receiver. The authors emphasize the suitability of ESP-based platforms for real-time Li-Fi applications due to their processing speed and peripheral support. This directly supports the selection of ESP32 in the present project for handling multi-mode data transmission.

4. Review on Audio, Image and Text Transmission Using Li-Fi Technology (2025 Review)

A recent literature survey consolidates advancements in Li-Fi systems designed for multi-modal data transmission including text, images, and audio. This review highlights hybrid system designs where Li-Fi is combined with RF links to maintain high-fidelity analog signal performance while leveraging Li-Fi's bandwidth for digital data, underscoring trends in multimedia Li-Fi implementations.

5. Image Transmission Over Li-Fi Using Embedded Systems (Sharma & Verma, 2020)

Sharma and Verma present a Li-Fi-based image transmission system using embedded controllers and serial communication protocols. Their research explains how image data can be converted into binary streams and transmitted sequentially using LED modulation. At the receiver side, the image is reconstructed using serial-to-USB conversion and displayed on a computer interface. Their study confirms that Li-Fi is suitable for low-resolution image transfer applications, supporting the image transmission methodology adopted in this project.

6. Text and Data Communication via LED-Based VLC Systems (Pathak et al., 2020)

Pathak et al. propose a microcontroller-based Li-Fi system for short-range digital text communication using high-brightness LEDs and photodiodes. The study highlights the simplicity of encoding ASCII text data using ON–OFF keying (OOK) modulation. Experimental results show reliable text transmission over indoor environments with minimal interference. This research supports the feasibility of transmitting predefined text messages in the current project using microcontroller-controlled LED switching techniques.

7. Audio Signal Transmission Using Visible Light Communication (Karthikeyan et al., 2020)

Karthikeyan and co-authors investigate the transmission of analog audio signals over Li-Fi channels using LED modulation and photodetector reception. Their system uses an audio amplifier at the receiver to recover intelligible sound signals. The authors demonstrate that Li-Fi can successfully transmit real-time audio with acceptable signal quality over

DOI: 10.17148/IJARCCE.2026.15103

short distances. This work directly aligns with the audio transmission module of the present project, where audio signals are transmitted via LED and reproduced using an LM386 audio amplifier and speaker.

II. DESIGN AND IMPLEMENTATION

The proposed Li-Fi system consists of a transmitter section and a receiver section. The transmitter encodes text, audio, and image data into electrical signals that modulate an LED. The receiver converts the received light signals back into electrical form and processes them accordingly.

[1] 3.1 Block Diagram Description

Transmitter Section:

- ESP32 Microcontroller
- 4×1 Switch for text selection
- Audio input (Laptop/AUX)
- USB-to-TTL Converter (Image data)
- High-power LED driver

Receiver Section:

- Solar panel
- Signal conditioning circuit
- ESP32 Microcontroller
- LCD Display
- Audio Amplifier (LM386)
- Speaker

➢ **Text Transmission:**

Text transmission is implemented using predefined messages stored in the ESP32 program.
A 4×1 switch selects the desired message, which is converted into binary form and transmitted through LED modulation. At the receiver, the decoded text is displayed on a 16×2 LCD.

➢ **Audio Transmission:**

Audio signals from a laptop or mobile device are fed into the transmitter circuit. The audio signal directly modulates the LED intensity. At the receiver side, the solar panel detects the variations and converts them into electrical signals, which are amplified using an LM386 audio amplifier and played through a speaker.

➢ **Image Transmission:**

Image data is transmitted using serial communication via a USB-to-TTL converter. The ESP32 sends pixel data serially, which modulates the LED. The receiver decodes the serial data and reconstructs the image at the receiving end.

IMPLEMENTATION

The proposed Li-Fi system is implemented using a microcontroller-based transmitter and receiver architecture to enable text, audio, and image transmission through visible light. At the transmitter side, an ESP32 microcontroller interfaces with a laptop to receive text and image data via serial communication, while audio input is provided through an auxiliary audio source. The ESP32 encodes the digital data and modulates a high-brightness LED using rapid ON–OFF keying, whereas the audio signal is transmitted through analog intensity modulation of the same LED. At the receiver side, a solar panel detects the modulated light signal and converts it into an electrical signal, which is then conditioned using filtering and amplification circuits. Digital data corresponding to text and image transmission is decoded by the ESP32 receiver and displayed on an LCD or computer interface, while the recovered audio signal is amplified using an LM386 audio amplifier and reproduced through a speaker. The system operates under line-of-sight conditions and demonstrates reliable short-range indoor communication, validating the feasibility of Li-Fi for secure and interference-free multimedia data transmission.

