

Transfer Data from PC to PC Based on Li-Fi Communication Using Arduino

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Abstract— Light Fidelity (Li-Fi) is a new technology that has been developed in the last few years and still needs more investigation and experiments to prove its perfection to be an alternative solution for wireless fidelity (Wi-Fi) technology. Li-Fi utilizes light as a medium of communication instead of traditional radio frequencies as in Wi-Fi. Li-Fi technology has the essential features compared to Wi-Fi, such as its ideal for high-density wireless data coverage in a confined area and reducing radio interferences issues. In this paper, a PC-to-PC wireless data transfer system is proposed based on Li-Fi technology. Data is transmitted from transmitter Pc via the light of an array of high-power white LEDs connected to Arduino UNO. The data is then received on the PC receiver using a photodiode, connected to another Arduino UNO device, to sense the light and decode it to its original format. This work aims to improve the transmission and reception mechanism by increasing the data bit rate. After experimenting, the evaluation results showed that the data bit rate was improved using the proposed transmission mechanism and reached up to 147 bps with an accuracy of 100%, over 20 cm as a distance between the transmitter and receiver.

Keywords— Li-Fi; VLC; Arduino; LED; photodiode sensor.

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I. INTRODUCTION

Nowadays, there is massive growth in the request for wireless data communication. Wireless communication utilizing the radio frequency spectrum is the most common. A wireless network is one of the essential activities to transfer data from one device to another. When multiple devices are connected over the internet, thus wireless networks will be much slower. Because of the increasing number of devices that access the internet and fixed bandwidth availability, it is not easy to transfer high data rates. Radio waves are not more than a small part of the spectrum that is used to transmit data. Using light fidelity (Li-Fi) is a solution to this problem: a fast and cheap wireless communication system [1].

At the TED Global conference in Edinburgh on 12th July 2011, Professor Harald Hass, the chair of Mobile Communications, demonstrates the capability of using light waves of Light Emitting Diodes (LED's) for data transmission, and he proves that through his experiment, so he enables from sending a video of blooming flower via a light of LED bulb of a table lamp. Meanwhile, the light of the LED bulb was

blocked from time to time to prove that the blub was the video data source [2], [3].

Li-Fi technology infrastructure is based on a light source, which is already available anywhere and the light source can be used for illumination and communication concurrently. The studies on using LED in the application point are environmentally friendly and absorb harmful radiation. They have a quick switching speed [4] and require low power [5], which makes them flick more quickly so that they are undetectable to human eyes.

Besides, Li-Fi has many powerful advantages as compared to radio communication technique [6]:

- The ability to transfer data at high-speed exceeding 10 Mbps.
- Li-Fi could prove to be the future of secure wireless transmission since light waves do not break through the wall.
- The visible light spectrum is 10,000 times wider than the spectrum of radio waves.
- Li-Fi is harmless technology, while a transmission based on radio waves cannot be made in all

environments such as in airplanes, hospitals, and power towers.

Many studies have been developed to examine the Li-Fi technique in a wireless communication system where the data has been transferred between two personal computers through light waves. This research has deeply studied and analyzed the most essential and up-to-date related works in the Li-Fi communication system that pretends to prove the advantage of using light wave as a communication medium instead of using radio waves for sending data. A wireless data communication system was proposed based on the Li-Fi technique to transmit text data between two PCs using visible light [7]. The transmitter part of this system consists of an Arduino UNO circuit and white LED as the primary source to transmit the data, while the receiver part consists of another Arduino UNO circuit and a Light-dependent resistor (LDR).

Eighteen characters were transmitted over a maximum distance between transmitter and receiver is 6 cm. Li-Fi application was developed based wireless communication system using light where the transmitter section consists of an array of LEDs. The receiver section consists of an array of PNP diode (BPW34) connected to Arduino UNO. The current effective data transmission speed is 100 bits/sec. A bidirectional Li-Fi data communication system was implemented to transmit a data file between two PCs via light waves [9]. This system consists of a transmitter section and a receiver section. The transmitter section comprises connecting LED to the Arduino UNO board connected to the transmitter PC. While at the receiver section, an LDR sensor is connected to the Arduino UNO board, which is connected to the receiver PC. The data is encoded in the transmitter section and sent through the light of the LED. This light is detected at the receiver part by the LDR sensor, and the data is decoded back to the original format and displayed via the serial port on the PC screen.

