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TRANSMISSION OF DATA, AUDIO SIGNAL AND TEXT USING LI-FI

[1]A.Vinnarasi, [2]S.T.Aarthy
Department of Electronics and Communication Engineering, SRM University, Chennai, India
[1,2]Assistant Professor (O.G.), Department of Electronics and Communication Engineering, SRM University
[1]vinnarasi.a@ktr.srmuniv.ac.in, [2]aarthy.s@ktr.srmuniv.ac.in

Abstract: With the onset of modern communication, and the increase in the bandwidth usage that led to its congestion, it is paramount that we find an alternative or a faster means of communication. Light Fidelity – more commonly referred to as Li-Fi- is one such concept that is gaining momentum to become the possible alternative. In Li-Fi, the data is transmitted in several bit-streams through high-speed flickering of the LED bulb and decoded on the receiver side which consists of a photo-detector. This happens in the form of a binary transmission of data, where '0' is the LED in its 'off-state' and '1' is the LED in its 'on-state'. In this paper, we use this concept to transmit data to demonstrate the use-cases and the possible impact it can have in the ever-growing field of communication. In this paper, we transmit two types of data using Li-Fi: Audio and Text. We study the various topologies to understand the characteristics a Li-Fi based system can have.

Keywords: Visible Light Communication; Data transmission; Li-Fi

1. Introduction

The demand for data usage has increased exponentially in the last decade, people want to be connected to the Internet all the time, on multiple devices, update the latest happenings etc. With the advent of IoT more devices will connect to the LTE which will result in congestion and decrease in speed.

To solve this crisis, multiple options were considered and one was to utilize the unused visible light spectrum which gave rise to the new concept called Li-Fi.

Li-Fi:

Li-Fi stands for Light-Fidelity which provides transmission of data through illumination by sending data through an LED light bulb. Li-Fi uses Light Emitting Diodes (LED) which have high modulation bandwidth and energy efficient illumination.

These LED's have high switching speeds that enable them to modulate according to the stream of bits that are sent. This transmission takes place in a parallel stream such that more data is being transmitted simultaneously. The switching speed is too fast to be visible to the naked eye and thus this transmission is not noticeable. This technology was proposed by German physicist Harald Haas in University of Edinburgh.

Li-Fi, at its core is light-based Wi-Fi with the main difference is that it uses light instead of radio waves to transmit data. The Li-Fi system would consist of regular, off-the-shelf, LED bulbs that provide internet or data transmission as well as illumination. It utilizes the visible light portion of the electromagnetic spectrum (380 nm to 780 nm). Thus, it has 10,000 times more space available thus more available bandwidth is present. Theoretically, it can reach the speeds up to 224 Gbps. [4]

2. Related Works

This section discusses the various advantages of VLC and elucidates on the differences between Li-Fi and Wi-Fi. By the year 2020, 10 billion devices will be subscribed in the LTE, which would result in an exponential growth of wireless traffic demand and result in a congested, scarce, and expensive RF-spectrum. The last few generations like 2G, 3G, etc., there have been many conventional methods employed to improve the capacity of the spectrum like spatial re-use and inter-cell interference coordination. Li-Fi can play a major role in relieving the heavy loads which the current wireless systems face since it adds a new and unutilized bandwidth of visible light to the currently available radio waves for data transfer. [7]

Visible Light Communication may also be used to complement current RF systems as Li-Fi will guarantee safer networks and higher speeds. In offices and schools the maximum data is exchange happens within the same building. Usage of Li-Fi system along with the 5G Wi-Fi, would help solve this issue. Due to Li-Fi, the transmission of video etc., will become faster, since it is

viewed or downloaded, indoors and 5G can be used only when data exchange is needed outside the premises. [4] [7]

Wi-Fi is very susceptible to man-in-the-middle attacks etc. Li-Fi works only in LOS condition which thus, increases the security of the transmission. The technology is highly directional and localized as communication only takes place where the light can be seen, therefore the light can be directed towards certain areas within the office.

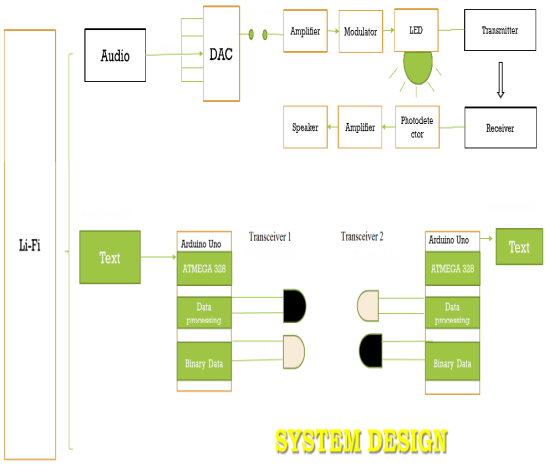
Visible light cannot penetrate opaque objects, which means that the wireless signal is constrained to within a strictly defined area of illumination. Secure can be created by closing blinds and shutting doors. [7]

3. Design Methodology

Li-Fi can be used for transmission of audio signals, text, images, and videos. It can also be used for providing internet.