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

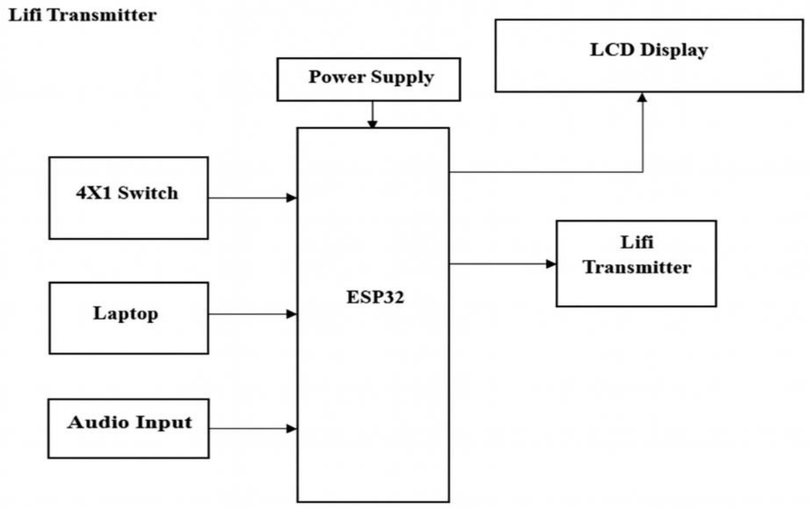


Fig 2.1: Li-Fi Transmitter

The given block diagram illustrates the Li-Fi transmitter section designed for transmitting text, audio using visible light. A regulated power supply provides the necessary voltage to the ESP32, which functions as the main control and processing unit. Input data is fed to the ESP32 from a laptop for text and image transmission and from an audio input source for audio signals, while a 4×1 switch is used to select the required message to be transmitted . Based on the selected input, the ESP32 processes and modulates the data and drives the Li-Fi transmitter (LED) by varying light intensity at high speed. An LCD display connected to the ESP32 and transmission information, enabling real-time monitoring of the transmitter operation.

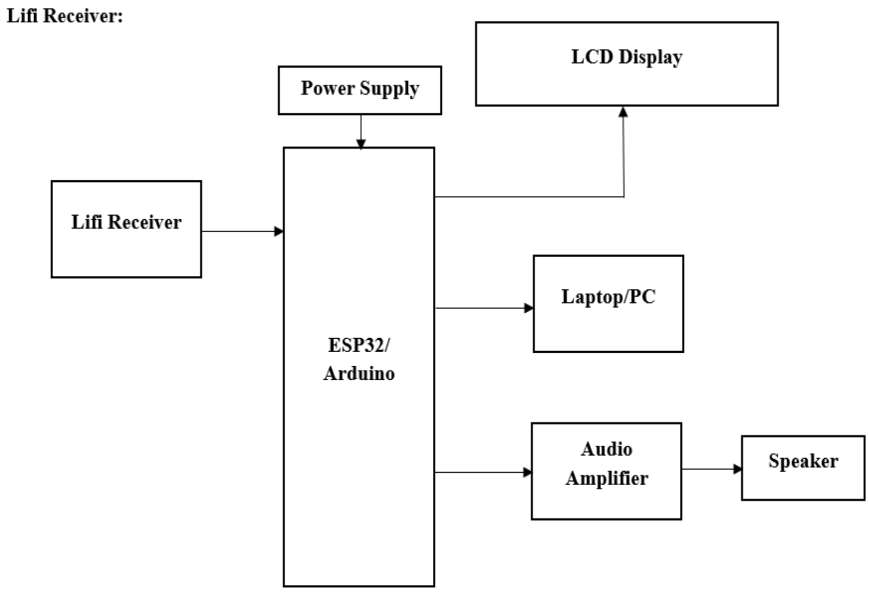


Fig 2.2 : Li-Fi Receiver

The given block diagram represents the Li-Fi receiver section used for receiving and recovering text, audio data transmitted through visible light. A regulated power supply provides the required operating voltage to the ESP32 , which serves as the central processing unit. The Li-Fi receiver (solar panel) detects the modulated light signal from the transmitter and converts it into an electrical signal, which is then fed to the microcontroller for decoding. The recovered text and image data is transmitted to a laptop/PC via serial communication and can also be displayed on an LCD display for real-time monitoring. Simultaneously, the decoded audio signal is passed to an audio amplifier, which amplifies the signal and drives a speaker, enabling clear audio output at the receiver end.

