"Audio, Text, and Image Transmission with LiFi Technology using ESP32 Camera and Python"

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Abstract

This project investigates the development and implementation of a Light Fidelity (LiFi)-based system for secure, real-time wireless transmission of multimedia data, including audio, text, and images. As an emerging wireless communication technology, LiFi utilizes the visible light spectrum instead of conventional radio frequency (RF) channels used by technologies such as Wi-Fi, Bluetooth, and Zigbee. By leveraging visible light communication (VLC), LiFi offers several distinct advantages over traditional RF-based systems, including significantly higher data transmission rates, enhanced security due to the confined nature of light propagation, and lower latency.

1. Introduction

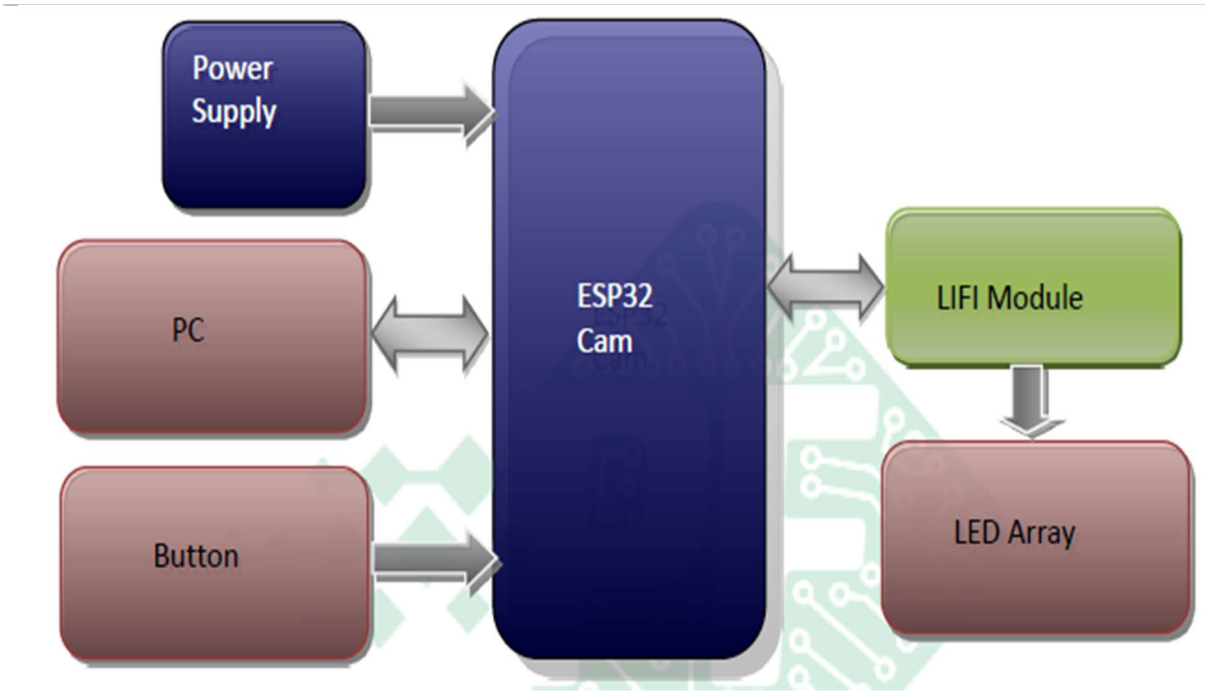
In the age of rapid digital communication, the demand for faster, more secure, and interference-free wireless data transmission continues to grow. Traditional wireless technologies such as Wi-Fi, Bluetooth, and Zigbee operate using radio frequency (RF) bands, which are increasingly congested and vulnerable to security threats. To address these limitations, Light Fidelity (LiFi) has emerged as a promising alternative. LiFi utilizes the visible light spectrum for data communication, offering high bandwidth, low latency, and enhanced security by confining data transmission to the illuminated area. This project aims to design and implement a LiFi-based system capable of transmitting multimedia data—specifically audio, text, and images—using low-cost, commercially available components. At the core of the system is the ESP32-CAM module, a compact microcontroller with an integrated camera and Wi-Fi capabilities. The ESP32-CAM captures image data and serves as the source of other media content such as audio files or text. This data is encoded and transmitted via a custom-built LiFi transmitter that modulates light signals to carry the information. On the receiving side, a photodiode-based LiFi receiver detects the light signals and converts them into electrical signals. These signals are then decoded either through a Python-based application running on a personal computer or with the help of an Arduino Uno, depending on the specific use case. The decoded output reconstructs the original multimedia content in real time. The objective of this project is to evaluate the effectiveness of LiFi in transmitting various types of multimedia data within indoor environments. Key performance indicators include transmission accuracy, latency, resistance to noise (e.g., ambient light), and ease of system integration. By combining LiFi technology with the ESP32-CAM and Python, this work

