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# Li-Fi Visible Light: Data Transfers via LED Technology

Ankita Shirke, Nakusha Mohite*

***Abstract***

*Li-Fi (Light Fidelity) is a cutting-edge technology that uses visible light to communicate data wirelessly, like how Wi-Fi uses radio waves. Light Emitting Diodes (LEDs) are the principal source of light in this system for information transmission. To transmit data, the LED light blinks on and off very quickly, quicker than our eyes can detect. After then, a sensor records these light signals and transforms them back into data that can be used. Li-Fi (Light-Fidelity) is a fast communication technology that sends data by using light. Like Wi-Fi, it is speedier, enabling users to send and receive larger amounts of data more quickly. Using visible light communication (VLC), Li-Fi focuses on using LEDs to send multimedia data between two terminals. Wireless data transfer and illumination are combined in Li-Fi, which fits a tiny microchip into every conceivable illumination source. By 2025, the data transmission speed is expected to increase to 100 Mbps. Li-Fi can expand access to the internet and transform the telecom sector. It addresses issues with capacity, effectiveness, availability, and other aspects of wireless communication.*

**Keywords:** Data transmission, Li-Fi, LEDs, visible light communication, wireless communication

## INTRODUCTION

Within the category of optical wireless communications, Li-Fi, or Light Fidelity, is a state-of-the-art wireless communication technology that makes use of visible light. Li-Fi transmits data digitally by modulating the intensity of LED lights, as opposed to conventional Wi-Fi, which uses radio waves.

This approach not only enables high-speed data transmission, typically in gigabytes per second, but also addresses concerns about electromagnetic wave exposure, as data can only be accessed when the light is visible, ensuring enhanced security. Li-Fi has various benefits over other wireless communication techniques such as Wi-Fi. It is more secure since it employs visible light, which cannot travel through walls, making it more difficult for unwanted entry. Furthermore, Li-Fi can provide quicker data transfer speeds, less interference, and more effective communication in areas with congested or limited radio frequencies, such as hospitals or airlines.

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Coined by Haas and Cogalan at the University of Edinburgh, Li-Fi offers faster communication rates compared to Wi-Fi, potentially revolutionizing the telecommunications industry by providing quicker data exchange [1]. By simply replacing incandescent bulbs with LED counterparts, which possess electronic properties, Li-Fi could extend internet access to previously inaccessible areas, expanding coverage and accessibility. In today's wireless-centric world, where data transmission is integral to daily activities, Li-Fi emerges as a pivotal player, using light as a medium for communication rather than conventional radio waves. While Wi-Fi caters to broader wireless coverage within premises, Li-Fi excels in compact, defined areas, minimizing radio interference issues and offering efficient multimedia data transmission between terminals [2–5].

With an initial data transmission velocity of around 10 Mbps, Li-Fi aims to achieve speeds of up to 100 Mbps by 2025. This advancement is made possible by integrating microchips into illumination devices, combining illumination with wireless data transmission. By addressing fundamental challenges such as capacity, cost, efficiency, and security, Li-Fi paves the way for a future where every light bulb doubles as a Li-Fi Access Point (AP), fostering a cleaner, greener, and more connected world [6–14].

## PROBLEM STATEMENT

As more people and devices connect to the internet, the demand for fast, reliable, and efficient wireless communication continues to grow. However, traditional technologies like Wi-Fi are beginning to face challenges. These include limited bandwidth, which slows down data transfer, network congestion when too many devices connect simultaneously, and security vulnerabilities that increase the risk of unauthorized access.

## OBJECTIVES

The project's goal is to develop a robust data transmission system utilizing Li-Fi technology, comprising both a transmitter and a receiver, to effectively transmit text data.

The specific objectives are as follows:

- Designing and building the microcontroller unit for the transmitter, ensuring seamless integration and functionality.
- Creating the microcontroller unit for the receiver, focusing on efficiency and reliability in data reception.
- Implementing Java code on the PC for both the transmitter and receiver components, facilitating text data processing and enabling seamless communication between the two devices.