This paper mainly deals with the transmission of two types of data; audio waves and text. We have transmitted audio signals from one source to one output (SISO), more than one source to a single output (MISO), more than one source to multiple outputs (MIMO) and studied topologies and different characteristics and variations observed in the data being transmitted at different setups. [2] We have achieved the transmission of text between two users using a setup of Arduino boards, L.E.D. and Silicon photo-diode.

Li-Fi can also be used to transmit images and eventually even provide internet by using modulation techniques like OFDM. [2] Li-Fi when combined with Wi-Fi, provides an ideal set up where the disadvantages of Li-Fi are covered up by the handoffs of the devices to Wi-Fi. [7]



AUDIO SEGMENT:

The transmission of audio signal was done through a phone at the transmitter end, providing the audio signal through the 3.5 mm jack that would convert the digital signal to an analog signal. This analog signal is amplified and sent to the array of LEDs that were connected on the breadboard. A power supply is also given to the LED array. This power supply is provided by a 9V battery that is connected to the 3.5 mm jack and the LED array.

This variation in the intensity of light, however, is captured on a solar panel that acts as a photodetector. It captures all the variations and sends the received signal to the pre-amplified speaker.

Using the same concept, instead of providing an analog signal from a phone, a text to speech software was used. A text was typed into the software and the software reads out the text.

This audio signal, generated while reading out the text, was transmitted through the fluctuation of LED arrays as mentioned above, and captured on a solar panel. This was then heard through a pre-amplified speaker. [8]

TEXT SEGMENT:

The text transmission segment, was done in three parts. Firstly, text transmission from Arduino to itself. Secondly, text transmission between two Arduinos using IR. Thirdly, text transmission between two Arduinos using VLC.

4. Data Transmission

The transmission was done in various parts: Audio and Video.

A. Audio Transmission using Li-Fi

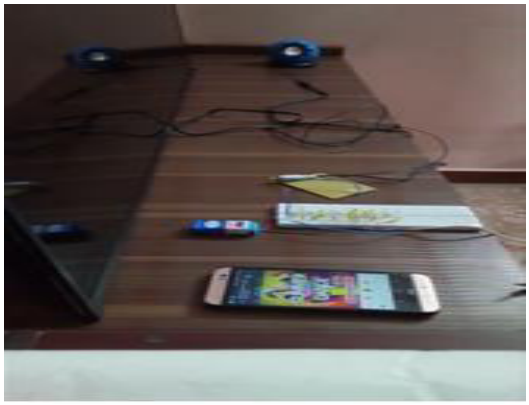
The transmission of audio signal was done through a Smartphone at the transmitter end, providing the audio signal through the 3.5 mm jack. The 3.5mm audio jack and the input audio from the phone is converted from digital to analog. A typical 3.5mm audio jack has three output lines namely, right, left and the ground. The left and right have the audio output signal, which is connected to the negative of the 9V battery. The ground of the 3.5mm jack is given to the negative of the LED array connected on a breadboard and the positive of the 9V array is given to the resistors in series with the LED array.

This circuit effectively modulates the intensity of the LED's light, which acts as carrier wave, according to the effective voltage difference. The fluctuations occur at a high speed, invisible to the naked human eye. Thus, the

variation in intensity of light from the LED array is not realized by the human eye.

This variation in the intensity of light, however, is captured on a solar panel that acts as a photo detector. It captures all the variations and sends the received signal to the pre-amplified speaker. The analog signal that was transmitted through the fluctuating LED array to the solar panel gets amplified in the pre-amplified speaker and emits the sound waves to be heard from the speaker. The sound intensity received from the speaker varies based on the distance of the solar panel from the LED arrays. This shows that the information can be received from the line of sight of the LED array.