A system was designed to demonstrate Li-Fi technology in audio transmission with a home or office automation system [10]. Thus, the voice is sent through light waves on the transmitter part of this system after converting it to an electrical signal using a microphone. This electrical signal is amplified by the amplifier circuit and fed to LED. The light intensity of the LED is varied based on the intensity of electrical signals; the louder the voice, the glower the LED. At the receiver part of this system, the LDR is utilized to sense the light signal of LED and generates the electrical signal equivalent to it. Finally, this electrical signal is fed to the demodulating circuit and fed to the speaker to generate an audio signal. Using the Li-Fi technique in an audio transmission system, the audio signal was obtained in the form clear, loud, and without any loss. The maximum distance between transmitter and receiver is 2 meters.

Li-Fi technology was utilized to transmit audio signals between two PCs through light [11]. This system consists of a transmitter section and a receiver section. The transmitter section consists of a PC and Li-Fi transmitter circuit with a laser diode and an audio amplifier. The sine wave generated using the MATLAB program at PC is amplified and encoded to send through the laser diodes light. At the receiver part, another PC and receiver Li-Fi circuit consists of a solar panel connected to a low power audio amplifier, which connects to the speaker. The laser beam that is sent from the transmitter

section is fallen on the solar panel. The output signal from the solar panel is amplified and turned into a speaker. The sound generated by the speaker is given to the mike. This audio signal from the mike is used to reconstruct the original transmitted sine wave using a second PC MATLAB program. The maximum distance can receive the sine wave at the receiver section with less distortion is 2 meters.

Moreover, in this paper, a wireless communication system is developed that utilizes a Li-Fi technology to transfer data between two PCs, which achieves a high data transmission rate. While the system performance is tested by changing the distance between transmitter and receiver. The proposed system comprises the transmitter part and receiver part. In each part, there is an Arduino UNO circuit, one connects to the transmitter PC, and the other connects to the receiver PC. Besides, the proposed system utilizes an array of white LEDs as a source to transfer data, and a light detector sensor to sense the light data and convert these data back into the original format.

II. MATERIALS AND METHODS

In this section, we comprehensively discuss the research methodology and overall architecture of the proposed system.

A. Overview of Proposed System Architecture

This study considers the most influential features of existing PC to PC Li-Fi communication system. The features are subject to increase the data transmission rate. The enhanced hardware components and transmission techniques have been suggested and adopted in the proposed system. This study's proposed system consists of transmitter and receiver part, which are listed in Figure 1.

The device definition of Figure 1 are as follows:

- A transmitter PC is a personal computer used to send data through a software-implemented using Arduino IDE.
- Two Arduino UNO boards are connected to a personal computer, transmitter PC, and Receiver PC by using USB cable via USB port. The Arduino UNO board is open-source hardware that is equipped with an ATmega328P microcontroller, 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button [12], [13]. Moreover, an Arduino IDE software is used to write a code in the c-programming language [12] that implements a proposed mechanism to execute a proposed transmission and receiving process.
- An array of high-power white LEDs that are used as a source of light to send data.
- Multi-output voltage conversation is used as an external power supply to provide the Array of LEDs component with 5v.
- The breadboard component is used to connect all system components.
- A photodiode sensor is one of the light detector sensors that is used to sense the light of the LEDs.
- THE receiver PC is another personal computer that is used to receive the transmitted data and display these data on its screen via software that is also implemented using Arduino IDE.