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

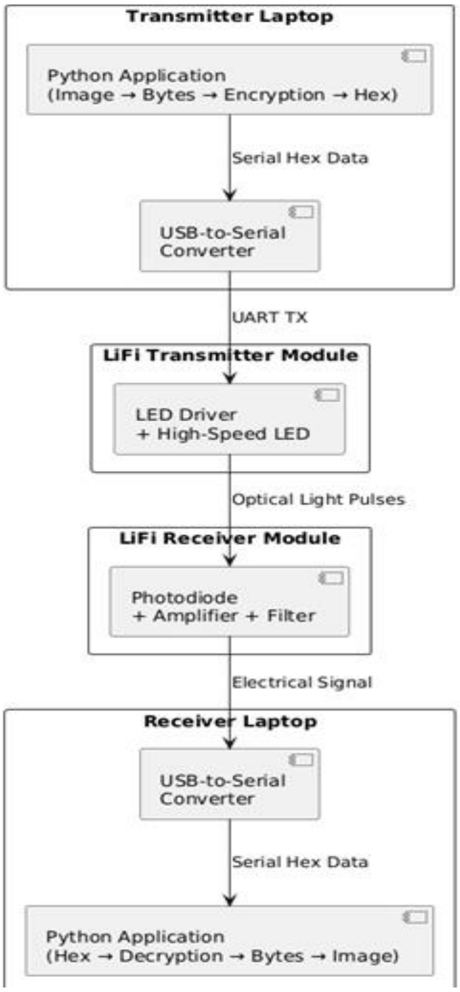


Fig 2.3 : Image Transmission

The given block diagram illustrates the end-to-end Li-Fi–based image transmission process between a transmitter laptop and a receiver laptop. At the transmitter side, a Python application converts the image into byte data, encrypts it, and encodes it into hexadecimal format, which is then sent as serial data through a USB-to-serial converter using UART communication. This serial data drives the Li-Fi transmitter module, where an LED driver modulates a high-speed LED to generate corresponding optical light pulses. At the receiver side, the Li-Fi receiver module, consisting of a photodiode, amplifier, and filter, detects the optical pulses and converts them into an electrical signal. The recovered serial hex data is passed through another USB-to-serial converter to the receiver laptop, where a Python application decodes the hex data, decrypts it, reconstructs the original byte stream, and finally regenerates the transmitted image.

The given Flowchart represents the basic working principle of a Li-Fi communication system, divided into transmitting and receiving sections. In the transmitting section, the input data is first processed and then converted into a suitable format for communication, after which the LED is toggled at high speed to encode the data into light signals. These modulated light pulses propagate through free space and are detected at the receiver side by a photodetector, which converts the optical signal into an electrical form. The received signal is then passed through an operational amplifier acting as a comparator to filter noise and regenerate clean digital pulses. Finally, the processed signal is decoded in the receiving section to retrieve the original data, completing the Li-Fi data transmission process.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 1, January 2026