As the distance between LED array and the solar panel increases, the intensity of light reduces and the light becomes more scattered thus, making it difficult for the solar panel to detect all the light rays being emitted.



a) Observations

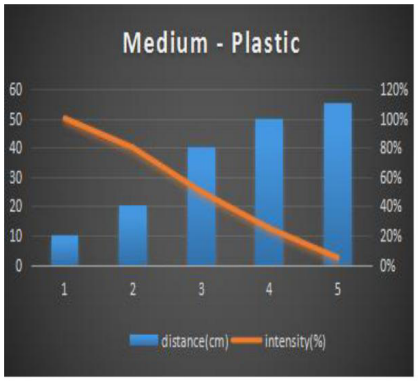
Si.no.	**Trials with various components**	
	Setup	***Observation***
1.	Use of rechargeable battery	No change
2.	Using two batteries in series	No change
3.	Using two solar panels	No change
4.	Using 10mm LEDs	Reduced clarity but increased distance.
5.	Using colored LEDs	No change

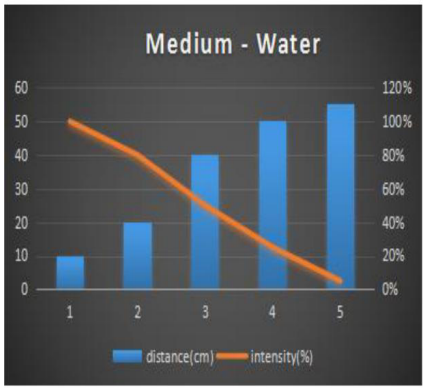
Si.no.	**Effects of reflection off white wall**	
	Transmitters	***Observation***
1.	White LEDs	10-15cm
2.	10mm LEDs	45cm

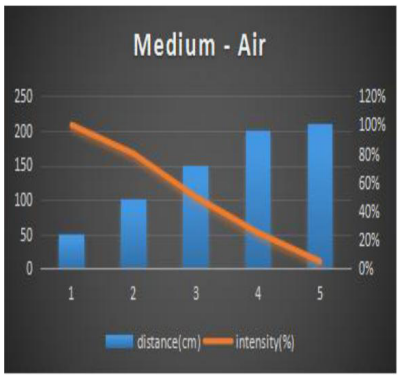
Si.no.	**Varying mediums using 10mm LEDs**	
	Medium	***Maximum Range***
1.	Plastic	50cm
2.	Water	50cm
3.	Glass	90cm
4.	Air	200cm

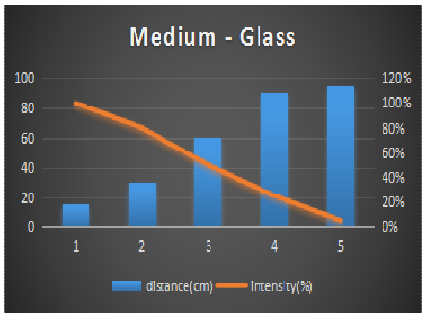
b) Graphs

Based on the tables shown above, graphs were designed to give a clearer description of the variation in the characteristics. The transmitted data is passed through different mediums to observe the characteristics *b)*









Li-Fi based Audio transmission is the live transmission of Audio signals without any signal loss. The sound clarity is clear and loud and using a focusing lens further enhances the output received.

The 4G audio streaming shows that Li-Fi can work as a complementary network with 4G or 5G. Most corporates and schools use internet to access video or text. By completing the 4G audio we can indicate that video streaming too can be done using Li-Fi. This would mean that educational institutions and organizations could utilize their illumination systems for data. This would give them the ability to access Videos and Audio files without use of cellular data and Wi-Fi. [6]

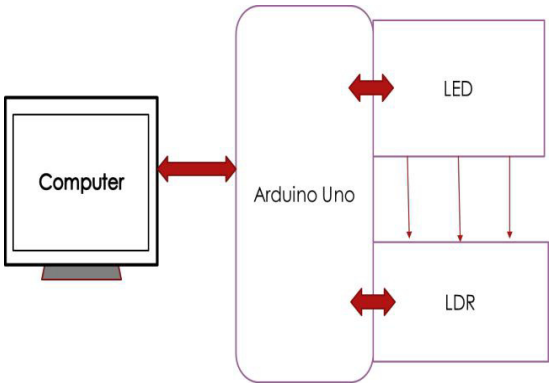
The study of topology shows that multiple users can access the same luminary without data loss. This is an important aspect of Li-Fi, where each light in a room can cater to many users. [1]

B. Text Transmission

The various stages of text transmission that was done are:

a) Micro-controller to itself

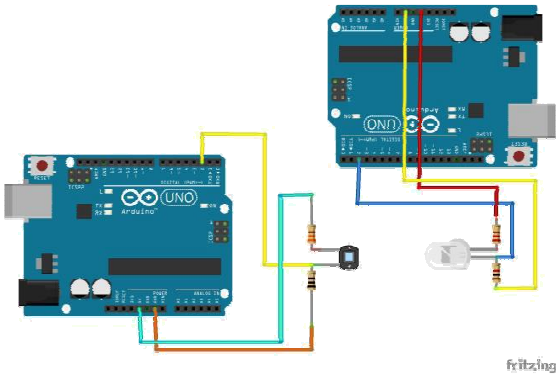
A circuit is designed such that the LED and a phototransistor are interfaced with an Arduino. An algorithm is mounted on the Arduino. When data is transmitted to the Arduino using the serial monitor, the LED flickers. These flickers are captured by the photo-diode, which is then decoded to the original data. The algorithm consists of different binary values for each alphabet or character that is to be entered. These binary values are based on the switching of LED bulbs between on state and off state. When the data to be transmitted is entered, the LED blinks according to the characters entered. The photo-diode decodes these blinks based on the binary values entered in the algorithm. In this way, a single micro controller transmits the data and receives it on another serial port.