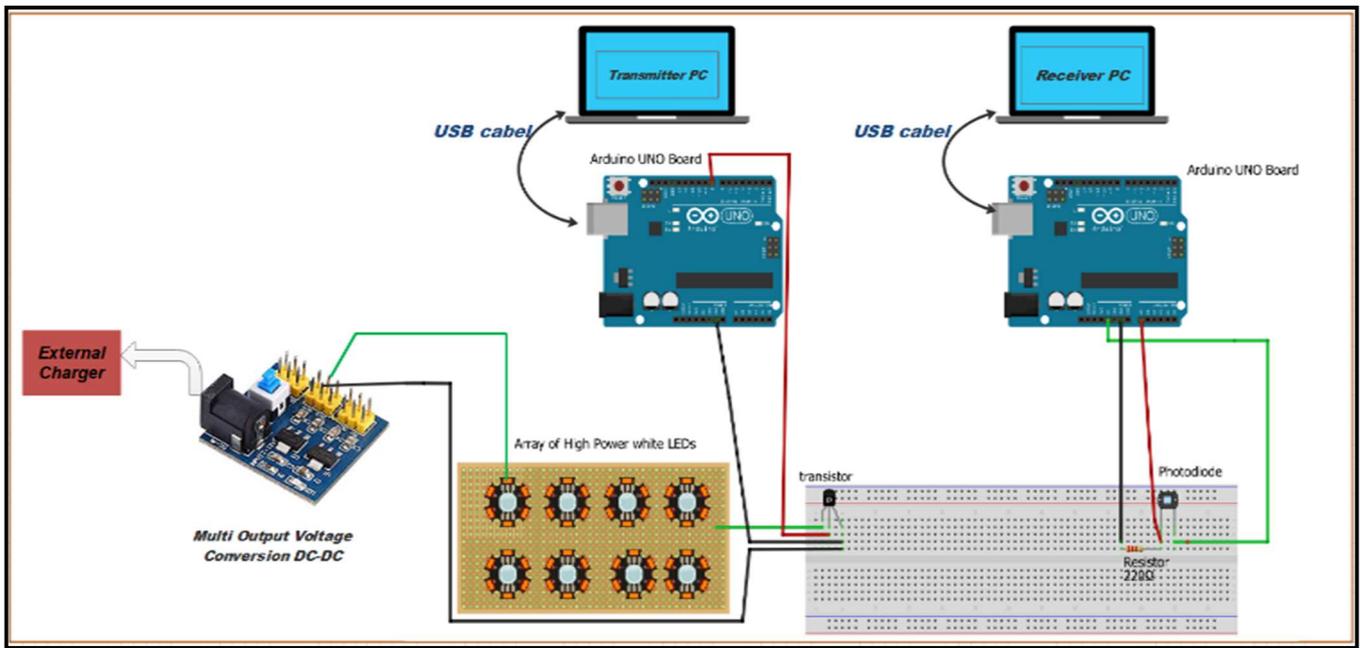


Fig. 1 System architecture overview

Selecting the components of the transmitter and receiver part is the most critical factor in the proposed design. Therefore, we consider the following points while choosing the components of the transmitter part and receiver part:

- The LED is utilized to be a source to send data with high speed for a long distance. Therefore, the brightness and frequency speed of the LED should be considered when selected LED component.
- Also, the light detector sensor is used to sense the light source and interpreted the light waves. Therefore, the most important feature that must be considered while choosing a light sensor is response time. Thus, a Light sensor with a fast response time is required to achieve our system goal, higher data transmission rates.

The following subsection demonstrates the proposed system's mechanism that consists of two phases: the transmission phase, which is responsible for sending data from first PC through a light, and the receiver phase, which is used to receive data and convert it to the original format.

1) Transmission Process:

The main components which are used in the transmitter part of the proposed system are shown in Fig. 2 and listed as follows:

- An array of high-power white LEDs that are used as a source for data transmission.
- Arduino UNO that is connected to the transmitter PC using a USB port. An external power supply that provides additional power to the transmitter circuit.

To increase the data transmission rate that associates with the existing PC to PC data transmission system based on Li-Fi, the enhanced hardware model and new suggested transmission method are adopted to construct the proposed transmission phase to be able to increase data rate as well as to solve the issue that is occurred with data encoding.