DOI: 10.17148/IJARCCE.2026.15103

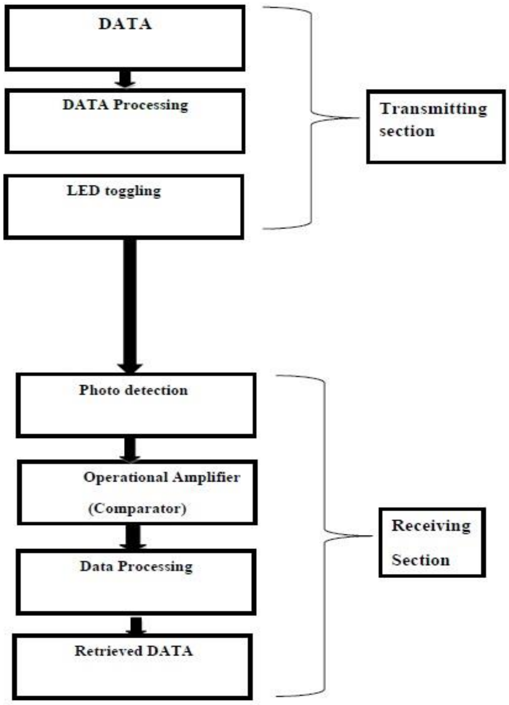


Fig 2.4 : Flow chart of Data Transmission

Modulation and Encoding Strategy

For digital data transmission, On–Off Keying (OOK) modulation is employed due to its simplicity and compatibility with low-cost microcontrollers. Binary data bits are represented by switching the LED ON for logic '1' and OFF for logic '0'. To ensure reliable reception, hexadecimal encoding is used for image and text data, reducing synchronization errors during serial communication. The encoding strategy also allows seamless switching between different data types without modifying the underlying hardware.

Signal Conditioning and Noise Mitigation

At the receiver end, the detected optical signal is often weak and susceptible to ambient light interference. To address this, a signal conditioning stage comprising amplification and filtering is implemented. The amplifier boosts the photodiode output to a usable voltage level, while the filter suppresses unwanted noise from artificial lighting and sunlight. A comparator-based thresholding technique is further applied to regenerate clean digital pulses before decoding, improving bit error performance.

The implementation follows the workflow :

1. **Image Selection** – user selects an image from the transmitter application.
2. **Image Conversion** – convert the image to raw bytes using Pillow.
3. **Encryption** – encrypt the byte stream using AES/RSA/custom algorithm.
4. **Hex Encoding** – convert encrypted bytes to hex strings for serial communication.
5. **Data Framing** – split the hex data into transmission packets.
6. **Serial Transmission** – send packets to LiFi transmitter via UART.
7. **Optical Transmission** – LED modulates packets as optical pulses.
8. **Optical Reception** – solar panel captures light pulses.
9. **Signal Conditioning** – amplifier + filter remove noise and shape signals.
10. **Serial Reception** – receiver laptop reads incoming hex packets.
11. **Hex Decoding** – convert hex data back to encrypted bytes.
12. **Decryption** – reconstruct original byte stream.
13. **Image Reconstruction** – save and display the reconstructed image.

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁞ Peer-reviewed & Refereed journal ⁞ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

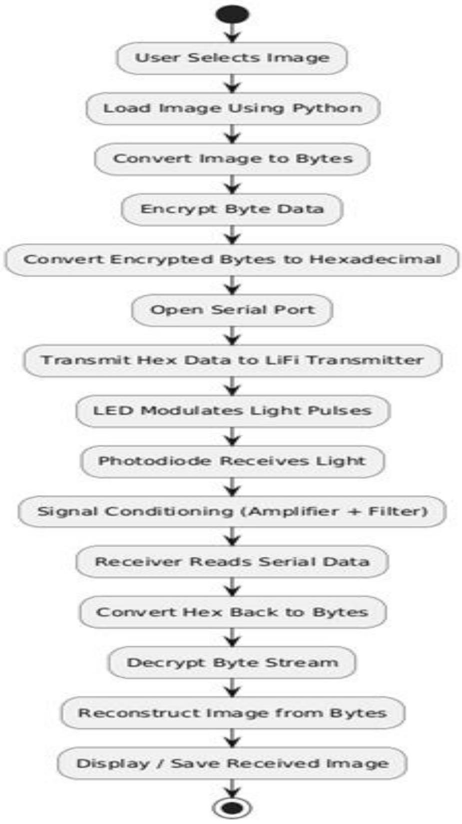


Fig 2.5 : Flow Chart of Image Transmission

Synchronization and Data Integrity

To maintain synchronization between the transmitter and receiver, predefined start and stop delimiters are embedded within the data stream. This ensures correct packet framing during text and image transmission. Basic checksum verification is implemented at the receiver to detect transmission errors. In case of corrupted data, the affected packets are discarded, ensuring reliable reconstruction of images and text.

Security and Privacy Considerations

Li-Fi inherently offers enhanced security because visible light does not penetrate walls. In addition to this physical layer security, the proposed system incorporates basic encryption at the application layer for image data transmission. This dual-layer security approach ensures data confidentiality even in scenarios where unauthorized optical interception is attempted within the same environment.