## METHODOLOGY

- Conduct a comprehensive review of existing literature and theories relevant to the project's scope and objectives to inform the design and implementation process.
- Develop a detailed block diagram depicting the overall architecture and functioning of the system, illustrating the integration of components and data flow between the transmitter and receiver.
- Create circuit diagrams for both the transmitter and receiver units, detailing the connections and components required for their construction.
- Assemble the necessary components on a breadboard for initial testing and prototyping, followed by transferring the circuitry to a Vero board for more permanent installation.
- Package the assembled components into a cohesive Li-Fi text transmission system, ensuring proper organization and protection of the internal components.
- Conduct rigorous testing and analysis of the Li-Fi text transmission system to validate its functionality and performance against the specified design criteria, making any necessary adjustments or improvements to ensure compliance with project requirements.

## LITERATURE REVIEW

Data processing involves handling or manipulating data in various ways to assign meaning to it. Regardless of the specific tasks involved, the overarching aim of data processing is to convert raw data into meaningful information. It encompasses gathering data, interpreting its significance, communicating it to relevant stakeholders, and storing it for future reference. Therefore, data processing can be described as a series of activities or functions that transform data into actionable insights. The term "data processing system" encompasses all the resources utilized to execute these data processing tasks.

 

Haas and Cogalan emphasized the necessity of developing new communication technologies to meet the growing demand for wireless networks [1]. They introduced four main technologies that use light for communication: Visible Light Communication (VLC), which uses visible light to send data quickly; Optical Camera Communication (OCC), which uses cameras to detect light signals; Free-Space Optical (FSO) Communication, which sends data using lasers through the air; and Light-Fidelity (Li-Fi), which uses LED light to transmit data. These technologies are faster, more secure, and more energy-efficient, especially for private networks in industries.

Elgala *et al*. examined the most recent advances in optical wireless (OW) communication, with a focus on indoor applications [13]. They discussed the issues that this technology faces, how it can be employed, and what the future holds for it. The article also discusses how to send and receive data at the same time (duplex transmission), how multiple users can share the same communication channel (multiple access), data flow management rules (MAC protocols), and how to improve the system's ability to handle more data (link capacity improvements).

Tsonev *et al*. studied the communication capabilities of regular laser diodes (LDs) in different situations where the lighting is limited [8]. Their results show that optical wireless communication can achieve data speeds greater than 100 Gb/s, even in typical indoor lighting conditions. This means that with standard equipment, extremely fast data transfer is possible in regular indoor environments.

Komine and Nakagawa suggested a system where lights are used not just for illumination, but also for optical wireless communication [15]. In rooms, several lights are usually installed, so it is important to consider the differences in the paths that the light takes. The authors examined how interference and reflections from these lights can impact the communication system. Their analysis shows that this approach could be a key part of future indoor communication systems.

Khan *et al*. provided a complete overview of cooperative underwater wireless sensor networks, examining how nodes (or devices) might collaborate at various network levels [3]. They concentrated on ways for improving signal quality at the physical layer, error correction and access control at the link layer, and routing approaches at the network layer to enable better communication in submerged situations.

## SYSTEM DESIGN

The design of the Li-Fi data transmission system to be controlled is divided into two main sections: the hardware section and the software section, as illustrated in Figure 1. In this system, an Arduino microcontroller performs a dual function, acting as both the encoder for data transmitted through a blinking LED and the decoder for data received by the photodiode. The circuit diagram delineates two primary sections: the transmitter part positioned above, and the receiver part situated below in Figure 2. It intricately illustrates how the hardware components of the system interconnect for seamless data transmission. Notably, despite the circuit diagram depicting distinct transmitter and receiver parts, a single microcontroller (Arduino board) is utilized during the system's implementation, consolidating functionality and streamlining operations.

