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Data Transmission Using Li-Fi Technique

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Abstract- Light fidelity (Li-Fi) technology is a wireless communication system that utilizes visible light spectrum to transmit data with high speed and secure manner compared to the traditional Wireless Fidelity (Wi-Fi) architecture. In this paper a smartphone is used in Li-Fi communication system. The aim of this proposed approach is to maximize the bit rate with high accuracy by using the flashlight of built-in smartphone camera as a source to send data and detect the effect of using a built-in smartphone ambient light sensor and external light detector sensors that is connected to Arduino UNO circuit to receive data. Four practical experiments were conducted to discover which light sensor accomplish higher data bit rate and tested the system performance under changing the distance between transmitter and receiver. The evaluation results demonstrated that the data bit rate is better with the proposed research than the others, where it reached more than 100 bps with accuracy 100%.

Keywords- Android, Arduino, Li-Fi, Light Sensor, Smartphone.

I. INTRODUCTION

Li-Fi is a wireless communication technology that uses visible light to send data at high speed between devices. In the most recent years, the studies on Visible Light Communication (VLC) are conducted to overcome the radio spectrum congestion. The process behind Li-Fi is to transfer data at high speed using light waves from any light source even the ordinary light table. Li-Fi can be considered as an optical version of Wi- Fi, so that instead of using radio waves to transfer the data it uses visible light .

Professor Harald Hass, the chair of Mobile Communications at the University of Edinburgh, institute Li-Fi; demonstrated a Li-Fi prototype at the TED Global conference in Edinburgh on 12th July 2011. He illustrated the ability of using Light Emitting Diodes (LED's) for data transmission . In his experiment, a LED bulb of table lamp was used to send a blooming flower video which was displayed on a screen. In the meanwhile, the light of LED bulb was blocked from time to time with his hand to prove that the blub was the source of the video data .

In real sense, a smartphone can be defined as a mobile phone with advanced features and functionality beyond traditional functionalities like making phone calls and sending text messages. The smartphone is equipped with advance hardware, such as sensors (environment sensors, position sensors, and motion sensors), built-in camera, wireless internet connection, and more powerful software that are used to play videos, display photo, email, weather application, and much more .
In this research, data wireless communication based on Li-Fi technique is investigated, where a transmitter is smartphone that send data using built-in flash of camera. Moreover, at the receiver, it takes advantage of existence of smartphone built-in ambient light sensor, which motivate us to examine a smartphone to smartphone communication system based on Li-Fi. In addition, the effect of connecting external light detector sensor to Arduino circuit instead of using built-in smartphone ambient light sensor on data rate.

Li-Fi Technology
Li-Fi technology mechanism is bidirectional communication that utilize a visible light to transmit data. The infrastructure of such technology is already available where the light source can be used for lighting and communication concurrently. Li-Fi can be consider as an optical version of Wi-Fi, so that instead of using radio waves to transfer data it uses visible light [5]. Table 1 illustrates a comparison of speed transmission for several wireless technologies [6].

Table 1: Comparison of Speed for Different Wireless Technologies

Technology	Speed
Li-Fi	~1 Gbps
Wi-Fi – IEEE 802.11n	~150 Mbps
IrDA	~4 Mbps
Bluetooth	~3 Mbps
NFC	~424 Kbps

In order to prove the truth of Li-Fi, a comparison must be made to know the fundamental difference between Wi-Fi and Li-Fi technologies. Therefore, according to the studies that made in [5]. Li-Fi has many great features such as it can achieve high data rates as compared to Wi-Fi technology. In addition, the Li-Fi consume less power, more efficient, and word world availability of light source, while Radio waves cannot be used in all environments, particularly in airplanes, chemical and power plants, and in hospitals since it causes malfunction or substantial problems to the human and this equipment. No other infrastructure is required when Li-fi technology since light of sources are already installed [5]. Moreover, Li-Fi could prove the future of secure wireless communication since

definitely does not penetrate through walls and thus data transmission using Li- Fi does not lead to hack the network [5].By using the Internet of Things (IoT) technology, there will be an enormous number of devices that will be connected to internet. This causes another issue for the current Wi-Fi networks and might be completely saturated and incapable to accommodate that number of users [5]. This features could solve the four essential problems namely, capacity, cost, efficiency, and security, that a wireless communication is faced these days. Thus for a green, clean and even a safe future many wireless data transmission systems will be deployed utilizing Li-Fi instead of Wi-Fi technology. Table 2 shows a comparison of Li- Fi with Wi-Fi [7].