Scalability and System Limitations

The system is designed to be scalable by increasing LED intensity, using high-speed LEDs, or employing parallel LED arrays to improve data throughput. However, performance is constrained by factors such as line-of-sight requirement, ambient light interference, and limited transmission distance. These limitations highlight the need for adaptive thresholding and advanced modulation schemes in future enhancements.

Experimental Setup and Validation

The experimental setup was evaluated under controlled indoor lighting conditions with varying transmission distances. Performance metrics such as transmission reliability, latency, and reconstruction accuracy were analyzed for text, audio, and image data. The results confirm stable data reception over short distances with acceptable signal quality, validating the feasibility of the proposed Li-Fi system for practical indoor applications.

IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940
International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

III. RESULTS

The proposed Li-Fi system was experimentally evaluated to validate its ability to transmit text, audio, and image data using visible light as the communication medium. The performance of the system was tested under indoor line-of-sight conditions with controlled ambient lighting. The results demonstrate that the system successfully achieves reliable short-range wireless communication with minimal electromagnetic interference.

Text Transmission Results

Text transmission was tested using predefined and user-entered messages sent from the transmitter to the receiver through serial communication. The received text matched the transmitted data without noticeable errors for short transmission distances. The LCD display at the receiver accurately displayed the transmitted text in real time, confirming correct data encoding, LED modulation, optical reception, and decoding. The results indicate low latency and high reliability for digital text data transmission.

Audio Transmission Results

Audio transmission was evaluated using real-time analog audio input signals. The transmitted audio was clearly recovered at the receiver side and reproduced through the speaker using an audio amplifier. Minor noise was observed under high ambient light conditions; however, the overall audio quality remained intelligible and stable. The results confirm that Li-Fi can effectively support short-distance audio communication without RF interference.

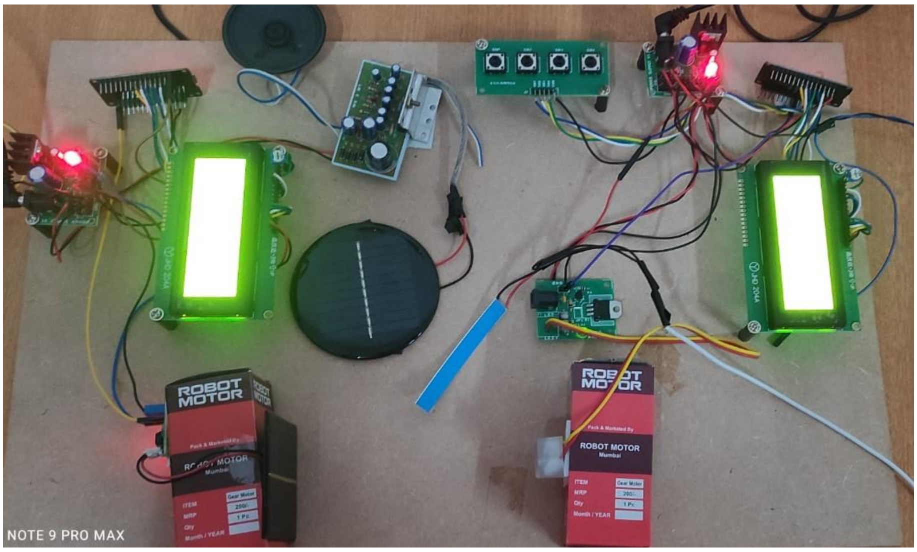
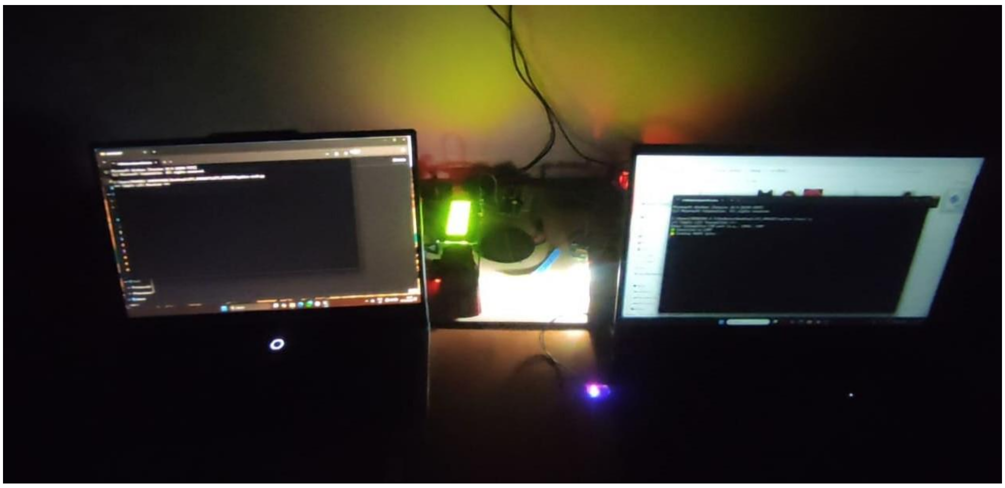


