LiFi Based Visible Light Communication

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Abstract - *A high speed communication network plays a vital role with the focus on the higher security. Due to this research in the newer communication techniques is becoming the popular area. Among these LiFi a .k. a. Light Fidelity obtained importance specially when the there is demand for short distance and local intranet communication. In LiFi communication, a video processing approach is used to get the data unlike previously, wherein photo detectors were deployed. Also, a new method of modulation using Morse code has been elaborated which results in a faster decoding rate and also lowers the need for a large transmission bandwidth. The method elaborated gives a maximum speed improvement of almost 48 times as opposed to previous state of art technologies.*

***Key Words*: Histogram analysis; LDR; LiFi; Light Fidelity; Manchester coding; Morse code; NRZ-OOK; OOK; Segmentation; Video processing.**

1. INTRODUCTION

In LiFi, the transmission is done with the help of the LED or infrared light which is a two way wireless system. With the help of a light source including a chip is used to transmit the internet signals through light waves. Light from LED televisions, lamps or lamps are used for the connection to the internet. LiFi have major advantages over the wifi, 3G and 4G which an exceptional advancement in the field of the wireless networks. LiFi is a descent communication system which has the ability to transmit the data with the help of infrared spectrums ultraviolet and visible light at high speed. In its present state, the transmission of data in visible light is done with the help of LED lamps. LiFi uses the modulation of light intensity to transmit data. LiFi can theoretically transmit at speeds of up to 100 Gigabit/s. LiFi's ability to safely function in areas otherwise susceptible to electromagnetic interference (*e.g.* aircraft cabins, hospitals, military) is an advantage. It is faster, cheaper, more sustainable, and more reliable. With LiFi, its band frequency of 200,000 GHz, versus the maximum 5 GHz of the wifi, is 100 times faster and can transmit much more information per second.

LiFi was first introduced in 2011 at a TED Global conference by Professor Herald Haas, Chair of Mobile Communications at the University of Edinburgh and co-founder/chief scientist of pure Li-Fi Ltd., the company trying to bring LiFi to the market .Haas says he was inspired to create LiFi because of the spectrum crunch. He said he was working for Siemens on 4G when he realized the RF spectrum wasn't enough for things like multimedia. Since then he developed the world's first. LiFi dongle, and partnered with French lighting manufacturer Lucibel to make the first fully integrated LiFi luminaries, which was shown at this year's Mobile World Congress .LiFi is where Wi-Fi is fifteen years ago, and in five to ten years, LiFi will be as ubiquitous as Wi-Fi is now. It has stressed that LiFi is a supplement to Wi-Fi and 4G/5G, not a replacement.

The prime objective of the project is to create an application that transmits data be it text, audio or video using Li-Fi technology for coping with the limited bandwidth problem face in RF (Radio frequency) signals. For better, client, secure and a faster connection LiFi is used. Quicker Data Transmission than Wi-Fi {an essential selling purpose of LiFi innovation is that it has a quicker information transmission rate than Wi-Fi. Noticeable light range has a transmission capacity that is multiple times bigger than whole radio recurrence and microwave range. Lifi has a range of approximately 100 meters. Inaccessibility of Compatible Technologies- It will take a long time for LiFi to turn out to be more reasonable than Wi-Fi. Current gadgets, for example, PCs, cell phones, and tablet PCs actually use equipment for Wi-Fi organizing.

2. Literature Survey

Sudhir Rao Rupanagudi, *et al.* [1] stated that a high speed communication network plays a vital role with the focus on the higher security. Due to this research in the newer communication techniques is becoming the popular area. Among these LiFi *a .k. a.* Light Fidelity obtained importance specially when the there is demand for short distance and local intranet communication. Sergio Silva *et al.* [2] explained the ability of the Arduino platform to enhance student interest and performance in science, technology, engineering, and mathematics. Many past inventions crave the future, so their understanding is a bridge of knowledge that must be passed to students. Therefore, an increase on IT careers is also expected. The Morse code and the telegraph revolutionized long-distance communication in the past and laid the groundwork for the communications revolution. Singh, Yash Gupta *et al.* [3] proposed a smart user-centric visible light communication (VLC) system for indoor communication application. In the proposed system, the VLC transmitter is incorporated with a barrier detection circuit which automatically detects the barrier between the VLC transmitter and receiver and dynamically changes its spatial location in two dimensions (2D) in order to get good signal-to-noise-ratio (SNR) performance at the receiver.

