Data Transmission using Visible Light Communication (Li-Fi)

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Abstract - In an era of wireless communication, a large number of devices are using the radio frequency range and due to this, congestion and interference occur. For instance, a wind turbine currently transfers ten terabytes of data every day. An excellent set of this computerized information is transferred from a supply to recipient crossing over huge separations, and this operation from beginning to end includes a foreign interface that uses the ability of the RF spectrum to transfer data. It is assumed that by 2025, we are going to use 44 zettabytes of data. This adds up to the sum of total bits on the world as same as the total count of stars present in the universe. Machines will generate this much information during their operation. Under the specific circumstance, it is assumed that there will be around eighty billion Internet-of-Things (IoT) gadgets by the year 2028. This project aims to create a wireless VLC device that can send data (video, text) between two computers using visible light. Li-Fi technology is used to transfer the information utilizing visible light correspondence with light-emitting diodes (LED). Signals are transferred from one system to the next using LEDs for transmission and Photodiodes for the reception. This is a significantly more secure strategy for the transmission of data compared with existing innovations. Recognizable Visible Light Communication (VLC) has expanded extraordinarily for the last decade due to the development in the manufacturing of the Light Emitting Diodes (LEDs). In this project, the video signal is transmitted by using the Li-Fi transmitter with the power of Light. The sufficient, persistent, and long life of LEDs make them a piece of promising private lighting equipment and an alternative way to exchange data and information in the fast-moving world. This project will be used for communicating information and measuring its efficiency in terms of data fidelity, speed, and cost in comparison with other communication media.

Key Words: IOT, Visible Light Communication, Li-Fi, LED

1. INTRODUCTION

VLC (Visible Light Communication) is the transmission of data using visible light from the electromagnetic spectrum's (300 GHz -30 PHz) (Peta Hertz) portion, which comprises the infrared, visible, and ultraviolet bands.

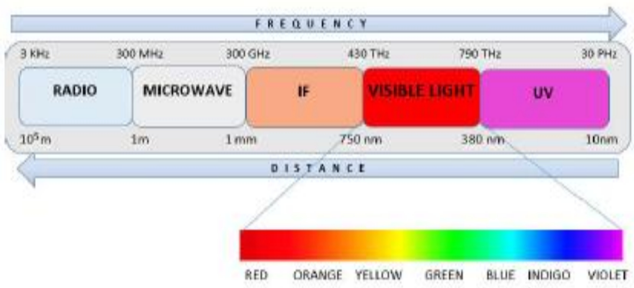

Fig.1 Electromagnetic spectrum

Figure 1 illustrates a portion of the electromagnetic spectrum with the optical range highlighted. Optical wireless communication (OWC) systems have several technological and operational advantages, including low power consumption, much higher bandwidth capability, strong security, electromagnetic interference immunity, and tolerant spectrum. The transmitter in this paper is an LED (Light Emitting Diode), the transmitting medium is air, and the signal receiving unit is an effective Photodiode. The requirement for wireless data connectivity has risen exponentially over the last few years. Wireless communication using the radio frequency spectrum, which has been the most prominent up until now, has resulted in spectrum congestion [1]. The introduction of visible light communication opens up a whole new world of possibilities for future computer communication. To begin with, the visible light spectrum bandwidth, which spans 430 THz to 750 THz, is significantly greater than the radio frequency spectrum bandwidth, which spans 3 kHz to 300 GHz, because of the increased bandwidth, it is possible to transmit data at a much faster rate and can handle a greater number of users [2]. Second, under certain areas, such as space stations, hospitals, and mines, radio frequency (electromagnetic waves) can be life-threatening, while visible light, as an efficient means of life, is safe[3]. Third, light sources are abundant and sufficient, and once replaced with LED lamps, they can serve as transmitters as well as light sources [4]. This ensures a plentiful supply of visible light communication systems at a low cost to introduce. Finally, unlike radio waves, light cannot pass through walls, so the data cannot be received by a receiver on the other side of the wall [5]. Since information is not broadcast for external sources to receive, this property of light improves security. The advancement of this technology is still in its development.

In Japan, more recent work started in 2004. A broadband networking system for indoor applications was proposed in a 2008 research paper [6]. "A visible light communication device capable of transmitting data at 500 Mbit/s was developed in 2009 as part of a research project" [7].

