# LiFi Data Transmission System Using Arduino

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**ABSTRACT**

***The process of communication may happen in many ways using various means starting from expressions, body gestures, pictorialrepresentation, letter writingand soon.Majortransformation ofcommunication was rapidlychanged after invention of wired communication like using telephones. Using conventional wireless technologies, the data can be transferred up to the bandwidth of 300GHz. But, transferring through Li- Fi can support the bandwidth nearly to 400THz. Obviously, it is clear that huge amount of data can be sent using the Li-Fi technology effectively. The transmission of digital data through LED lights using VLC method can be observed with flickering according to the 1's and 0's. If the LED is transmitting 1 in data then light is ON, and if it transmits 0 then light tends to OFF. The digital data contains consecutive 1's and 0's then the ON and OFF of LED light occurs rapidly and such flickers are not able to identify through naked eye and also makes to think the light is emitted with constant frequency.. To make the transmission of Data in parallel way (sending and receiving simultaneously), an array of LED's can be used.***

***Keywords:- Light Fidelity (LiFi), Light Emitting Diode(LED), Visible Light Communication, Internet of Things(IoT).***

## 1. INTRODUCTION

In simple terms, Li-Fi can be thought of as a light-based Wi-Fi. That is, it uses light instead of radio waves to transmission formation [1]. And instead of Wi- Fi modems, Li-Fi would use transceiver - fitted LED lamps that can light a room as well as transmit and receive information. Since simple light bulbs are used, there can technically be any number of access points [2]. This technology uses a part of the electromagnetic spectrum that is still not greatly utilized- The Visible Spectrum [3-4]. Light is in fact very much part of our lives for millions and millions of years and does not have any major ill effect [5]. Moreover, there is ten thousand times more space available in this spectrum and just counting on the bulbs in use, it also multiplies to ten thousand times more availability as an infrastructure, globally[6-8]. It is possible to encode data in the light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. The LED intensity is modulated so rapidly that human eyes cannot notice.

## 2. METHODOLOGY

**Proposed Block Diagram:**

LiFi data transmission using Arduino as shown in fig.1, is a visible light communication technique in which data is transmitted through light emitted by LEDs and received by photo detectors or LDRs, with an Arduino microcontroller handling data encoding and decoding.

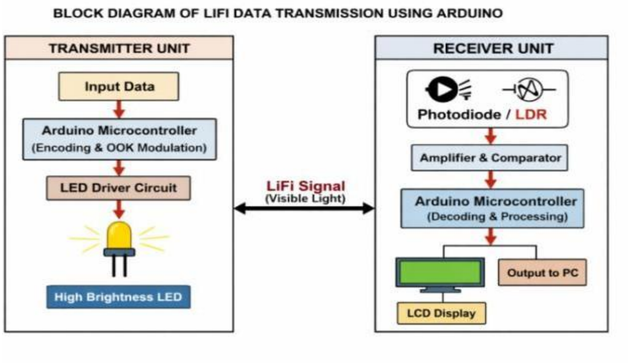

Fig.1: LiFi Data Transmission using Arduino

In this system, the Arduino modulates digital data into rapid light intensity variations at the transmitter, which are imperceptible to the human eye, and the receiver converts these light signals back into electrical signals for data recovery. Arduino-based LiFi systems are widely used in academic and prototype applications due to their low cost, simplicity, and ease of implementation. They offer advantages such as high security, freedom from radio frequency interference, and suitability for short-range communication. However, their performance is typically limited by short transmission range, low data rates, sensitivity to ambient light, and the requirement for a clear line of sight between the transmitter and receiver.

**Interpretation of Each Block:**

**Input Data Block:**

This block represents the source of information to be transmitted. The input data may be in the form of text, numbers, or digital signals provided through a computer, keypad, or serial monitor. The data is initially in human-readable form and must be converted into a digital format before transmission.

This block acts as the starting point of the LiFi communication process.

**Arduino Microcontroller (Transmitter Side):**

The Arduino microcontroller functions as the core processing unit of the transmitter. It converts the input data into binary form and applies On-Off Keying (OOK) modulation. In this modulation technique, binary '1' is represented by switching the LED ON and binary '0' by switching the LED OFF. The Arduino also controls the timing and synchronization of data bits to ensure accurate transmission.