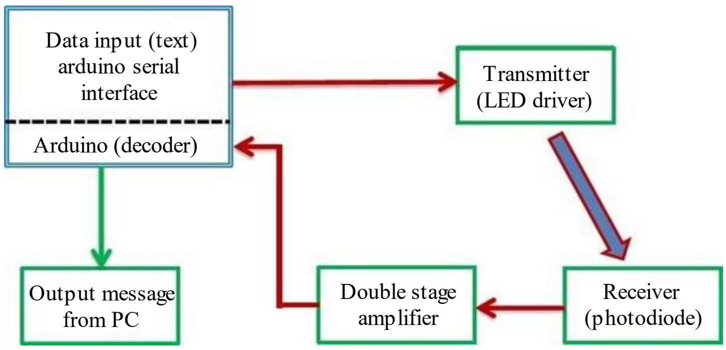


**Figure 1.** Li-Fi data transmission system block diagram.

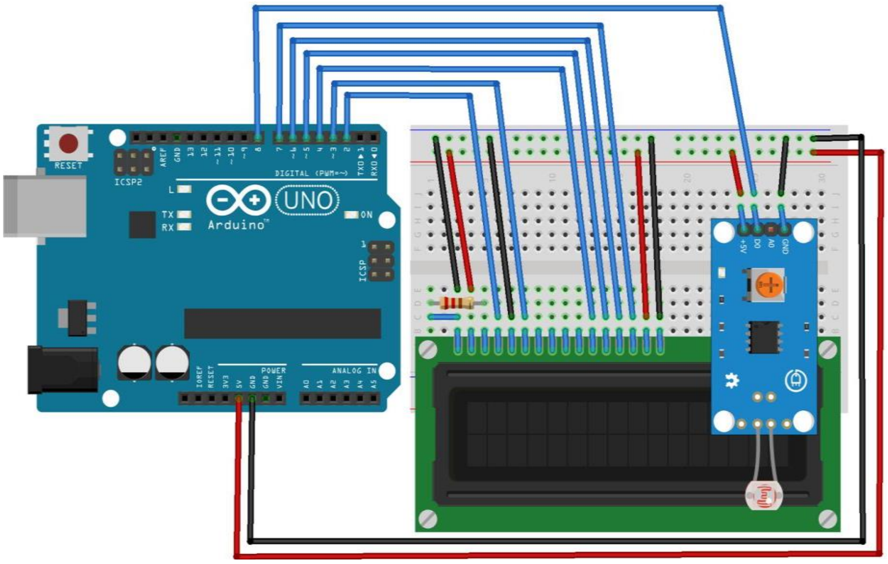

**Figure 2.** Circuit diagram of the system.

## SYSTEM IMPLEMENTATION AND TESTING

### Arduino Setup

The Arduino board is equipped with a built-in serial communication interface, commonly including a Universal Serial Bus (USB) controller in most models. This interface enables seamless program uploads from a personal computer to the board.

Leveraging the Arduino Integrated Development Environment (IDE), programmers can code the Arduino to execute various functions, such as controlling the LED's state in the transmitter circuit and reading analog signals from the photodiode in the receiver's circuit.

To streamline the system and avoid unnecessary complexity, the Arduino board serves a dual purpose as both the microcontroller and the Power Supply Unit (PSU) for the circuits. When connected to a PC via the serial connector cable, the Arduino board provides a steady voltage of approximately 5 V through its VCC port and serves as a virtual ground. This design ensures efficient operation while reducing the need for additional components.

### Hardware Implementation

To optimize the Li-Fi data transmission system, a single Arduino microcontroller board is utilized to handle encoding, decoding, and powering both the transmitter and receiver circuits. After designing the system and calculating the appropriate resistor values for both circuits, all components were carefully assembled on a breadboard using jumper wires. A multimeter was used to ensure circuit integrity by testing the continuity between various connection points.

To ensure accurate testing and minimize potential errors, the transmitter and receiver circuits were integrated onto a single breadboard. Additionally, the LED and photodiode were positioned near each other to facilitate efficient data transmission, as depicted in the provided Figure 3. This setup optimizes the functionality of the system while enhancing reliability during testing and operation.

Following thorough testing on the breadboard, the components were meticulously soldered onto separate Vero boards, maintaining the same circuit configuration as depicted in Figures 4 and 5. Post-soldering, a multimeter was employed to detect any potential issues such as dry joints, bridging of joints, and to ensure continuity of lines on the Vero board. This meticulous testing process serves to alleviate the burden of circuit construction and helps identify potential sources of errors prior to utilizing the circuit, ensuring optimal performance and reliability.

 

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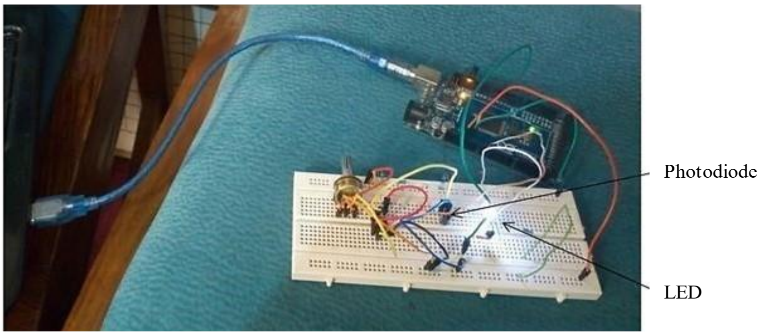