However, proper commercialization of this technology is several years away. LEDs, in addition to their lighting powers, use relatively little power and have very fast switching rates, with frequency fluctuations so fast that they are undetectable to the naked eye. The goal of this review is to use Li-Fi to create a visual communication link between two mediums. In this article, a basic device with two microprocessors (PCIn16f877a), a White LED (transmitter), and a Photodiode (receiver) is implemented. An application developed in .Net is developed since processors alone are insufficient in handling large amounts of data. The user will send a text or a video file to the transmission end of this device. The microprocessor decodes the data and sends it to the LED in different intensities, causing the LED to flicker at a faster rate that is undetectable to the naked eye. It depicts flashes of 1s and 0s by changing the intensity of light from a higher to a lower range. The Photodiode receives the transmitted data as a bitstream, which is decoded back to its original form by the microprocessor at the receiving end. The .Net application will assist the microprocessor in signal processing by translating the 0s and 1s into its equivalent data, which will be used to create the originally transmitted video signal.

System Design Objectives:

- Achieve high-speed wireless data transmission.
- Build a wireless communication network using existing light infrastructure for reliable and low-cost communication.
- Empowering the Internet of Things (IoT) across multiple devices (multiple times more gadgets).

2. System Model

The design and structure of a system model (as shown in fig.2). The device consists of two PCs, one on the end of the transmission, the other on the end of the receiver, two pic 16f877a microcontrollers on both ends, one white LED on the transmitter, and a Photodiode on the end of the receiver.

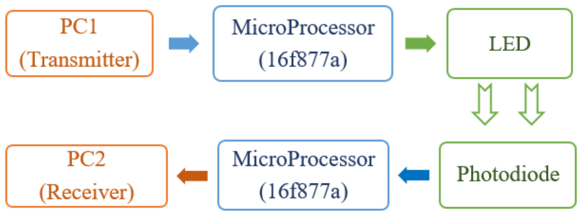

Fig.2 Block Diagram for data transmission between two PCs using Visible Light Communication.

The PC is attached to the Microcontroller, which is connected to the white LED at the transmission end. The Microcontroller causes the LED to flicker rapidly at a rate undetectable to the human eye [8], while simultaneously transmitting data. The fast blinking of LEDs generates fluctuations of varying durations [9]. The Photodiode is attached to the controller, which is connected to the PC2 at the receiving end. The Photodiode detects the LED's rapid flickering. Using the application program, the length of the pulses produced by the flickering is determined by the .net program and the controller itself. HIGH and LOW pulses are separated based on their durations, and a binary bit stream is formed. The Li-Fi Application receives this bit stream for further processing and output generation. When dealing with huge amounts of data that can be processed by the program, the processor faces many limitations. As a result, the receiver program is used to display the decoded output.

2.1 Transmitter

A personal computer (PC 1) is used on the transmitter side of the VLC system. The program for Hyper terminals and the. Net application software must be mounted on PC 1 for the device to run smoothly. This PC acts as a data source in this system.

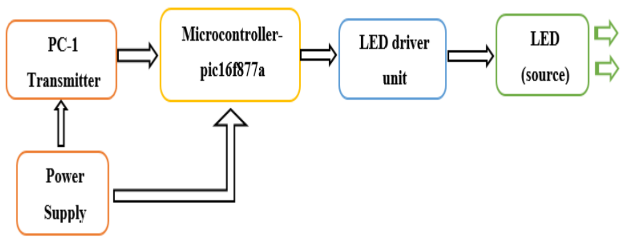

Fig.3 Transmitter Section Block Diagram

The functional block diagram of the transmitter segment is shown in Figure 3. A Microcontroller (PIC 16f877a) is attached to PC 1 by a UART cable. In order to provide the voltage needed to move the white LED effectively, an LED (Light Emitting Diode) Driver circuit is connected in series with it. The LED's Enable signal is attached to the Controller board's digital PIN 18 (Port-C). .Net programming aims to take a user's input and send the corresponding input data. To allow the transfer of input data, an interface is created between the Application and the Controller. The first step is to build a serial port object (s) for the Controller's serial port COM6. 9600 bits per second is the Baud Rate, which refers to the amount of signal or symbol shifts per second. The PIC Controller's UART port is then attached to the serial port object. The application receives video input from the user and transfers it to the Controller's IDE. A software-written machine code receives the embedded video data and decodes it into its ASCII value before generating the binary bit stream. To begin, the Controller board's PIN 17 (Port-C) has been specified and configured as an output. For serial communication, the baud rate is set to 9600 bits per second. The number of bits (characters) available for reading from the serial port is determined, and the serial data received is read. The digital pin 17 receives a HIGH or LOW value. The length of the pulse is varying according to the bit stream, which is applied using pulse width modulation (PWM). For example, if the transmitting signal is 101, one high pulse would be emitted for bit 1, a low pulse for bit 0, and another high pulse for the least significant bit 1. For high pulse=1, a specific delay is given. Similarly, for low pulse=0 a separate delay is given. As a result, data is transmitted as the LED rapidly flickers in response to the varying durations of delay offered for the high and low pulses. Natural eye identifies outlines each 1/tenth of a second.