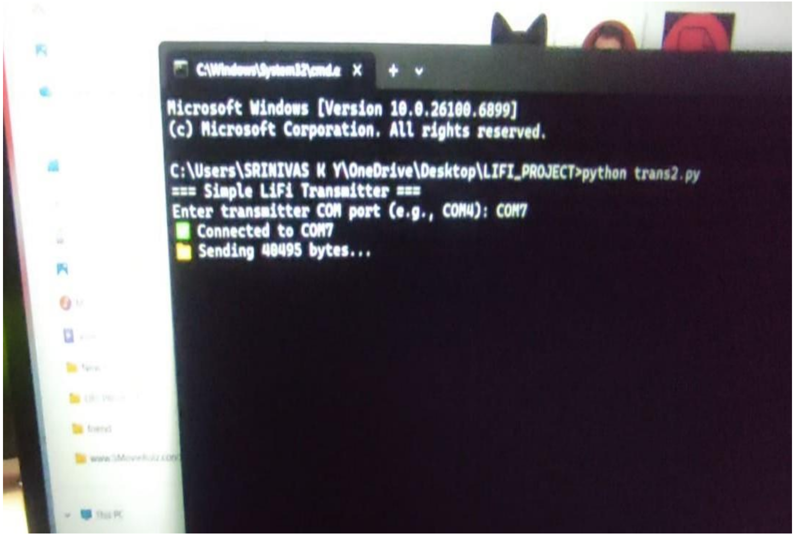
Image Transmission Results

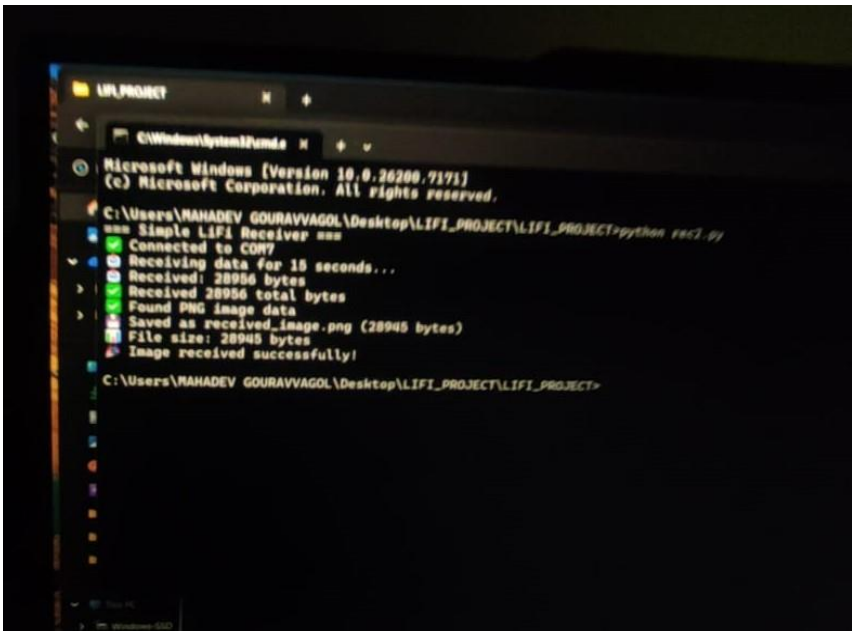


International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

For image transmission, image files were converted into byte streams, encrypted, and transmitted in hexadecimal format through the Li-Fi link. At the receiver end, the image was successfully reconstructed from the received data and displayed on the laptop. Low-resolution images were transmitted with high accuracy, while larger image sizes resulted in increased transmission time. No significant data corruption was observed, demonstrating the effectiveness of serial encoding, synchronization, and error handling mechanisms.