demonstrates a viable alternative to RF-based communication systems, particularly in secure or interference-sensitive applications This project not only highlights the potential of LiFi for high-speed, short-range wireless communication but also contributes to the practical understanding of integrating hardware and software components in real-world IoT and multimedia systems.

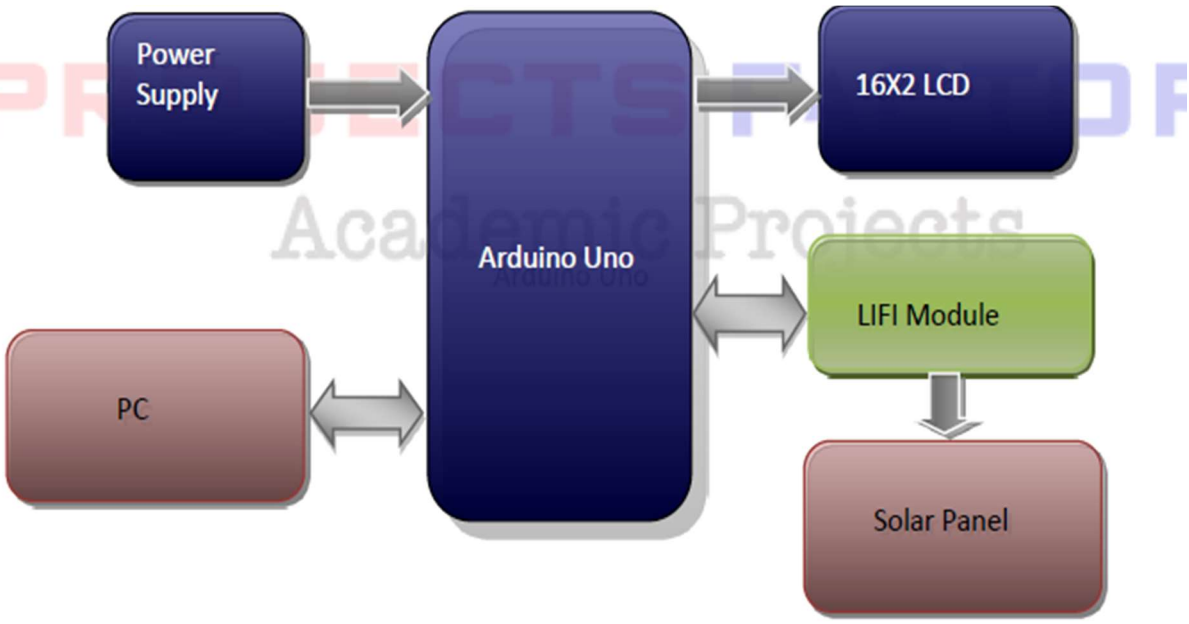
2. Methodology/Procedure adopted:

System Architectue

Transmitter



Receiver



Hardware Overview:

- **ESP32-CAM Module**: Captures and encodes image and audio data.
- **LiFi Transmitter Module**: Converts electrical data into modulated light signals.
- **LiFi Receiver Module**: Receives light signals and converts back to electrical form.
- **PC/Arduino Uno**: Acts as a receiver and decoder using either Python or Arduino IDE.
- **UART Cable**: Establishes serial communication between modules.
- **Power Supply**: 12V DC power source for stable operation.