Table 2. Comparison of Wi-Fi and Li-Fi

Parameters	Li-Fi	Wi-Fi
Transmitter	LED	Antenna
Frequency	band 1000 times of THz	2.4 GHz
Standard	IEEE 802.15.xx	IEEE 802.11xx
No of users All over	Under The Lamp.(LEDs)	Depend on access Point.
Topology	Point to Point	Point to Multipoint
Communication	Based on Visible Light Communication (VLC).	Based on Radio Frequency Communication
Availability	Anywhere, available in Airplanes and Underwater	Limited
Power Consumption	Less	More
Environment Impact	Low	Medium
Cost	Low	High
Bandwidth	Unlimited	Limited

Figure 1 illustrates how Li-Fi technology works. Li-Fi communication system consists of two parts; a transmitter part and receiver part. The transmitter part, is represented by LED lamp or flash, which is responsible for sending data. By turning LED on/off at very high speeds, the LED can send out high bandwidth wireless data. The switch on/off enables data transmission in binary format, turns LED on represents binary '1' and turns LED off represents binary '0'. Data is converted into pulses of light and directed to the receiver part. The receiver part consists of photo detector sensor (or known as a light sensor) that is used to senses the change in light intensity. This light signal is then converted into data original format [8].

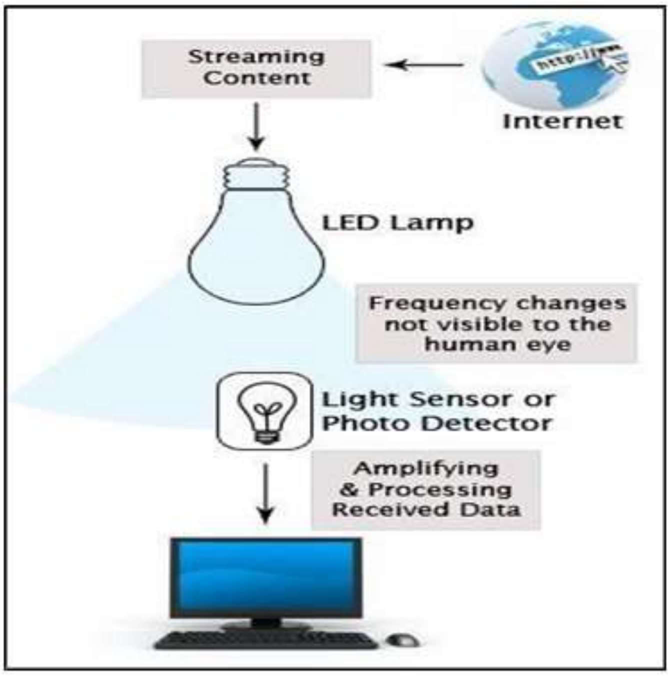

Figure1. Li-Fi working [8]

II. RELATED WORK

In the past few years, there has been a large amount of research tried with Li-Fi technology, and taking advantage of its many features to become an alternative transmission medium for wireless data transmission. In this section, experiences with the smartphone-based VLC communication system will be briefly discussed and analyzed. It may support us enhance the limitations of previous research and problem solving.

In [9], the authors developed a system for sending data between two smartphones based on VLC technique. This system consists of transmitter and receiver part. In the transmitter part, the flashlight of built-in smartphone camera is used to send binary data, by turning flash on/off, on if the binary data is 1 and off for 0, according to On-Off Keying (OOK) modulation scheme. In the receiver part, there is an ambient light sensor, which built- in smartphone sensor used to discover the flickering of flash (on/off). This system achieved a low data bit rate about 9 bps and the maximum distance between the transmitter and receiver was 15 cm.