1) Algorithm: The algorithm for the transmitter is shown below [12], [13].

2.1.1 ALGORITHM 1 - ALGORITHM FOR MATLAB AT TRANSMISSION END

1: START.

2: PERFORM INTERFACING WITH CONTROLLER.

3: TAKE AN USER INPUT IN THE FORM OF FILE (VIDEO, TEXT).

4: TRANSMIT THE FILE INPUT TO PIC CONTROLLER (16f877a).

5: STOP.

Software application takes the user data input and passes the data to the interfaced PIC Controller IDE. PIC converts each input into its equivalent binary (0/1) output.

2) PIC Controller Algorithm: Controller algorithm for the transmitter is shown below [14], [15].

2.1.2 Algorithm 2 Algorithm for PIC IDE at the Transmission end

1: START.

2: CONFIGURE THE PIN TO WHICH THE LED IS CONNECTED TO BEHAVE AS AN OUTPUT.

3: RECEIVE THE DATA INPUT FROM PC1.

4: CONVERT IT INTO ITS RESPECTIVE ASCII VALUE.

5: GENERATE THE RESPECTIVE BINARY BITS FROM THE ASCII VALUE.

6: TRANSMIT THE BITS BY FLASHING THE LED FOR DIFFERENT DURATIONS USING PWM.

7: WRITE A HIGH OR A LOW VALUE TO THE PIN TO WHICH THE LED IS CONNECTED.

8: STOP.

2. 2 Receiver

A PIC Controller board is connected to PC 2 via a UART cable. A Photodiode is connected to the analog pin of the Controller in order to receive the output from the sensor. The Photodiode is positioned within 5 meters of the LED to ensure a clear line of sight between them. As its junction voltage varies with differences in the amount of light incident on it, the Photodiode senses the rapid flickering of the LED when transmitting 0 (Low) or 1 (High) as seen in Fig 4.

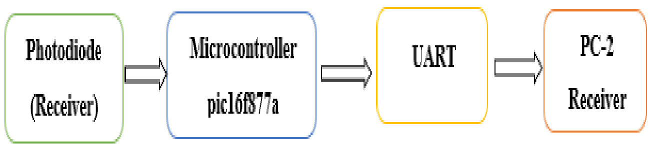

Fig.4 Receiver Section Block Diagram

The incoming (HIGH or LOW) pulses to the RC7 (Port C) pin are read using a predefined library feature pulseIn(). The width or length of the pulses in microseconds is returned by this function. With the aid of pulseIn(), two-time length ranges can be accessed. Since specific delays or pulse durations for high and low pulses have been set at the transmitter end, the LED glows with a certain intensity when a high pulse is transmitted and a different intensity when a low pulse is transmitted. This frequency difference can be detected by the Photodiode. After obtaining the time interval of the received pulses using pulseIn(), the high and low pulses can be quickly identified using a conditional if-else statement in which pulses with longer durations are classified as high pulse=1 and pulses with shorter durations are treated as low pulse=0. A binary bit stream of 0 and 1 is produced after obtaining the high and low pulses. The collected bit stream is then moved on to produce an output in the form of bits that is similar to the user's input. Application software receives a bit stream at the receiving end. This obtained bit stream is used to extract data. The whole stream of bits is stored in a vector form after a loop is started. This code is then decoded in order to translate the string of bits into data. At the receiving end, the transmitted bit stream is processed in a single column. A predefined library function reshape() is used to retrieve the transmitted stream of bits in a single one-dimensional sequence. There is one more issue to be managed. The communicated bit stream received the backward request. Assume the sending bit stream is 100 then it will be received as 001 at the less than desirable end. So the received bit stream should be switched to get the right yield. Using the predefined fliplr() module, the string is inverted. The program receives the decoded information in order to replicate the data from the received bits of the signal. This aggregated data is saved as a video file in PC2 which can be displayed on the PC, resulting in a faithful replication of the signal on display (PC2).

2.2.1Algorithm 3: Algorithm at the Receiver end.

1: START.

2: INTERFACE THE COMPUTER WITH PIC MICROCONTROLLER.

3: CONFIGURE THE PIN TO WHICH THE Photodiode IS CONNECTED TO BEHAVE AS AN OUTPUT.

4: READ THE PULSES ON THE PIN TO WHICH THE Photodiode IS CONNECTED AND RETURN THE WIDTH OF THE PULSES IN MICROSECONDS.

5: CHECK THE CONDITION FOR DETERMINING WHETHER PULSE IS HIGH OR LOW.