Clement Lartigue *et al.* [4] explained Visible Light Communications (VLC) use LED base lighting as transmitters. The lighting becomes a beacon to transmit its coordinates and other kind of information at low-transmission rates, typically 1 kbps. This can easily permit the Smartphone's camera to get and decode the message.

Huaping Li *et al.* [5] proposed with the widespread application of LED indoor lighting and the rapid development of visible light communication (VLC) technology, visible light positioning (VLP) technology is becoming a promising solution for indoor positioning systems. Compared with traditional indoor positioning technologies, such as WIFI, infrared (IR), ultrasonic, Bluetooth, and ultra-wideband (UWB), VLP has the advantages of high positioning accuracy and low cost.

3. Conclusion from Literature Survey

From all the above various papers and journals, the conclusion drawn is that LiFi can be implemented and can be used as for data transmissions. Morse code encoding and decoding algorithm can be efficiently used for implementing data transmission using LiFi. Manchester in combination with Morse code can be used to reduce the bandwidth of data that is to be transmitted. Till now LiFi applications are not much implemented and most of its applications have used cameras for transmitting data. Without using camera, LED's can be used for transmission. Even a smallest LED can efficiently transmit a data with a great speed.

4. Proposed Methodology

An overview of set-up is presented in the figure 1.

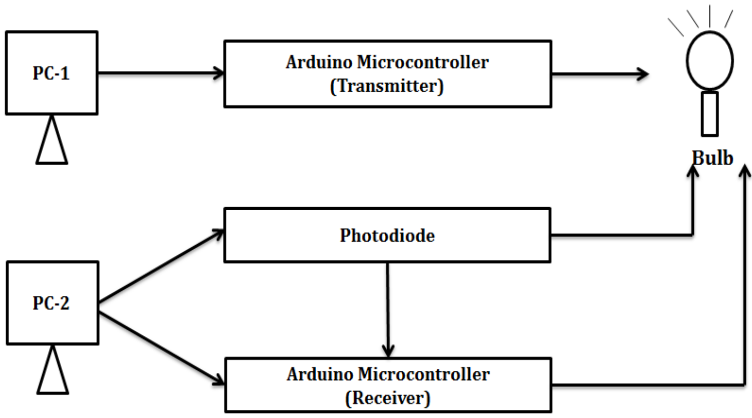

Figure 1: Project Components

In combination with above proposed methodology following algorithm, shown in figure (2) is used throughout project. The algorithm is explained below.

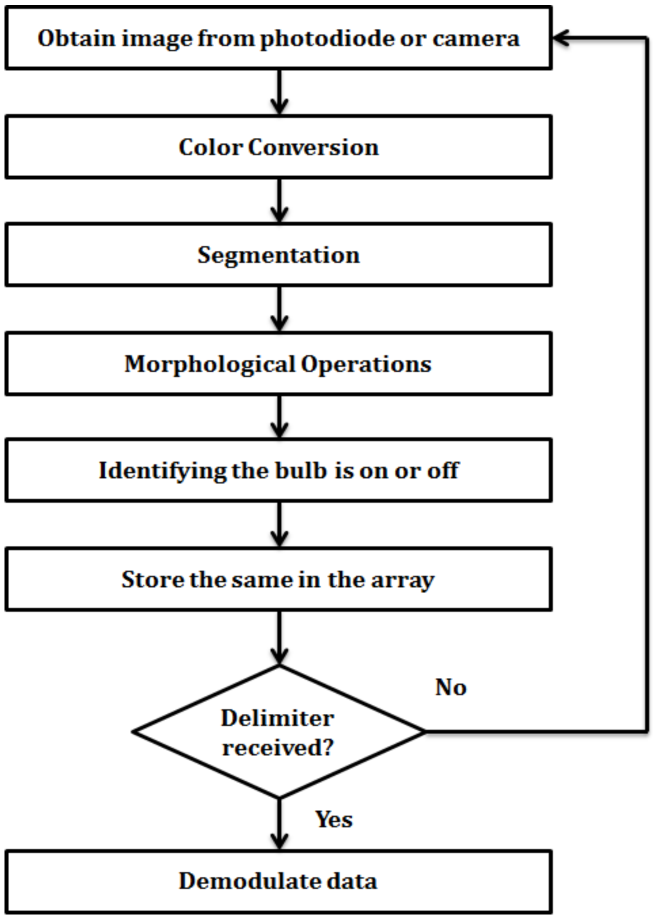

Figure 2: Flow Chart of Algorithm

A. Obtaining Image from photodiode or camera

An image from the photodiode along with its background is obtained and processed further.