This is the setup for Li-Fi–based image transmission. The right-side laptop functions as the transmitter, running a Python application that converts the selected image into a byte stream, encrypts it, and sends it as serial hexadecimal data to the Li-Fi transmitter module. The LED in the transmitter module modulates the light pulses according to the data, which are received by the solar panel in the receiver module.
The left-side laptop serves as the receiver, capturing the optical signal via the Li-Fi receiver, decoding the serial data, decrypting it, and reconstructing the transmitted image for display. This setup demonstrates a complete end-to-end image transmission system using Li-Fi technology under indoor line-of-sight conditions.





Discussion
The results confirm that Li-Fi technology is a feasible alternative for secure and interference-free wireless communication in indoor environments. While the system demonstrates strong performance for text, audio, and low-resolution image

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

transmission, its effectiveness is limited by line-of-sight requirements and ambient light noise. These findings highlight the potential of Li-Fi for applications such as secure indoor networking, smart classrooms, hospitals, and data-sensitive environments, while also indicating the need for advanced modulation and noise-reduction techniques in future implementations.

Key Takeaways Include

- **Ultra-High-Speed Data Transmission:** Li-Fi enables faster transfer of text, audio, and images compared to conventional Wi-Fi, leveraging visible light for high bandwidth communication.
- **Enhanced Security:** Data transmitted via light waves is confined to physical spaces, reducing the risk of external hacking and eavesdropping.
- **Energy-Efficient Communication:** Li-Fi uses existing LED lighting infrastructure, combining illumination with wireless data transmission, saving energy and resources.
- **Versatile and Reliable Multimedia Support:** It supports simultaneous transmission of multiple data types with low latency, making it suitable for real-time applications and high-density environments.

Limitations

- **Limited Range and Line-of-Sight Requirement:** Li-Fi signals require direct line-of-sight between the transmitter (LED) and receiver, making it less effective in obstructed or large-area environments.
- **Signal Blockage by Objects:** Physical objects such as walls, furniture, or even human movement can interrupt communication, limiting its usability compared to radio-based systems like Wi-Fi.
- **Dependence on Lighting Conditions:** Li-Fi performance is affected by ambient light conditions and requires LED illumination, making it less practical in environments without adequate lighting or where lights are off.
- **Limited Mobility:** Users cannot move freely outside the light coverage area without losing connectivity, which restricts its application in highly dynamic or mobile scenarios.

Summary

Li-Fi technology leverages visible light for high-speed wireless communication, enabling efficient transmission of text, audio, and image data with minimal latency and high reliability. By utilizing LED lighting for both illumination and data transfer, it offers an energy-efficient and secure alternative to traditional radio-frequency-based systems, with reduced risks of external interception. Li-Fi supports simultaneous multimedia transmission and is particularly suited for high-density or RF-congested environments, as well as integration with IoT devices. However, its practical deployment is limited by factors such as line-of-sight requirements, susceptibility to physical obstructions, dependence on lighting conditions, and restricted mobility. Despite these challenges, Li-Fi holds significant potential for future communication networks, promising faster, safer, and more versatile wireless connectivity.

IV. CONCLUSION AND FUTURE WORK

The project titled **"Text, Audio, and Image Transmission Using Light-Fidelity (Li-Fi) Technology"** successfully demonstrates the feasibility of using visible light for high-speed wireless communication of multimedia data. By integrating LED-based transmitters with photodiode or solar panel receivers, the system enables efficient transmission of text, audio, and images without relying on traditional radio-frequency channels. The inclusion of modulation techniques and signal processing ensures reliable, low-latency data transfer, validating the effectiveness of the proposed architecture. The implemented system highlights how LED lighting infrastructure and embedded controllers can be combined to create practical and energy-efficient Li-Fi applications. The results confirm accurate data transmission, secure communication, and stable performance under controlled lighting conditions, making the system suitable for smart environments, high-density networks, and next-generation human–machine interaction scenarios.