As mention above, the LED component with high brightness and switching at high speed is preferable to

transmit data quickly and reliably under ambient light and across more considerable distances. Thus, after many tests, we conclude that using the Surface Mounted Devices (SMD) LED is the most suitable LED for our proposed system. It is a special type of high-power LED that provides high brightness, long operation life, and more efficient energy utilization than incandescent and most halogen lamps [14]. After many tests, the LED level's brightness will increase if more than one SMD LED is connected to the Arduino. Therefore, as shown in Fig. 2, an array of 8 SMD LEDs is connected to Arduino UNO, to achieve the proposed system's goal, increasing the data transmission rate and sending data across a long distance. Also, an external power supply is used to provide additional power to the transmitter part. Therefore, it is ensured that an array of 8 SMD LEDs are receiving enough current to illuminate brightly and transfer data for long-distance.

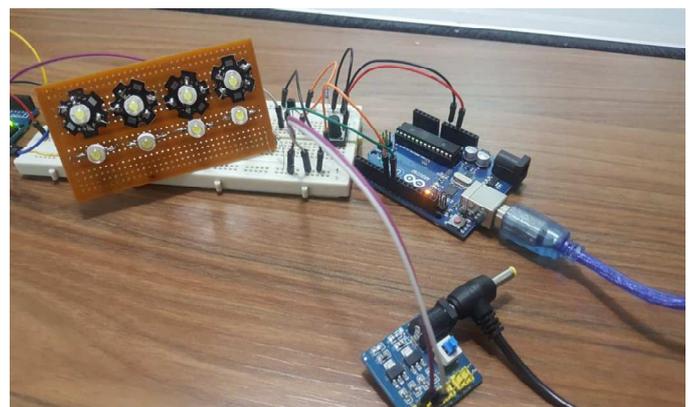


Fig. 2 Transmission phase components

At the transmitter PC, the data is converted to binary format and encoding according to the On-Off Keying (OOK) non return to zero (NRZ) modulation scheme so that when the bit is "0," each LED in the array of SMD LEDs will be turned off and when the bit is "1" each LED will be turned on. However,

the practical experiments we made on data encoding using OOK NRZ prove a lack of synchronization between the transmitted signal and the received signal. Therefore, to solve this drawback, the new transmission technique is adopted here, so that the binary data is segmented into packets, as shown in Fig. 3, where each packet consists of 8 bits, and these packets

are transmitted sequentially, for this reason, there is a small-time (3 ms) between the beams.

At the beginning of transmitting each packet, an initial bit is sent, which is bit 1, to notify the receiver that the packet's transmission process will begin. After completing a packet transmission, a stop bit (32-bits of 0) is sent to notify the receiver part that data transmission is finished.