**LED Driver Circuit:**

The LED driver circuit provides the required current and voltage to operate the LED efficiently. Since Arduino pins cannot supply sufficient current to drive high- brightness LEDs directly, this circuit typically consists of resistors and a transistor or MOSFET. It ensures fast switching of the LED according to the control signals received from the Arduino.

**High Brightness LED (Transmitter):**

The high-brightness LED serves as the LiFi transmitter**.** It emits visible light whose intensity is modulated according to the binary data signal. The rapid switching of the LED enables data transmission without affecting normal illumination, as the switching occurs faster than human visual perception.

**LiFi Channel (Visible Light Medium):**

This block represents the free-space visible light path between the transmitter and receiver. Data is transmitted through light waves and requires a clear line-of-sight. Unlike RF communication, visible light cannot penetrate opaque objects, which enhances communication security but limits transmission range.

**Photodiode / LDR (Receiver Sensor):**

This block acts as the optical receiver. The photodiode or LDR detects variations in light intensity from the transmitter LED and converts them into corresponding electrical signals. Photodiodes offer faster response times, while LDRs are simpler and more economical but slower in operation.

**Amplifier and Comparator Circuit:**

The electrical signal obtained from the sensor is usually weak and affected by noise. The amplifier strengthens this signal, and the comparator converts it into a clean digital signal by comparing it with a reference threshold. This block improves signal clarity and minimizes the effect of ambient light interference.

**Arduino Microcontroller (Receiver Side):**

The receiver-side Arduino processes the conditioned signal received from the comparator. It decodes the binary data, reconstructs the original information, and performs error checking if implemented. This block ensures proper synchronization and accurate recovery of transmitted data.

**Output Display / PC Interface:**

The decoded data is displayed through an output device such as an LCD displayor sent to a computer via a serial interface. This block allows the user to observe and verify thesuccessful reception of data transmitted using LiFi technology.

**Relevant Mathematical Equations**

**1. Binary Data Representation**

The input data is first converted into a binary sequence equation (1):

$$\mathbf{b(t) \in \{0,1\}} \qquad (1)$$

where b(t) represents the digital data bit at time t.

**2. On–Off Keying (OOK) Modulation**

In LiFi systems using Arduino, On–Off Keying (OOK) is commonly employed. The transmitted optical signal (2) is defined as:

$$\mathbf{s(t)=b(t)\cdot PLED} \qquad (2)$$

where:

s(t) = transmitted optical signal b(t) = binary data (0 or 1)
LED = optical power of the LED
For:

- b(t)=1⇒ LED ON
- b(t)=0⇒ LED OFF

**3. LED Optical Power Output**
The optical power emitted by the LED is proportional (3) to the forward current:

$$P_{LED}=\eta \cdot I_{LED} \quad (3)$$

where:

- η = LED efficiency
- ILED = LED drive current

**4.** Free-Space Optical Channel Model
The received optical power (4) at distance d is given by:

$$P_r=P_{LED} \cdot A_r/4\pi d^2 \quad (4)$$

where:

- Pr = received optical power
- Ar = effective area of the receiver
- d = distance between LED and receiver

**5.** Photodiode / LDR Current Generation
The received optical power(5) is converted into electrical current:

$$I_{pd}=R \cdot P_r \quad (5)$$

where:

- Ipd = photodiode current
- R = responsivity of the photodiode (A/W)

**6.** Signal Amplification
The weak electrical signal (6) is amplified using an operational amplifier:

$$V_{out}=A_v \cdot V_{in} \quad (6)$$

where:

- Vout = amplified output voltage
- Vin = input signal voltage
- Av = amplifier gain

A. Hardware Implementation

**1. Arduino UNO**

- Microcontroller: ATmega328P
- Operating Voltage: 5 V
- Input Voltage (Recommended): 7–12 V
- Digital I/O Pins: 14 (6 PWM pins)
- Analog Input Pins: 6
- Clock Speed: 16 MHz
- Flash Memory: 32 KB (0.5 KB used by bootloader)
- SRAM: 2 KB
- EEPROM: 1 KB
- Communication Interfaces: UART, SPI, I²C
- Function in Project:

Used for data encoding, LED modulation at the transmitter side and signal decoding, data processing at the receiver side.

**2. High Brightness LED**

- Type: White LED
- Forward Voltage: 3.0 – 3.4 V
- Forward Current: 20–30 mA
- Luminous Intensity: 10–20 cd (varies with LED type)
- Switching Speed: Up to several MHz
- Function in Project:

Acts as the optical transmitter by emitting visible light modulated with digital data.