**Figure 3.** Breadboard implementation.

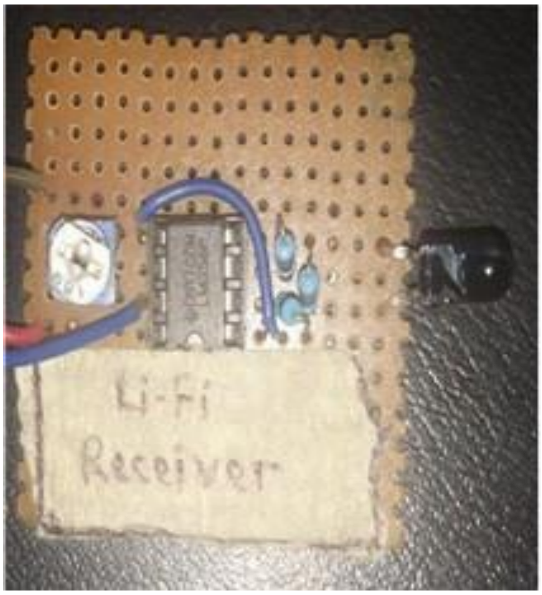


**Figure 4.** Li-Fi transmitter.

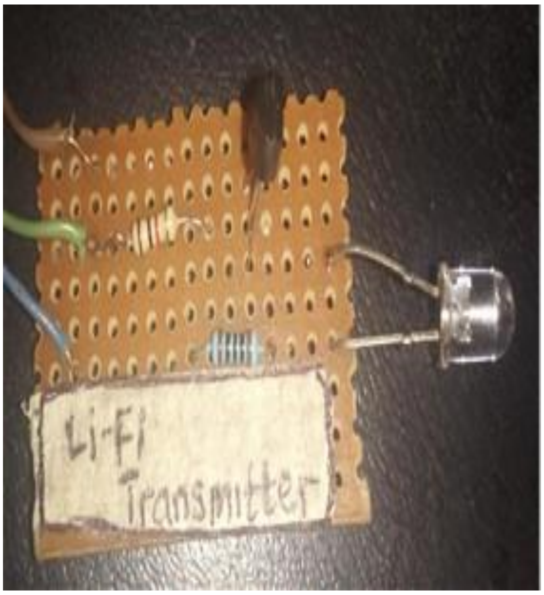


**Figure 5.** Li-Fi receiver.

**Software Implementation**

The software design implementation primarily focused on creating an application that decodes messages received from the transmitter and displays them on its output window. This application was developed using the Java programming language within the NetBeans Integrated Development Environment (IDE). To facilitate communication between the Java application and the Arduino microcontroller, the Arduino library was imported into the NetBeans IDE. This library serves as an external resource specifically designed to ensure seamless interaction between Java applications and Arduino microcontrollers, enabling effective data exchange and processing.

By leveraging the capabilities of Java and integrating the Arduino library, the software design effectively enables the decoding and display of messages transmitted from the transmitter, enhancing the overall functionality and usability of the Li-Fi data transmission system. The Graphical User Interface (GUI) developed from the program is depicted in the provided Figure 6. It features a “Connect” button and a dynamically generated list of system ports, offering users flexibility in selecting the port on the Receiver PC. Users can access the application via a link embedded in the NetBeans IDE, which was employed for its development. Upon launching the application, they are prompted to connect the Arduino microcontroller by selecting the appropriate port from a drop-down menu, as illustrated in Figure 7. To ensure accurate port selection, users should verify the port number within the Arduino IDE, which was previously used to upload the microcontroller-encoding program to the Arduino board. Once the appropriate port is selected, the system automatically establishes the connection. Any error in port selection may hinder users from viewing messages sent from the first computer.

Upon successful port connection, a confirmation message is displayed, acknowledging the correct port selection, as illustrated in Figure 7. This streamlined interface and port selection process enhances user experience and ensures efficient communication between devices. The 'Connect' button now becomes locked and changes to 'Disconnect' to prevent the user from changing the port when a message is being received and thus disrupting the decoding process.

## TESTS AND RESULTS

The final design verification was done using the complete system; a transmitter, receiver and software, and the results are shown in Figure 8.