In [10], the authors proposed a method to enable bidirectional VLC communication between smartphone and tabletops. In smartphone to tabletop stage, they utilize a flash of built-in smartphone camera to transmit data optically to the camera of tabletop. The authors developed an android application, which is used to turn the flash on/off to transmit data. The pulse width modulation (PWM) is utilized to encode binary data, 0 and 1, using different length of flash pulses. When the authors tested that system a transmission data rate was reached to 20bps. Moreover, to transmit data from tabletop to smartphone, the authors utilized a built-in camera in smartphone, and they implemented a test program on the tabletop that transmits bit sequences at different frequencies. Based on results they conclude that data is transmitted at rates of up to 33 bps.

In [11], the authors implemented a system which transmits the information of credit card that are stored on the smartphone, over a secure visible light link to a simple inexpensive receiver circuit module that is attached to the ATM machine. The authors used an embedded flashlight of smartphone as a transmitter while a receiver part consists of Arduino Mega kit and photodetector sensor, which is Light Dependent Resistor (LDR) that is used to detect light signal. Many experiments are conducted by replacing LDR with photodiode sensor and using PWM scheme instead of OOK to get data bit rate from 4.2 to 15 bps.

In [12], the authors implemented the Li-Fi data transmission system that consists of transmitter circuit and receiver circuit. The transmitter circuit comprised of Arduino UNO and LED where the data is encoded and send via light of LED, while at receiver circuit the photodiode is utilized to sense the incoming light of transmitter circuit and decode the data back to original format. This prototype achieves a speed about 11,520 bps only that is not of a high arrangement of Gbps.

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In [13], the authors developed an application of Li-Fi based wireless communication system using VLC, where the transmitter section consists of array of LEDs that connected to

Arduino UNO circuit, while the receiver section consists of array of PNP diode (BPW34) that are connected to Arduino UNO. Current effective data transmission speed is 100 bits/sec, while the distance between transmitter and receiver does not exceed 1 foot because of the infiltration of ambient light.

III. PROPOSED SYSTEM DESIGN

Proposed System Proposed system consists of two parts; transmitter part and receiver part. The transmitter part contains a light source, which is LED flash of built-in smartphone camera that is used to transmit data. While the receiver part composed of light detector sensor, which is used to detect the light signal and convert it to original data.

Initially, the proposed model investigates how the smartphone built-in light sensor can be utilized to implement smartphone to smartphone communication system based on VLC, then figures out if the data rate achieved by this type of communication is approved by the expected Li-Fi‘s throughput. Later, the external light sensor was examined to demonstrate how to improve the data bit rate.

The next section illustrates the proposed system structure together with each module that construct the overall system architecture as follows:

1. Transmitter Part
Transmitter part based on Li-Fi technique which consists of light source such as LED to transmit data. In this system, flash of built-in smartphone camera is utilized to send data. The data is converted to binary format and encoded according to one of modulation scheme, which is OOK NRZ “non-return-to-zero”. Hence, when the bit is “0” the flash will be turned off and when the bit is “1” the flash will be turned on. Thus, by turning

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The data is converted to binary format and encoded according to one of modulation scheme, which is OOK NRZ “non-return-to-zero”. Hence, when the bit is “0” the flash will be turned off and when the bit is “1” the flash will be turned on. Thus, by turning flash light on and off at a very high speeds enables data to be transferred through light as a medium of communication. The following figure 2 displays the OOK NRZ mechanism.

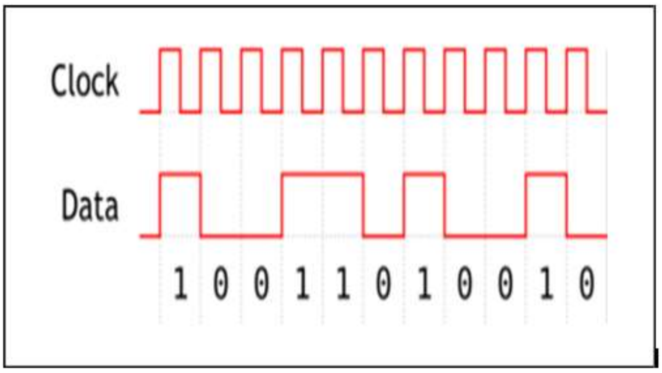

Figure 2. OOK Scheme [9]

The transmitter read a data that is received from the user and it converts data into binary then transmits it after the flash light turn on by using OOK ‟ if the binary code is „1‟ and „off‟ for „0‟.