B. Color Conversion

Once the image from the camera is obtained, it is made to undergo a process called color conversion. It is a well-known fact that each pixel of a picture is made of a combination of red, green and blue pixels which in a digital image require 24 bits of memory per pixel. By converting the image to a particular color model, not only does it help in highlighting the object of interest but also reduces the memory requirements to a mere 8 bits per pixel. Conversion of the color image to the grayscale color model was performed utilizing following formula

$$Y = (0.299 * R) + (0.587 * G) + (0.114 * B)$$

Where R is the red subpixel, G - the green subpixel and B is the blue subpixel of the pixel of the image.

Once color conversion is complete, the next step is to extract the bulb area from the background of the picture taken.

C. Segmentation

Once color conversion is complete, the process of segmentation is performed. It is the process wherein the background is made black and the object of interest is made white. However, in order to perform the same a threshold value is necessary.

In the case the bulb is off the maximum non-zero value obtained would always be less than 500. Hence, any threshold obtained lesser than 500 will be disregarded and the bulb will be considered off. By default any pixel having an intensity value less than 500 shall also be made black. This whole procedure can be mathematically represented by

$$S_{(x,y)} = \begin{cases} 1, Y_{(x,y)} > (M - \delta), (M - \delta) \geq 200 \\ 0, \text{otherwise} \end{cases}$$

Where S is the segmented image and 'x' and 'y' represent the row and column of the image respectively. Once thresholding is complete and the bulb is made white and the background black, morphological operations are performed to remove the noise and enhance the image. This has been explained in detail next.

D. Morphological Operations

Once the process of segmentation is complete, a part of the background is sometimes erroneously converted to white. In order to rectify the same, a morphological operation known as erosion is performed.

In this process, a structuring element of a particular shape is traversed across the image and the center pixel of the image below the center pixel of the structuring element is checked. In the case the center pixel is white and is surrounded even by a single black pixel (within the radius of the structuring element), the center pixel is made black in a new image. By doing so all stray white pixels are eliminated in the background. This whole process can be mathematically represented by,

$$E = B \Theta S$$

Where, E is the image resulting after erosion B is binary image, and S is structuring element.

The major disadvantage of the erosion process is that even the edges of In the dilation process, the exact opposite of erosion is performed wherein the center pixel below the center pixel of the structuring element is checked to see if it is black and whether it is surrounded by any white pixels. In such a case, the black pixel in the center is converted to white in a new image and in turn the image is enhanced. This process is mathematically represented by,

$$D = E \oplus S$$

Where, D is the image resulting after dilation E is eroded image, and S is structuring element. Once this is complete, the next process would be to identify whether the bulb is on or off.

E. Identifying the status of bulb

Once the image is dilated, it is then verified programmatically for the status of the bulb – in other words whether the bulb is on or off. This is performed by counting the total number of white pixels (Tot_{WP}) in the image.

In case the total number of white pixels are greater than a threshold θ (which is pre-calculated based on experimentation), the bulb is considered to be 'on' and a '1' is stored in an array. Similarly in the case the bulb is found to be 'off', a '0' is stored in the array.

This is represented by,

$$Arr_{(i)} = \begin{cases} 1, Tot_{wp} > \theta \\ 0, \text{otherwise} \end{cases}$$

Where Tot_{wp} is represented by

$$Tot_{wp} = \sum_{x=1}^{X} \sum_{y=1}^{Y} d_{i(\mathrm{x,y})}$$

Where Arr is the array and 'i' is the index of the array. 'x' and 'y' represent the row and column respectively of the pixel under consideration and 'X' and 'Y' are the total number of rows and columns in the dilated image respectively. Once a delimiter character has been obtained, the data is then demodulated and converted to meaningful information. This has been explained next.

