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Design and Implementation of Li-Fi Communication System using Arduino Uno

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Abstract:

Li-Fi (Light Fidelity) is an innovative wireless communication technology that utilizes visible light spectrum for high-speed data transmission. Unlike conventional Wi-Fi systems, which depend on radio frequency signals, Li-Fi transmits data using rapid modulation of LED light. This project presents the design and implementation of a low-cost Li-Fi communication system using Arduino UNO, LED, LDR sensor module LM393, and 16x2 LCD display with I2C module.

The proposed system consists of transmitter and receiver sections. In the transmitter section, text data entered through serial communication is converted into binary form and transmitted through LED light pulses. The receiver section uses an LDR sensor to detect variations in light intensity and reconstruct the transmitted message. The decoded data is displayed on an LCD module. Experimental results demonstrate successful short-range optical communication under controlled environmental conditions. The proposed system is cost-effective, secure, energy-efficient, and suitable for future indoor communication applications.

Keywords **Li-Fi, Arduino UNO, Visible Light Communication, LED Modulation, LDR Sensor, LCD Display.**

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I. INTRODUCTION

Wireless communication is now a part of modern technology. The growth of internet services, devices, Internet of Things (IoT) and cloud-based applications has increased the need for faster more reliable and energy-efficient communication systems. Current wireless communication technologies like Wi-Fi, Bluetooth and cellular networks use the radio frequency (RF) spectrum to transmit data. Although these technologies have changed communication systems they have some limitations, including bandwidth, spectrum congestion, security issues and electromagnetic interference.

The number of devices has grown exponentially causing heavy traffic in the RF spectrum, which leads to reduced efficiency and slower communication speeds. Also RF-based communication systems are not suitable for areas where electromagnetic interference can be risky such as hospitals, aircraft cabins, petrochemical industries and military communication zones.

To overcome these limitations researchers have looked into communication technologies and Li-Fi (Light Fidelity) has emerged as a promising solution. Li-Fi was introduced by Professor Harald Haas in 2011 during a TED Global conference, where he showed that data can be transmitted through light from LED bulbs.

The principle of Li-Fi is based on high-speed modulation of light. LEDs can switch ON and OFF quickly so binary data can be encoded in light pulses without causing visible flickering. A receiving sensor, such as a photodiode or Light Dependent Resistor (LDR) detects these variations and converts them back into electrical signals for data reconstruction.

The visible light spectrum has advantages, over the RF spectrum. It offers larger bandwidth, better security because of line-of-sight communication, reduced interference and improved energy efficiency since existing lighting infrastructure can be used for both illumination and communication. Li-Fi uses light. Li-Fi has potential. Li-Fi can provide communication.

Li-Fi technology has been getting a lot of attention lately in home systems and things like that. It is also used in communication, vehicle-to-vehicle communication, industrial automation and indoor positioning systems.. We still need to actually use Li-Fi in a real setting to see how it works and what problems we might have with it.

This project is about making a Li-Fi communication system using an Arduino UNO, an LED, an LM393 LDR sensor module and a 16x2 LCD display with an I2C module. We want to send text data through the air using light. So we turn the data into binary code. Send it through a light. The other end has a sensor that detects changes in the light. Turns it back into the original message, which we show on the LCD screen.

This system is an cheap way to show how Li-Fi works. It can help people learn about how light can be used to send information. It also shows that Li-Fi could be an alternative to the wireless communication systems we use now.

The main goal of this project is to see if we can really use light to send information through the air using an Arduino. We also want to see how well it works when we are in the room. We are looking at things like how other light, in the room might interfere with our signal and how apart the sender and receiver can be.

More and more people want to be able to send information wirelessly Li-Fi technology is going to become more important. It can work together with the systems we use now. So this project is helping us learn more about Li-Fi and how it can be used in the future.

II. Methodology

The construction of the proposed Li-Fi Communication System involved both the hardware and software components integrated into the system. The construction process was divided into a number of stages including system design, construction of the hardware, creation of the software, optical transmission of data, and evaluation of the system performance. The system is mainly divided into the transmitter subsystem and the receiver subsystem.

The transmitter subsystem of the system is designed to convert the input text into optical signals, which are then transmitted. The receiver subsystem is designed to capture the optical signals and convert them back to the original signals. System Architecture The proposed Li-Fi communication system incorporates two Arduino UNO boards, one functioning as a transmitter and the other as a receiver. The transmitter is designed to emit signals using light for communication.

A. System Architecture

Text input is done via the Arduino serial monitor. A microcontroller in the transmitter processes the text and encodes it in binary format.