The proposed transmission process is illustrated as follows:

- After convert the data to binary format, it will be sent it inform of packets where each packet consists of 8 bit as shown in figure 3.
- As illustrated in figure 3, at the beginning of transmit each packet, an initial bit is sent, which is bit 1, to inform the receiver that the transmission process of this packet will be start.

Coherently the packets of data are sent, and there is a 3. small time interval, which is equal to half of delay sensor response time, between one packet and another.

After sending whole packets, stop bits will be sent, which are 32 bits of 0, to inform the receiver part that the data transmission is completed.

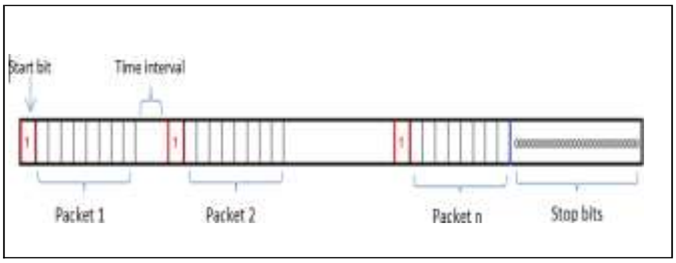

Figure 3. Proposed Process of Segmentation Data to the Packets

The flowchart that describes the flow procedure of proposed transmission process is shown in figure 4.

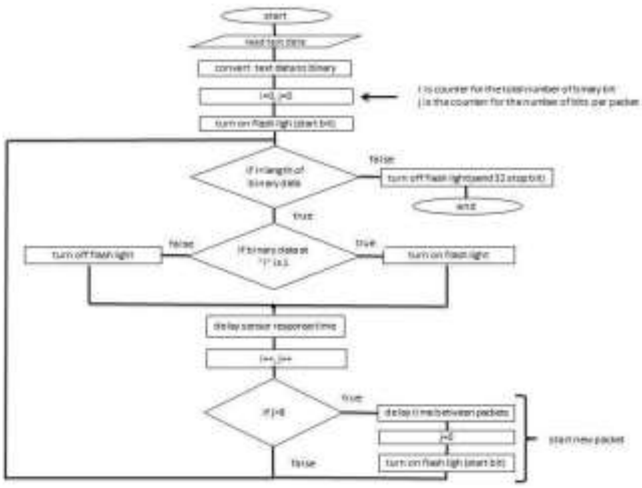

Figure 4. Proposed Transmission Process

2. Receiver Part

The receiver part comprises of light sensor to easily detect the light of smartphone's flash. In this proposed part, the following light detector sensors are experienced:

Using an external light detector sensor, like Light Dependent Resistor (LDR), BH1750, and phototransistor 3DU33 to sense the flashlight of the transmitter part. In the proposed system, light detector sensor is connected to Arduino UNO circuit, where this circuit is connected to computer via USB port. Arduino UNO is an open source hardware that is equipped with 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 [15].

The proposed receiving process is demonstrated as follows:

- The data reported by light detector sensor is compared with predefined threshold value, which is 500 lux (set by experiment), to identify whether this data represents bit 1 or 0.
- The received bits are decoded back to original format and displayed at the receiver part on computer screen
- .Figure 6 designates the flowchart of the proposed receiving process.