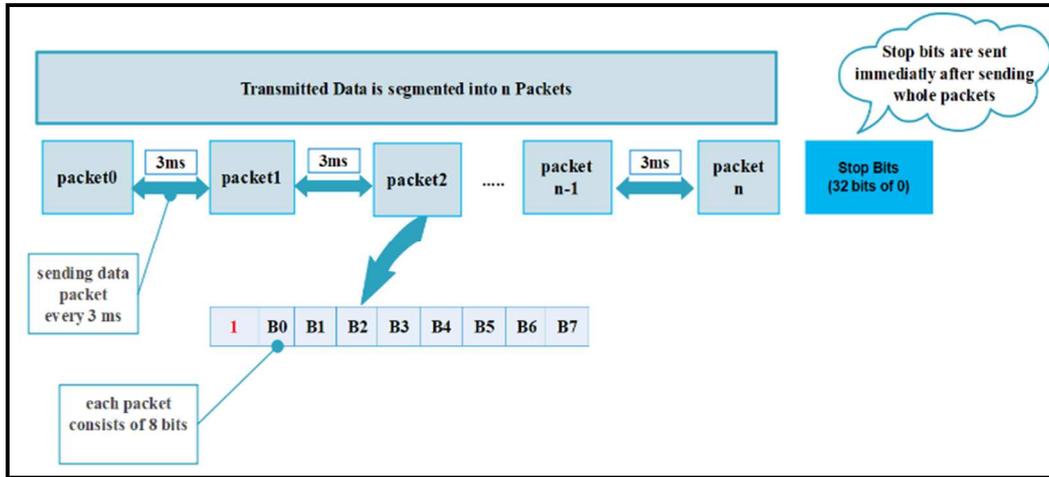


Fig. 3 Segmentation of data into packets

Algorithm 1 describes the proposed transmission phase mechanism:

Algorithm 1. Transmission phase

- 1- Start
- 2- Reading a user input in string format.
- 3- Convert string to its respective ASCII code.
- 4- Convert ASCII code into binary data.
- 5- Store binary data into an array (binary data []).
- 6- Set counter (i=0) that counts the total number of binary bits
- 7- set counter (j=0) that counts some bits per packet.
- 8- Start sending an initial bit by turning on LEDs.
- 9- If $i > \text{length of array binary array}$, then
 go to step 14
 Else
 if item in binary_array [i] == 0 then
 turn off LEDs
 else
 turn on LEDs
- 10- Delay for 7 ms
- 11- increase two counters i and j
- 12- If $j \geq 8$ then
 delay for 3ms for preparing to send next packet
 set counter j=0
 turn on LEDs
 Else
 go to step 9
- 13- Turn off leds
- 14- End

2) Receiver Process:

This phase is implemented on the receiver part of the proposed system. Figure 4 shows the components that are used in this phase, and they are listed as follows:

- A receiver PC is used to receive the transmitted data and display it.
- Another Arduino UNO circuit is connected to the receiver PC via USB port.

- Light detector sensor, which is a BPV10NF photodiode sensor that is connected to the Arduino.

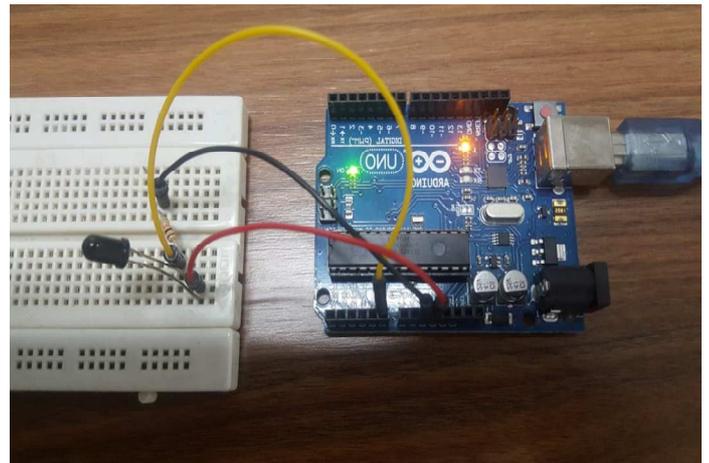


Fig. 4 Receiver phase components

As mention previously, the essential factor that is taken into consideration when selecting a photodiode is response time. Thus, to meet the proposed system requirements, photodiode must detect the light of LED fast enough so that the proposed system can support a fast data transmission rate. After many tests that are performed to select an appropriate photodiode, it is concluded that a photodiode with a response time of fewer than 10 ns is desirable as a shorter response time, which means that photodiode can react faster to each bit that is sent. The BPV10NF photodiode turned out to be most suitable for the proposed receiver part for its response time is equal to 2.5 ns [15], which is less than 10 ns. The following steps explain the proposed receiving process for this phase:

- The data reported by BPV10NF photodiode is compared with a threshold value to identify whether this data represents bit 1 or 0.
- The received bits are decoded back from binary format to corresponding ASCII code, and then, it is displayed on the PC's screen.