F. Demodulation of data

Before describing the actual demodulation of the data, it is better to first understand the modulation technique employed in the transmitter. Modulation can be defined as the process of adding the information to be transmitted with a carrier in order to ensure minimal data loss. In this paper the Non Return to Zero (NRZ) variant of the OOK technique of modulation was utilized where in case a binary '1' is to be transmitted then the light is switched on, else switched off. In order to further lower the error rate of transmission, the data is further encoded using the Manchester coding technique. In this method, a binary '1' is transmitted first as a '1' followed by a '0'. In the case of transmitting a '0', the opposite procedure is followed. Though advantageous it must be noted that since Manchester encoding is adopted, every bit requires 2 bits to be transmitted. This in turn doubles the bandwidth required for data transmission. For example, in the case the letter 'A' is to be transmitted, the letter is first converted to an 8 bit ASCII number (in this case 65) and then transmitted as a 16 bit number due to Manchester encoding. Two extra bits as delimiters are also transmitted making it a total of 20 bits.

5. Experiment and Result Analysis

As explained in above sections, the complete algorithm to identify the light emitted from the bulb, encoding the data transmitted from the sender and the receiver algorithm to decode the data transmitted, were designed and developed using ARDUINO 1.8.8 2020. The set-up of the sender and the receiver Arduino Microcontrollers connected to the single laptop can be seen below Fig.3.

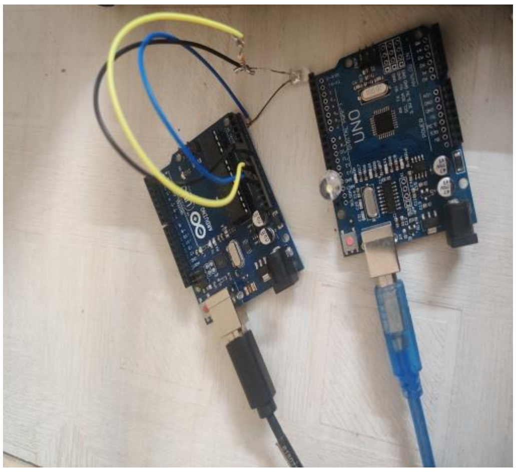

Figure 3: Set-up of Encoder and Decoder Arduino

The image of the Arduino after sending the data to the receiver through bulb on is shown in figure 4.

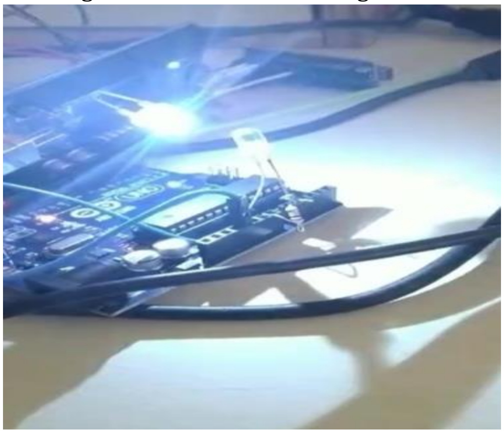

Figure 4: Transmitting data from sender and bulb turn ON.

The image of sender side frame while encoding data after the sender has send it to the receiver is shown in figure 5 below. As soon as the data is been send it is encoded using Morse code Encoding algorithm for security purpose. By default HELLO word is been send repeatedly.

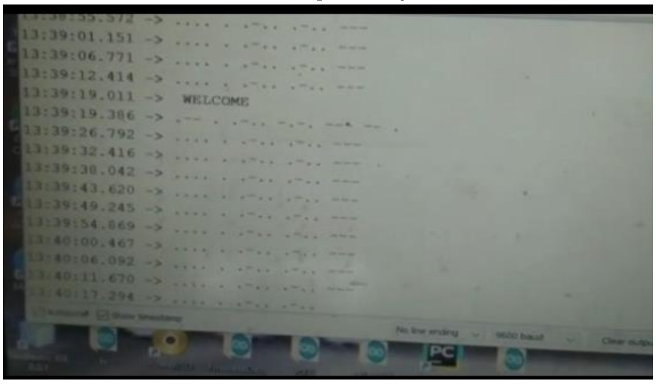

Figure 5. Sender side frame (*i.e.* Morse Encoder)

The image of receiver side frame is shown in figure 6. After receiving data from sender Morse code Decoding algorithm is used to decode the data received from sender in encoded form.