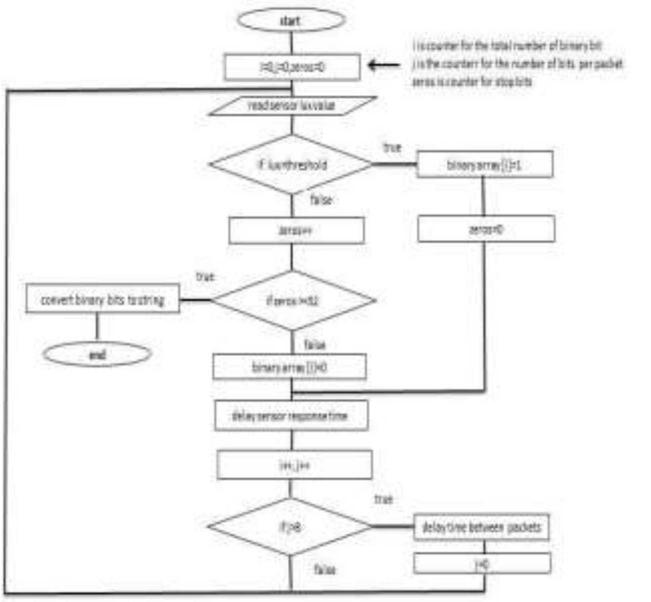

Figure 5. Flowchart of Receiver Scenario

It is an important to mention that a light detector sensor has a response time which effects on the data bit rate, as will be explained in section 5.

Experimental Results

Rx-application is implemented using an Arduino software IDE, which is uploaded to Arduino board and executed by microcontroller in Arduino UNO board. Rx- application uses a built-in Arduino function to read a values reported by external light detector sensor. The proposed system is

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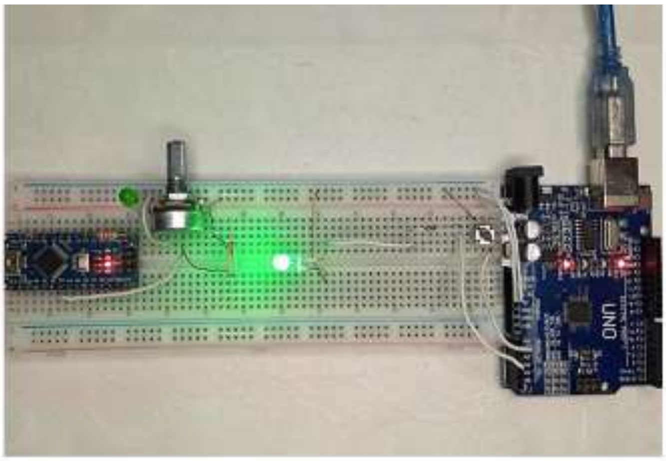
experienced to send actual data as a text, from transmitter part to receiver part. To test the performance of the proposed system, the following experiments are conducted. Thus, at each experiment, the execution of proposed applications is repeated for 10 times to test an accuracy of transmission. In addition, performance of the system has been tested under the effect of varying the distance between transmitter part and receiver part

Experiment 2

In this experiment smartphone to Arduino UNO circuit communication system is executed based on VLC as shown in figure



In this experiment, an external light sensor is used, which is called LDR or photo resistor sensor, where is connected to Arduino UNO circuit as illustrated in figure 8. LDR is commonly used to measure the light intensity.

Its resistor is decreased as the intensity of light that LDR is exposed to increase and vice versa.

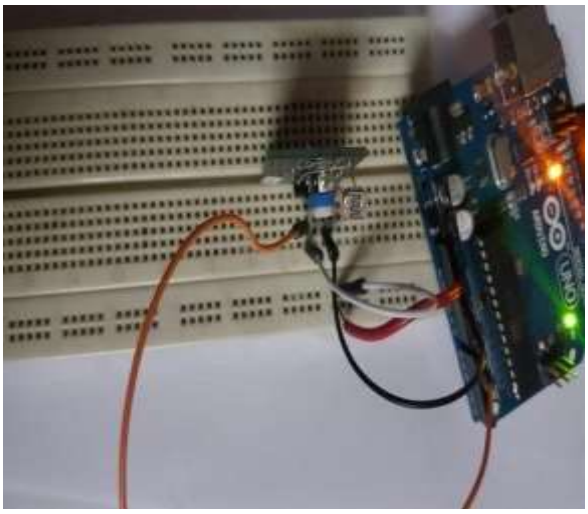


Figure 8. Connect LDR Sensor to Arduino UNO

This experiment is concerned with sending text data using Tx-application to the receiver part of the proposed system, which is represented by connected LDR sensor to the Arduino UNO circuit. The Rx-application at the receiver part is successfully received and display it on computer screen via serial port as shown in figure 9