Algorithm 2 illustrated the proposed receiver phase mechanism:

Algorithm2. Receiver phase

1. Start
2. Set counter ($i=0$) that counts a total number of binary bits.
3. Set counter ($j=0$) that counts many bits per packet.
4. Set counter ($z=0$) that counts several stop bits.
5. Define array (binary_array) to store binary data
6. Set lux variable =0
7. Read data that is reported by photodiode sensor and stores it in lux variable
8. If $lux > threshold$, then
 Store 1 in binary_array [i]
 Set counter $z =0$
 go to step 9
 else
 increase counter z by one
 if counter $z \geq 32$ the
 go to step 12
 else
 store 1 in binary_array [i]
9. Delay for 7 Ms
10. Increase both counters i and j by one.
11. If $j \geq 8$ then
 the delay for 3ms for preparing to receive the next packet
 set counter $j=0$
 go to step 7
 else
 go to step 7
12. Convert items of binary array to their respective ASCII codes.
13. Convert ASCII codes to their respective string value.
14. Display string value on the serial monitor.
15. End.

III. RESULTS AND DISCUSSION

This section will explain the results obtained from the experiment with the proposed system, and these results will be discussed deeply.

A. System Results

To implement the proposed transmission phase, (Tx-application) is developed to transmit text data via light on the transmitter part and implement the proposed receiver phase; (Rx-application) is developed on the receiver part to receive the transmitted data. Both applications are developed using Arduino IDE, an open-source Arduino software that makes it easy to write code and upload it to the Arduino board.

The proposed system is experienced to transmit text data from the transmitter part to the receiver part. To test the performance of the proposed system, the following

experiment is conducted. Thus, in this experiment, the execution of proposed applications is repeated 10 times to test transmission accuracy. Besides, the system's performance has been tested under the effect of varying the distance between the transmitter part and the receiver part.

PC to PC communication system experiment is executed based on Li-Fi technology as shown in Fig. 5.

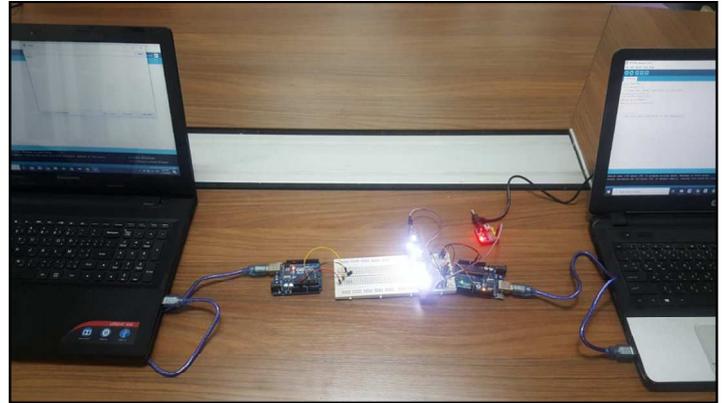


Fig. 5 Proposed communication system experiment

This experiment is set up as shown in Fig. 5, where a transmitter part is represented by connecting an array of 8 SMD LEDs to pin (D8) on the Arduino UNO circuit, which connects to the transmitter PC via USB cable. The receiver part is represented by connecting a photodiode light detector sensor to pin (A0) on the Arduino UNO circuit connected to the receiver PC using a USB cable.

As indicated in the proposed transmission phase, the text data is converted into binary data divided into packets in the sending PC. The modulation scheme used in this proposed system is OOK NRZ, where the SMD LEDs matrix is turned ON/OFF on binary data so that if the binary bit is 1 all LEDs are turned on and if the bit is 0 they are turned off.

At the PC receiver, the photodiode light sensor detects the incoming light from the array of LEDs and senses the exposed intensity of light. At the PC Receiver, there is (Rx-application) that reads the intensity of light and compares it with a threshold, so that if the intensity value is greater than a threshold, it means the receiver PC receives bit 1; otherwise, it receives bit 0. Thus, in this way, the received data is decoded to its original format and displayed on the receiver PC screen via serial port, as shown in Fig. 6.