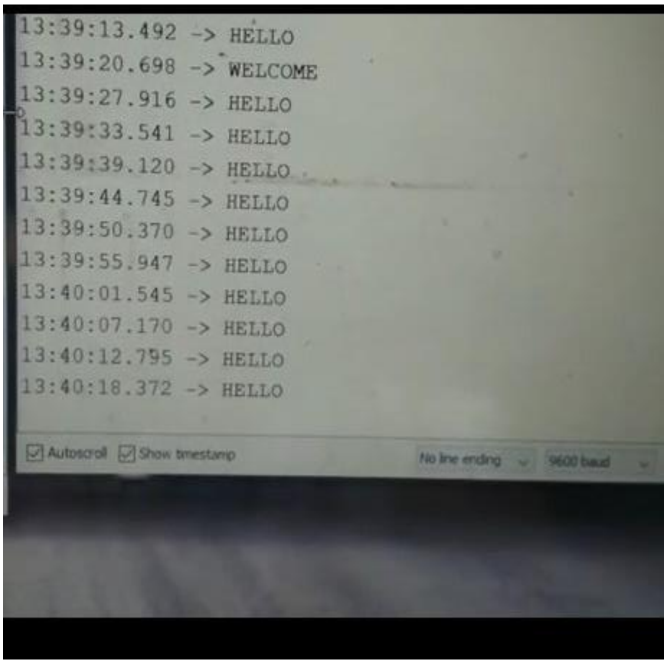

Figure 6. Receiver side frame (*i.e.* Morse Decoder)

Using this algorithm, small experiment of transmitting audio using Li-Fi through a Solar Panel was also performed. The set-up of mobile connects to multiplayer using audio cable and LED is shown in figure 7(a). And the set-up of solar panel is shown in figure 7(b). The set-up of Speakers connected to play a audio send is shown in figure 7(c).

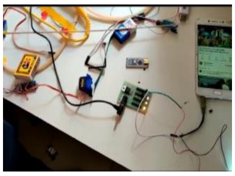

Figure: 7(a)

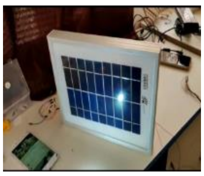

Figure: 7(b)

Figure: 7(c)

The experiment was successful. The audio was transmitted using Li-Fi with a great rate. The quality of sound varies depending upon the position of LED/light. If LED is close to solar panel the sound and quality of audio increases and vice versa.

6. Conclusion

In this paper a novel method of transmitting and receiving data using LiFi has been explained. If technology can be put into practical use, every bulb can be used something like a Wi-Fi hotspot to transmit wireless data and we will proceed towards the cleaner, greener, safer and brighter future.

The modulation of data involves utilizing a combination of OOK, Manchester and Morse code to reduce the bandwidth of the data to be transmitted. The developed prototypes allow users to lay the basis of communication and introduce the concept necessary to understand Visual Light Communication. Results show that even with a simple hardware configuration it is possible to achieve a high-quality transmission with low error rates at speed of 1200 words per minute. To achieve higher transmission rates, it is necessary to change the firmware used by the prototypes, for example, using interrupts to measure the received signal allowing even higher transmission rates. In the transmitter side, it is necessary to use an array of LEDs and faster microcontrollers in order to process the data received in the serial port and convert it to Morse before sending it to receiver. In the receiver side, an amplifying receiving stage will allow longer receiving distances. The use of the amplifying receiving stage will also allow the receiving firmware to use interrupts instead of time sampling, making measurements more precise.

7. Future Work

Future work will implement a more detailed application of Li-Fi systems in various areas for easy, secure and fast transmission of data at a higher rate of transmission speed.

Some the applications of Li-Fi can be in the malls where there is huge source of light 24X7. They can implement the Li-Fi at entrance for security purpose and to transmit a data to the system regarding whether it's a male or female entered.

Another application of Li-Fi can be transmission of data of emergency vehicles in traffic using headlights of vehicles. Emergency data like weather it's an ambulance stuck in traffic it can send an emergency alert to other vehicles through headlights.

How to implement a prototype that uses the LED driver 6 channels, developed by Globaltronic, to allow customers to interact with end users throw a short message system, giving information about the location and general information of the products exhibit.

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