A light-dependent resistor (LDR) sensor in the receiver is used to capture the emitted signals. The signals are then rendered in a digital format for display using an LCD module.

The system architecture is divided into:

1. Input unit
2. Processing unit
3. Transmission unit
4. Receiving unit
5. Output display unit

The architecture supports communication through visible light, thus ensuring data is transferred from the source to the destination without loss.

B. Hardware Implementation

This project was built with inexpensive and commonly available electronic elements.

1) Arduino UNO

Arduino UNO serves as the main controller for transmitter and receiver components. It is built with an ATmega328P microcontroller that provides the necessary digital and analog I/O pins for interfacing with sensors and performing signal processing.

The transmitter Arduino is responsible for:

- Reading Input text
- Performing binary conversion
- Modulating the output as LED

The receiver Arduino performs:

- Reading data from LDR sensor
- Performing threshold comparison
- Reconstructing binary data
- Generating output to LCD

2) The Optical Transmitter

An LED is used for optical transmission. The LED is connected to PWM digital pin 9 of the Arduino transmitter. The LED transmits data by varying its brightness.

Transmission logic is as follows:

- Binary 1 = LED HIGH brightness
- Binary 0 = LED LOW brightness or OFF

The rate of brightness change is controlled by a delay in the Arduino code. LEDs are suitable components for optical communication systems due to their fast switching capabilities.

3) LDR Sensor Receiver

An LM393 LDR sensor module is used for optical reception. The sensor detects incident light and converts it to an analog voltage.

Connection for the sensor are as follows:

- VCC → 5V
- GND → Ground
- AO → Arduino A0

The output of the sensor is read in a continuous manner.

If the sensor value is greater than a specified threshold the state is set to:

$$Light > Threshold = 1$$

Otherwise, the state is set to:

$$Light < Threshold = 0$$

4) LCD Display Module

To display the received text data, a 16x2 LCD is used with an I2C module.

Connections for I2C are:

- SDA → A4
- SCL → A5
- VCC → 5V
- GND → Ground

The LCD display enhances the system's usability by allowing the user to view the messages that have been received in real time.

C. Software Development

The proposed Li-Fi system utilizes visible light for data transmission. An input text is converted to binary data through an Arduino transmitter and sent through LED modulation. The LED changes its light intensity rapidly to represent binary values, with binary '1' as high intensity (high light) and binary '0' as low intensity (low or no light).

The LDR sensor in the receiver section is used to sense the changes of light intensity. The light intensity variations are translated to the raw binary data by the Arduino receiver, and the output is displayed as the readable data. The output is shown by the LCD module.

The system can achieve short-range wireless communication without any form of radio frequency transmission.

D. Experimental Setup

The experimental setup was built on a breadboard using an Arduino UNO, LED, LM393 LDR sensor module and 16x2 LCD display.

The transmitter and receiver were positioned at a short distance with direct alignment of LED and sensor. The experiment was performed in an enclosed room with low ambient light to avoid signal interference.

The LED modulated the text messages, and the text was shown on the LCD display after reception.

E. Performance Evaluation

Performance of the suggested system was assessed by the successful reception of messages, the distance of communication, and the stability of the received messages.

From the experiment, the system was able to effectively operate over a distance of between 5 and 10 cm. Communication was less reliable at these ranges and when the ambient light was strong.