Illustrative Image (Insert Diagram):

Block diagram showing ESP32-CAM → LiFi Transmitter → LiFi Receiver → PC/Arduino

Software Overview:

- **Python Script**: Used on PC for receiving, decoding, and displaying image/audio/text data.
- **Arduino IDE**: Used to program Arduino Uno to receive and display incoming text/audio.
- **OpenCV + Serial Libraries**: Handle camera input and serial communication in Python.

Operational Flow

1. The **ESP32-CAM** captures an image/audio/text.
2. Data is encoded and sent via **UART** to the **LiFi Transmitter**.
3. **Modulated light** carries the signal through visible light to the receiver.
4. The **LiFi Receiver** demodulates the signal and sends it to a **PC/Arduino Uno**.
5. **Python script or Arduino code** processes the received data and displays/stores it.
6. A **manual or automatic mode switch** determines whether the system is in audio or text/image transmission mode.

System Modes:

- **Mode 1 (Text/Image Transmission to PC)**: Uses Python to decode image and text data.
- **Mode 2 (Audio/Data to Arduino)**: Uses serial buffer and decoding logic for basic playback/display.

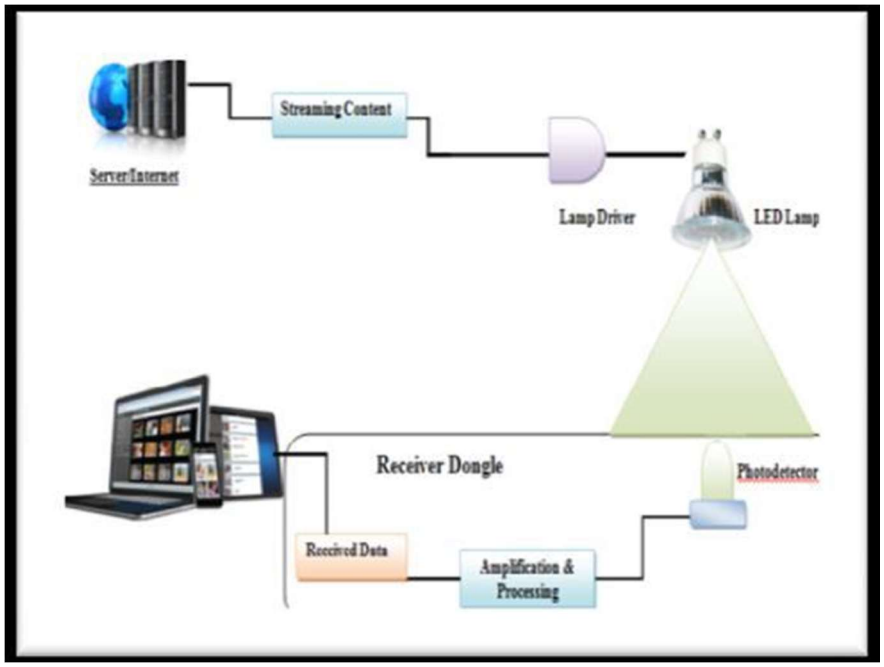


Figure 1:Illustrative Image

Work Flow

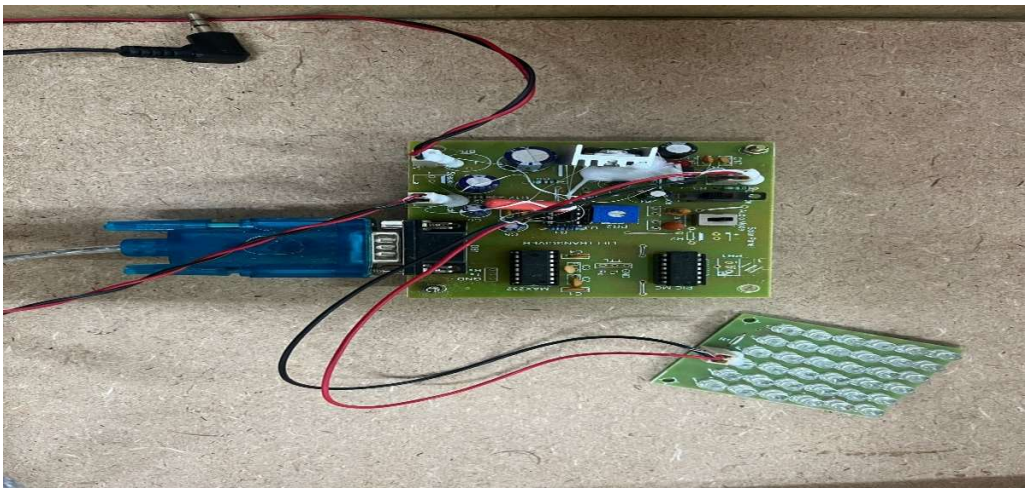


Figure 2:Sender Board

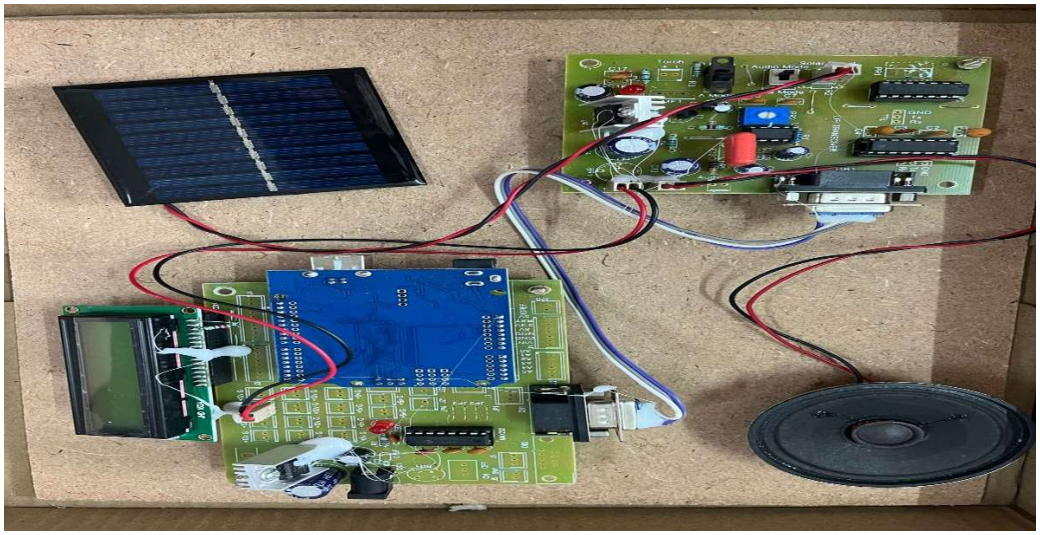


Figure 3:Receiver Board

3. Conclusions

This project successfully demonstrates the feasibility of transmitting multimedia data—specifically **text**, **images**, and **audio**—using **LiFi technology** with an **ESP32-CAM module** and a **Python-based receiver system**. The implementation confirms that visible light, when modulated appropriately, can serve as a low-cost and secure medium for short-range data communication.

Through a series of tests, the system was able to achieve accurate transmission of short text messages and small image and audio files using On-Off Keying (OOK) modulation. The ESP32-CAM efficiently handled data conversion and LED modulation, while the Python script running on a PC successfully decoded the received light pulses into the original content using a photodiode interface.

While the results were promising, the project also highlighted some **key limitations**, including:

- Restricted transmission range (optimal below 20 cm),
- Sensitivity to ambient light,
- Limited data transmission speed due to basic modulation schemes,
- Hardware constraints, especially on the ESP32-CAM's memory.

Despite these challenges, the project establishes a strong foundation for exploring LiFi as an alternative to traditional RF-based communication, particularly in scenarios requiring **secure, short-distance, and interference-free data transfer**, such as in hospitals, research labs, or industrial environments.

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