**3. Photodiode**

- Type: Silicon Photodiode
- Spectral Response: 400–700 nm (Visible spectrum)

- Responsivity: 0.4–0.6 A/W
- Response Time: < 10 µs
- Reverse Bias Voltage: 5–10 V
- Function in Project:

Converts received light intensity into an electrical current.

**4. Light Dependent Resistor (LDR)(Alternative Receiver)**

- Dark Resistance: > 1 MΩ
- Light Resistance: 1–10 kΩ
- Spectral Peak: ~550 nm
- Response Time: 10–100 ms
- Function in Project:

Low-cost optical sensor for detecting light intensity variations (used in low-speed systems).

**5. LCD Display (16×2)**

- Display Type: Alphanumeric LCD
- Operating Voltage: 5 V
- Characters: 16 characters × 2 lines
- Interface: 4-bit / 8-bit parallel
- Backlight: LED
- Function in Project:

Displays received data at the receiver end.

**6. Resistors**

- Typical Values: 220 Ω, 330 Ω, 1 kΩ, 10 kΩ
- Power Rating: ¼ W
- Tolerance: ±5%
- Function in Project:

Current limiting, voltage division, biasing, and signal conditioning.

**7. Power Supply**

- Supply Voltage: 5 V DC
- Current Rating: ≥ 1 A
- Source: USB / Adapter
- Function in Project:

Provides regulated power to Arduino and peripheral circuits.

B. Software Implementation

The software implementation of the LiFi data transmission system using Arduino is responsible for data encoding, modulation, reception, decoding, and display. The software is developed using the Arduino Integrated Development Environment (Arduino IDE) and programmed in Embedded C**.** Separate programs are written for the transmitter Arduino and the receiver Arduino to ensure synchronized communication.

**1. Transmitter Software Implementation**

At the transmitter side, the Arduino program begins by initializing the required I/O pins, serial communication, and timing parameters. The input data is obtained either from a serial monitor, computer interface, or predefined character array. This data is then converted into its ASCII equivalent and further transformed into a binary sequence**.**

The transmitter software implements On-Off Keying (OOK) modulation**,** where each binary bit is transmitted by controlling the LED state. A logic '1' switches the LED ON, while a logic '0' switches the LED OFF. The LED is driven through a digital output pin connected to the LED driver circuit. Precise delay timing is introduced using software delay functions to maintain a constant bit duration and ensure synchronization between the transmitter and receiver.

**2. Receiver Software Implementation**

At the receiver side, the Arduino software initializes the input pins connected to the comparator output, as well as the LCD display and serial communication interface. The receiver continuously monitors the incoming digital signal from the comparator, which represents the decoded light intensity variations. The receiver software detects the start bit to synchronize data reception.

**3. Timing and Synchronization**
Proper timing synchronization is a critical aspect of the software implementation. Both transmitter and receiver use predefined bit durations to maintain consistency. Software delays are carefully calibrated to match the LED switching speed and sensor response time, ensuring minimal bit errors during transmission.

**4. Noise Handling and Reliability Enhancement**
To minimize the effects of ambient light and noise, the receiver software filters unwanted transitions by validating signal stability before accepting a bit. Repeated sampling and majority voting techniques may also be employed to improve accuracy under varying lighting conditions.

**5. Software Testing and Validation**
The software is tested under different lighting conditions and transmission distances to verify reliable data communication. Debugging is performed using the Arduino serial monitor to analyze transmitted and received data streams.

## 3. RESULTS & DISCUSSIONS

The proposed Li-Fi data transmission system was successfully designed, implemented, and tested using Arduino as the control unit at both the transmitter and receiver sections. The experimental results confirm that digital data can be reliably transmitted using visible light without employing any radio frequency spectrum.

**Transmitter Side Results:**
When input data was provided to the transmitter through a computer via serial communication, the Arduino successfully encoded the data into a digital bit stream. This data was modulated using On–Off Keying (OOK), where logic '1' corresponded to the LED being switched ON and logic '0' corresponded to the LED being switched OFF. The LED driver circuit ensured sufficient current to the LED while maintaining high switching speed.

**Receiver Side Results:**
At the receiver, the photodiode converted the received light signal into a corresponding electrical signal. This signal was initially weak and contained noise due to ambient light sources. The signal conditioning circuit, consisting of an amplifier and filter, successfully increased the signal amplitude and removed unwanted noise components.