**Figure 6.** Java application on receiver PC.

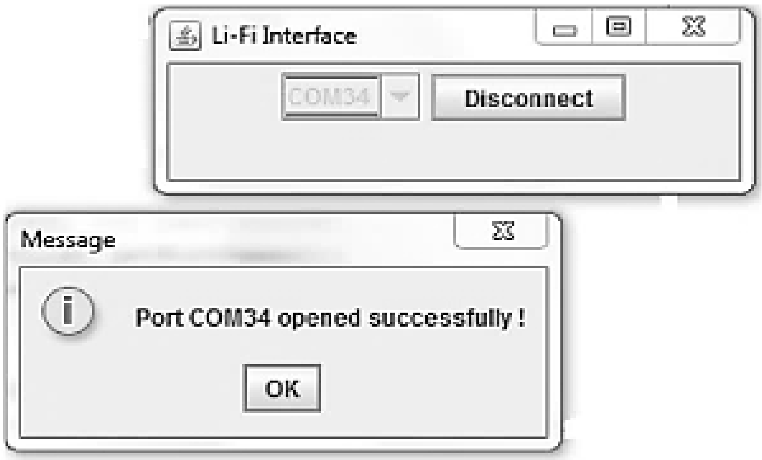


**Figure 7.** Li-Fi receiver port.

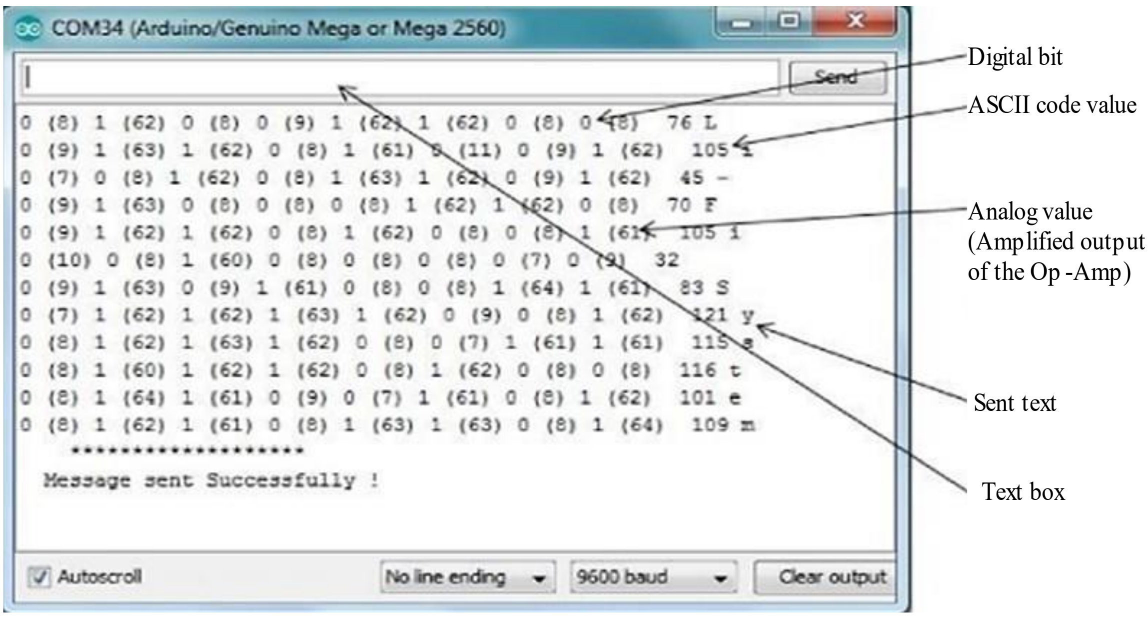


**Figure 8.** Encoding and decoding monitor.

 

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## CONCLUSION

The development of a Java application within the NetBeans IDE, coupled with the integration of the Arduino library, has enabled the decoding and display of messages received from the transmitter in the Li-Fi data transmission system. This software design implementation represents a crucial step in enhancing the system's functionality and usability, as it provides a user-friendly interface for interpreting transmitted data. By leveraging the capabilities of both Java and Arduino, the system can effectively communicate with the microcontroller, facilitating seamless data exchange and processing. Moving forward, further refinements and enhancements to the software design could unlock additional features and capabilities, paving the way for broader applications and commercialization of the Li-Fi technology.

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