The project can be further enhanced with several innovative extensions and integrations:

Advanced Modulation Techniques: Incorporating sophisticated modulation schemes such as OFDM (Orthogonal Frequency Division Multiplexing) or color-shift keying can improve data rates, reduce errors, and enable simultaneous transmission of multiple data streams.

Multimedia Compression and Optimization: Implementing adaptive compression algorithms for audio, text, and image data can increase transmission efficiency, reduce latency, and improve performance under varying light conditions.

International Journal of Advanced Research in Computer and Communication Engineering
Impact Factor 8.471 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 15, Issue 1, January 2026
DOI: 10.17148/IJARCCE.2026.15103

Expanded Coverage and Mobility: Future versions can integrate multiple LED transmitters and receiver arrays to expand coverage areas, support seamless mobility, and enable continuous connectivity in dynamic environments.

Adaptive Ambient Light Compensation: Introducing real-time ambient light sensing and automatic signal adjustment can reduce interference from sunlight or artificial lighting, improving reliability in diverse indoor and outdoor scenarios.

Integration with IoT and Smart Environments: The Li-Fi framework can be extended to smart home, office, and industrial applications, enabling secure and high-speed communication between devices, sensors, and control systems.

Hybrid Li-Fi/Wi-Fi Systems: Combining Li-Fi with traditional Wi-Fi can provide seamless fallback communication, improving reliability in areas where light-based transmission is blocked or unavailable.

Security and Data Encryption Enhancements: Future implementations can incorporate advanced encryption and authentication protocols to protect sensitive multimedia data, ensuring secure transmission in critical applications.

Research and Educational Applications: The system can serve as a platform for exploring next-generation communication technologies, optical networking research, and real-time multimedia transmission experiments in both academic and industrial settings.

REFERENCES

[1]. Haas, H., Yin, L., Wang, Y., & Chen, C. (2020). What is LiFi? *Journal of Lightwave Technology*, 34(6), 1533–1544.
[2]. Pathak, P. H., Feng, X., Hu, P., & Mohapatra, P. (2020). Visible light communication, networking, and sensing: A survey, potential and challenges. *IEEE Communications Surveys & Tutorials*, 17(4), 2047–2077.
[3]. Karthikeyan, S., Balaji, S., & Kumar, M. (2020). Audio signal transmission using visible light communication. *International Journal of Engineering Research & Technology*, 9(5), 421–425.
[4]. Sharma, R., & Verma, P. (2020). Image transmission using Li-Fi technology. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 9(7), 2871–2877.
[5]. Singh, R., Kaur, A., & Gupta, N. (2020). Performance analysis of LED-based Li-Fi communication system. *International Journal of Communication Systems*, 33(14), e4542.
[6]. Rao, K. S., Reddy, V. P., & Kumar, N. (2020). Embedded system implementation of Li-Fi using Arduino and ESP modules. *International Journal of Embedded Systems*, 12(3), 215–222.
[7]. Kulkarni, M., Patil, S., & Deshmukh, A. (2021). Li-Fi based visible light communication for multimedia transmission. *Procedia Computer Science*, 172, 356–363.
[8]. Kim, S., & Jung, H. (2022). High-speed visible light communication for multimedia services. *IEEE Access*, 10, 118245–118256.
[9]. Arnon, S., Kedar, D., & Kopeika, N. S. (2022). Optical wireless communication for secure indoor networks. *IEEE Communications Magazine*, 60(3), 84–90.
[10]. Patel, D., & Mehta, R. (2022). Secure indoor communication using Li-Fi technology. *International Journal of Information Security Science*, 11(2), 92–101.
[11]. Chen, Y., Wang, Z., & Liu, J. (2023). Performance enhancement techniques for image transmission in visible light communication systems. *Optical Engineering*, 62(4), 046104.
[12]. Tripathi, A., & Mishra, R. (2023). Design and implementation of text, audio, and image transmission using Li-Fi. *International Journal of Advanced Computer Science and Applications*, 14(8), 213–220.
[13]. IEEE Standards Association. (2023). *IEEE Standard for Visible Light Communication (VLC) and Li-Fi Systems*. IEEE Std 802.15.7-2023.
[14]. Espressif Systems. (2024). *ESP32 Technical Reference Manual*. Espressif Systems Official Documentation.