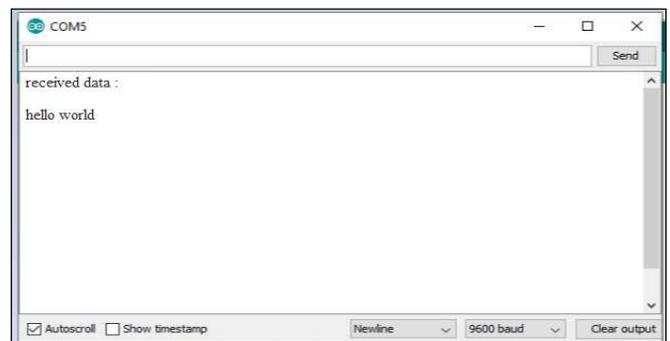


Fig. 6 Serial monitor displays received data.

After repeating the execution of this experiment 10 times, it obtained the following result:

- The data bit rate is reached up to 147 bps with an accuracy of 100%.
- The distance between the transmitter part and the receiver part is 20 cm.

B. Discussion

This paper developed a data transmission system between two PCs based on Li-Fi technology that utilizes two Arduino UNO boards, one at the transmitter part and another at the receiver part. An array of 8 white SMD LEDs, which are utilized as a source to send data via light, and using a photodiode light detector sensor with a fast response time to sense the incoming light of that array of LED and convert the data back to its original format. Thus, to describe and illustrate the performance result obtained from an experiment performed on the proposed system, the following results are used to evaluate the proposed system's ability to transfer data at a rate up to 147bps.

The OOK NRZ modulation scheme analysis shows an absence of synchronization between the transmitted signal and received signal; thus, to solve this issue, it is proposed to transmit the data informs packets, where there is a time interval between each packet. This period is used to synchronize the transmitter part with a receiver part and notify the receiver to be ready for the next packet.

From the proposed system, it was recognized that although the photodiode detector sensor has a rapid response time of 2.5 ns [15], we could not reach a higher data rate because of the Arduino UNO board clock speed of 16MHz that leads to reduce data transmission [12], [8].

After the experiment was conducted under different distances between the transmitter and receiver part, the results demonstrate that varying distances up to 20cm do not affect the data transmission rate. However, if the distance increased, interference occurs between the light of the array of 8 SMD LEDs and light of other sources in the room, which leads to the data transmission with noise.

For the evaluation process, a comparison, shown in the following table, is made between existing related works and the proposed system.

TABLE I
COMPARISON BETWEEN PROPOSED SYSTEM AND RELATED SYSTEMS

PC to PC Li-Fi communication systems	The light source at the transmitter part	Light detector sensor	Bit rate	Distance
[7]	Single LED	LDR	18 character	6 cm
[8]	Single LED	An array of BPW34 diode	100 bps	1 meter
[9]	Single LED	LDR	-	-
[10]	Single LED	LDR	-	2 meters
[11]	Laser diode	Solar panel	-	2 meters
Proposed system	An array of 8 SMD LEDs	Photodiode BPV10NF sensor	147 bps	20 cm

The symbol (-), shown in the above table, refers to the related studies that did not mention either bit rate or distance.

IV. CONCLUSION

This research performed a precise analysis and identified the most Li-Fi features compared to Wi-Fi to implement a wireless system capable of transmitting text data between two computers using Li-Fi technology, which achieves a high data rate (up to 147 bps). This research also mentioned the drawbacks that prevent us from achieving a data transfer rate above 147 bps. Some improvements can then be considered in the additional research to increase the data transmission rate with the expected use of Li-Fi technology. These are given as follows:

- It would be useful to investigate the use of a pulse width modulation (PWM) scheme in place of the OOK NRZ for coding the transmitted data.
- As mentioned earlier, the Arduino UNO board clock speed prevents us from getting a higher data throughput. Therefore, it can be investigated using other high-speed integrated circuits around the clock and efficient processors to overcome this challenge.

The proposed system has accomplished the transfer of text data between two computers, but transferring large multimedia files like (images and video) is still the main point of our concern.

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