F. System Workflow

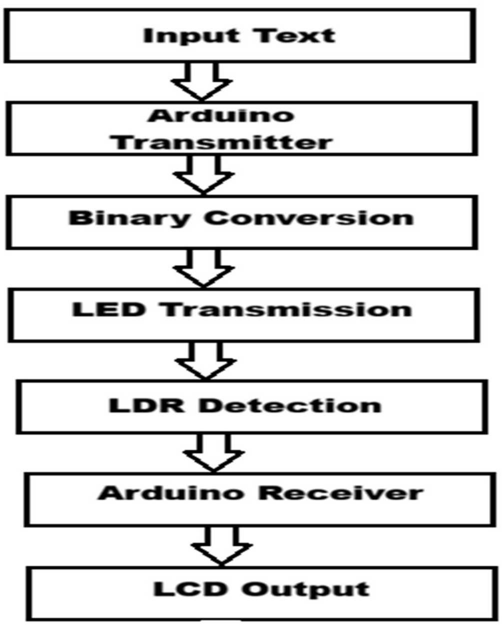

Fig.1: System Workflow

III. Circuit Diagram

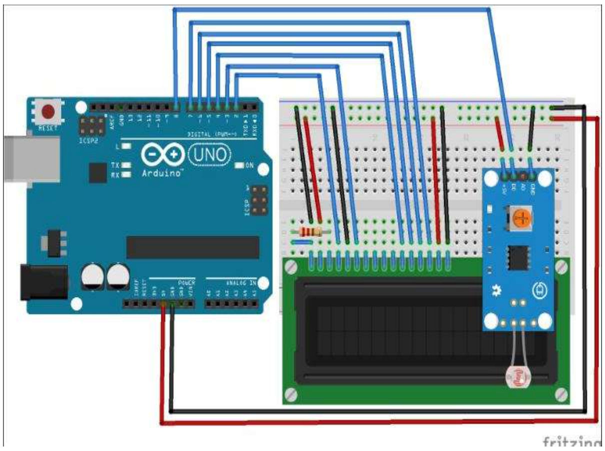

Fig.2:Circuit Diagram

The circuit diagram of the Li-Fi system has two main parts: the transmitter and the receiver. The transmitter part uses an LED that is connected to the pin 9 of the Arduino UNO. This LED is used to send data through light.In the part we use the LM393 LDR sensor module. This module is connected to the analog pin A0 of the Arduino UNO. It helps us detect how bright or dim the light is. We also have a 16x2 LCD display, with an I2C module. This display is connected using the SDA and SCL pins. It shows us what we received. The whole circuit lets us talk to each other without using any wires. It uses light that we can see to send the messages. The Li-Fi system uses light to send information from the transmitter to the receiver.

IV. Result

The Li-Fi communication system that we made was a success. We used Arduino UNO and other things like LED LM393 LDR sensor module and 16x2 LCD display to make it work. When we tested it the part that sends information changed the text into binary code. Sent it through the LED light. The part that receives the information used the LDR sensor to detect the light signals. Then used Arduino to turn them back into the original text. The text that was received was shown correctly on the LCD module, which means that the wireless communication using light worked.

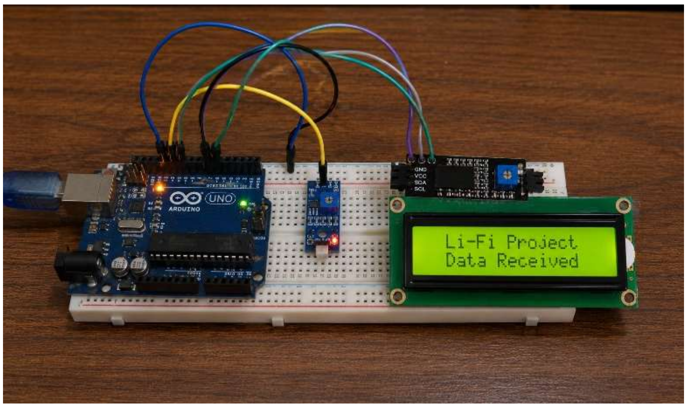

Fig 3:Result

We tried the system. It worked well when it was close like between 5 cm and 10 cm away and when everything was lined up properly. It worked really inside where the light was not too bright and the signal was strong and accurate.. When we moved it farther away or shone bright lights on it like sunlight the signal was not as good because the sensor got confused. With these problems the system we made still worked well and showed that Li-Fi can be a good way to send information using light. The results we got show that Li-Fi is a choice, for short-range communication inside because it is cheap secure and does not use a lot of energy.

V. CONCLUSION

This paper is about the design and implementation of a low cost LiFi communication system using Arduino UNO, LED LM393 LDR sensor module and 16x2 LCD display. The system we developed can do text communication through visible light. It uses LED modulation to send information and an LDR sensor to receive it. The transmitter module takes input text data. Turns it into binary format. Then it sends this data through the LED light by changing its intensity fast. The receiver module detects these changes in light turns the data back into its form and shows the message on the LCD screen.

We tested the system. It works well for short distances like between 5 cm and 10 cm when the transmitter and receiver are properly aligned.. We noticed that the quality of the communication is affected by how much light is around how far the transmitter and receiver are and if there is a clear line of sight between them. If there are light sources around they can interfere with the signal and make it less stable. With these limitations our Li-Fi system shows that visible light can be used for communication. It has some advantages over radio frequency systems like better security, less interference and it uses less energy.This project also shows that we can make a Li-

Fi system using parts that're not too expensive and are easy to find. This makes it a good option for people who want to demonstrate or develop Li-Fi systems. In the future we can work on making the system send data faster increasing the distance it can communicate over and using parts to detect the signal. We can also add features like sending data from mobile devices encrypting the data and connecting it to the internet.

In conclusion the Li-Fi communication system we made shows that visible light can be used for communication over short distances indoors. It is a technology for the future of optical communication systems and Li-Fi can be a good alternative to traditional wireless communication methods.

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