**Output Verification:**
The decoded data was displayed on the serial monitor/LCD, where the received output was observed to be identical to the transmitted data. This confirms successful end-to-end data communication using visible light. The system demonstrated low latency and consistent performance for basic text and binary data transmission.

**Overall System Performance:**
The results as shown in fig.2, clearly show that the Li-Fi system provides secure, interference-free communication, as light does not penetrate walls and hence reduces the risk of unauthorized access. The system also eliminates electromagnetic interference, making it suitable for environments where RF communication is restricted, such as hospitals and aircraft cabins.
However, the system performance is dependent on line- of-sight availability and ambient lighting conditions. The transmission range is limited compared to conventional Wi-Fi, which highlights the need for multiple LEDs and advanced modulation techniques for large-scale deployment.

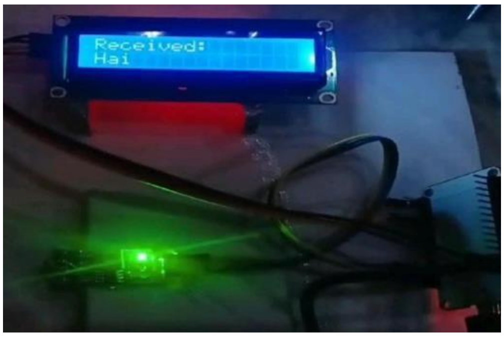

Fig 2: Actual Output of the system

## 4. CONCLUSION & FUTURE SCOPE

The concept of Li-Fi is currentlyattracting a great deal of interest, not least because it mayoffer a genuine and very efficient alternative to radio-based wireless. One of the shortcomings however is that it only work in direct line of sight. Li-Fi (Light Fidelity) is an advanced wireless communication technology that uses visible light from Light Emitting Diodes (LEDs) to transmit data. In Li-Fi systems, information is encoded by rapidly switching the intensity of an LED light on and off at very high speeds, which is invisible to the human eye. With the widespread adoption of LED lighting, Li-Fi has strong potential for future applications in smart homes, smart cities, healthcare, transportation, and Internet of Things (IoT) systems.

Future work in Li-Fi data transmission focuses on enhancing data rates, coverage, and system reliability to enable widespread adoption. Advanced modulation techniques, MIMO-Li-Fi, and the use of micro-LEDs or laser diodes can significantly increase transmission speed and bandwidth. Integration of Li-Fi with existing Wi-Fi networks will allow seamless connectivity and improved mobility through efficient handover mechanisms. Research is also directed toward overcoming line-of- sight limitations by utilizing reflected light, smart optical surfaces, and adaptive beam steering. Cost reduction through miniaturized hardware and integration into standard LED lighting systems is another key area of development.

## 5. REFERENCES

[1] P.P. Ray, 2020, "A survey on Internet of Thingsarchitectures", Journal of King Saud University – Computerand Information Sciences, 30, 291–319.

[2] Mostafa H. Ahfayd et al., " Selection ofhighpower LEDs for Li-Fi applications", IEEE 25th conferenceon ICT, pp 170-174

[3] Kwangyoung Kim and Joonhee Kwon, 2016,"A Pervasive Interconnection Technique for EfficientInformation Sharing in Social IoT Environment",International Journal of Smart Home Vol. 10, No. 1,pp. 9-22.

[4] Kajal, AshishSainiKanchan Gupta, "Lifi- Light FidelityTechnology- A Review," International Journal of EmergingResearch in Management &Technology, vol. 3, no. 10, Oct 2023.

[5] M. Mutthamma, "A survey on Transmission of data throughillumination - Li-Fi," International Journal of Research inComputer and, Dec 2023.

[6] Jyoti Rani and PrernaChauhan, 2023, "Li-Fi(Light Fidelity)-The future technology In Wirelesscommunication", International Journal of AppliedEngineering Research, ISSN 0973-4562 Vol.7 No.11.

[7] Lamya I. Albraheem et al.,, 2024," Toward Designing a Li-Fi-Based Hierarchical IoTArchitecture", IEEE Access Volume 6, pp 40811 - 40825.

[8] Richard Gilliard, "the lifi® lamp high efficiencyhigh brightness light emittingplasma with long life and excellent color quality,"ieee, sunny vale, usa ,2024.