6: DECODE THE BITS (HIGH OR LOW) RECEIVED INTO ITS EQUIVALENT DATA.

7: STORE THE REPRODUCED DATA INTO PC2.

8: STOP.

RESULT

A model was planned effectively and built to exhibit Data correspondence between two PCs. The goal was to build up an apparent light correspondence framework that communicates and gets Data like video, text over the light range. The distance between the LED and the Photodiode was set between 5 - 8 meters. A pictorial portrayal of a Pulse Width Modulated (PWM) signal created at the collector end of the Controller portraying the transmission and gathering of information, is shown below. The pulses created for one character are shown in Figure 5. A HIGH pulse denotes binary "1," while a LOW pulse denotes binary "0."

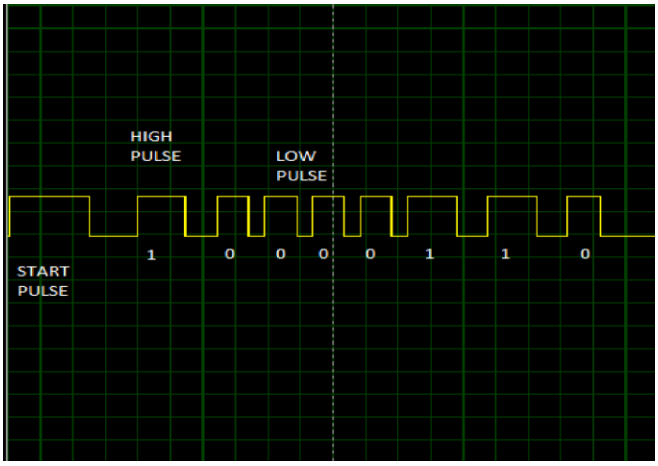

Fig. 5. Generated pulses at the receiver end

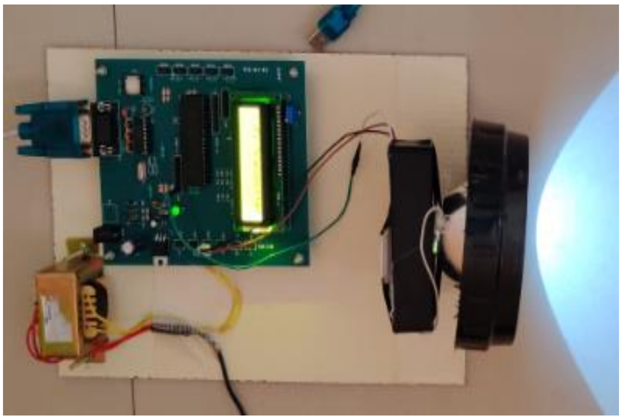

Fig.6 (a) Hardware Section of Transmitter

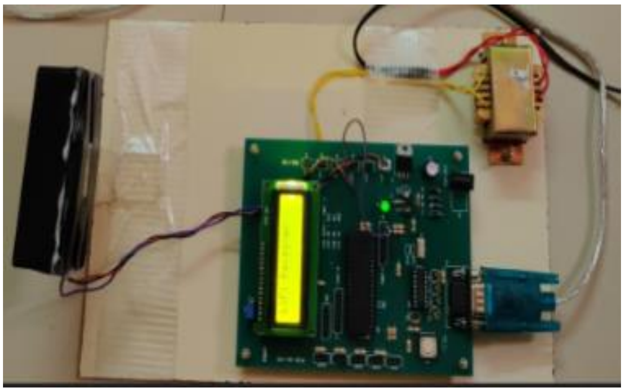

Fig.6 (b) Hardware Section of Receiver.

CONCLUSION AND FUTURE SCOPE

Li-Fi technology aims to have a quicker, simpler, greener, better, and healthier future for wireless networking systems as the electromagnetic spectrum becomes more crowded. When this model is completely developed, each light source will be used as a LiFi entry point, implying that anywhere there is an LED light bulb, there will be a data transmission service happening as well. We expect to see Li-Fi combined with other wireless complementary technology to create a modern powerful computing network within a few years. Under this forthcoming integration, every device large enough to mount a LED and a light sensor can be connected and powered by LiFi. This paper highlights LiFi's cutting-edge growth and technological capabilities, as well as the obstacles that remain for a fully integrated LiFi network. Since the primary focus of current research is on the development of appropriate modulation techniques for use in LiFi systems, we have found it necessary to underline in this paper a few of the most competitive advances to date.

In the future, this paper might be applied with a high-performance microcontroller capable of decoding data at a faster pace, giving the consumer a broader spectrum of bandwidth and enabling them to transmit data at a faster rate without compromising on security.

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