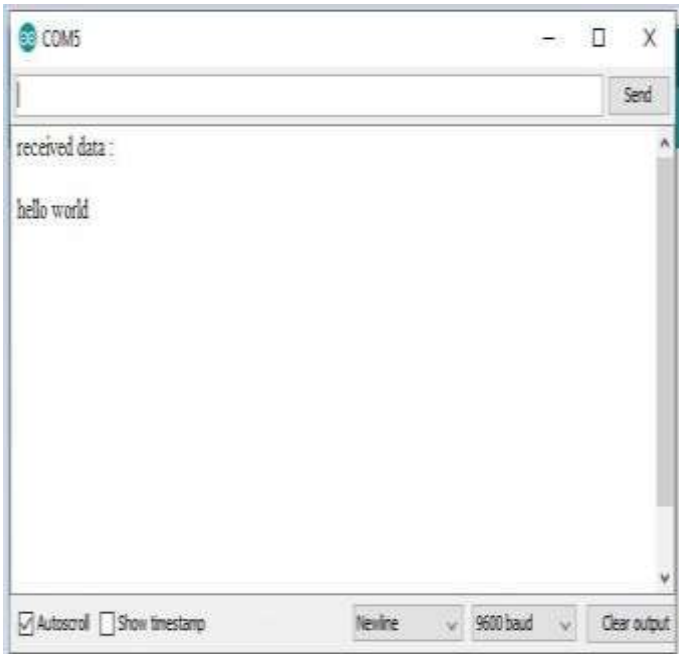


Figure 9. Serial Monitor Displays Received Data

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

- The bit data rate is reached up to 40 bps with an accuracy of 100%.

LDR sensor has a slow response time [11] [16], which makes it unsuitable for VLC data transmission application.

Discussion

In this paper, we deployed a communication system based on Li-Fi technology that utilizes a flash of smartphone camera at transmitter part to send data, while using light detector sensor to sense the intensity of flashlight at the receiver part.

Through the survey and development of the proposed system, number of facts are perceived and noticed:

The analysis of OOK NRZ modulation scheme it shows that there is an absence of synchronization between the transmitted signal and received signal, thus to solve this issue, and as mentioned in section 4.1, we proposed to transmit the data informs of packets, where there is a time interval between each packet. This period of time is used to synch the transmitter part with a receiver part and for notifying the receiver to be ready for the next packet.

By replacing the LDR with much faster light sensor, which is BH1750 leads to increase the data rate to 50 bps, but it still not sufficient, thus in experiment 4 we use phototransistor which has faster response time than BH1750 and data transmission rate we get is up to 100 bps.

Table 3: Summary of Bit Rate and Accuracy About Four Experiments.

Experiments	Sensor type	Bit rate	Accuracy
Experiment 1	LDR	40 bps	100%

It is worth mentioning that each experiment explained above is conducted for several time to figure out the effect of increasing the distance between transmitter part and receiver part on system performance. The result show that the effect of increasing distance up to 30 cm does not effect on the data transmission rate. While the intensity of flashlight begins to fade at distance higher than 30 cm, so that, the light sensor at the receiver part can't able to detect the sent data. Besides that, if the distance is increased, an interference is occurred between light of smartphone's flash and light of other sources in the room, which leads to the data transmission with noise.

V. CONCLUSION

The main purpose of our proposed project is to deploy a communication system based on Li-Fi technology that is capable of transferring data from transmitter part to receiver part. It has been successfully enabled sending text data via using flash of built-in smartphone camera as a media of communication, and receiving it correctly at the receiver part. However, this proposed system achieves 100bps data bit rate even if used the phototransistor, which is faster than LDR and BH1750.

Therefore, there are some enhancements can be taken into account in further research to improve the data bit rate above 100 bps, these are given as follows:

- It will examine replacing OOK modulation scheme PWM.
- It can be experienced using simple circuit in the transmitter part, which consists of Arduino UNO and array of high power LEDs instead of using flashlight of smartphone.
- In order to increase the data bit rate, it can be suggested connecting fast photodiode sensor, its response time in nanoseconds, to Arduino UNO at receiver part and check the data bit rate under this situation

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