b) One-way communication using IR

One-way PC-to-PC transmission using an IR transmitter and Receiver is achieved using two Arduino Uno boards. Each Arduino board is connected a PC using the COM ports of the PC. At the transmitter side, once the program is compiled and uploaded to the board the text is entered on a serial monitor of Arduino. This data is processed in the Atmega 328, microprocessor, present in an Arduino Uno board. The processed data converts ASCII characters into binary bits, which flickers the IR LED that is interfaced with the Arduino board.

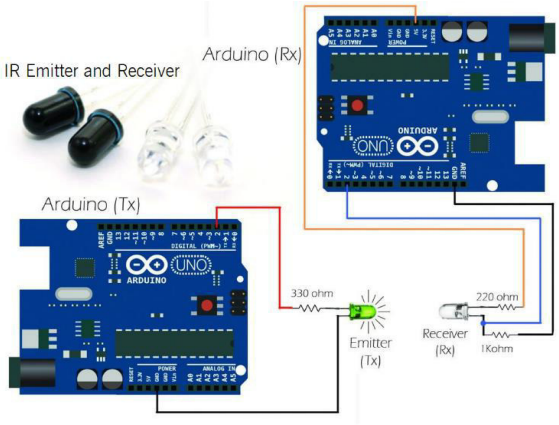
This flickering is captured in the receiving side IR receiver, which is interfaced with another Arduino board connected on a COM port of another PC. The receiver accepts the binary values from the transmitter and its processor converts these binary bits into ASCII characters. The receiver side has a dictionary in the code, which prints the alphanumeric character with respect to the received ASCII code. This alphanumeric character can be viewed in the serial monitor of the receiver Arduino Uno. This works only in LOS condition as the IR transmitter and receiver cannot communicate beyond 2cms.



c) One- way communication using VLC

In the previous case, text message was from one PC to another via IR sensors. This segment uses VLC for the same one-way communication. Two Arduino boards were taken on the transmitter side and receiver side respectively, with a setup like that of the above case. The transmitter side, however, was interfaced with an LED. The receiver, with a silicon photodiode 2CU10A.

The designed algorithm was run through the Arduino on both the sides (transmitter and the receiver), the LED flickers based on the message being sent. The photodiode acts optical sensor picks up these variations and the Arduino board of the receiver side translates these captured flickers to the message that was being sent. The algorithm of the receiver side was designed after measuring the various flickers of the LED bulb when each character, alphabets (capital letters and the lower-case letters), numbers etc. The photodiode decodes the flickers by mapping it to the corresponding ASCII code. **[4]**



Error Free transmission was achieved in both One-Way and Two-Way transmission. With off the shelf LED is a communication distance of 22cms was observed. Using better grade LED's and Photodiodes can enable two-way communication to much greater distances.

This research paper presents a novel approach to combat the Phishing attacks. An approach is proposed where user will retrieve the one-time password by Li-Fi Device LCD screen. After receiving the one-time password, the application software will create an encrypted token for the user's computer/device for authentication. The encrypted token will be used for identification, any time user wishes to access the website he/she must request the new password. The one-time password as name implies will expire after single use. The one-time password and encrypted token is a smart way to tackle this problem. [9]

d) Text to Speech

There are various reasons why text to speech is used a lot especially in e learning courses; it is easier to understand when words are converted into speech thus accommodating learning difficulties. It also develops literacy and speech skills.

Text to speech also increases the number of opportunities for blind people. This can be used in normal educational institutions thus keeping the blind in pace with the normal people.

Various software converts text to speech. Now this speech must be transmitted to multiple users, sending an audio file over Wi-Fi can take some time, and this is where Li-Fi comes in handy.

As the person is typing, that text is converted into speech using text to speech conversion software, the source for (e.g., a laptop or a mobile phone) is further connected to a Li-Fi audio hardware. This hardware then transmits the speech via light to one or multiple receivers, which consists of a speaker.

Using Li-Fi for text to speech will eliminate various issues like delay in the speech and the cost.

5. Result and Discussion

The Li-Fi system proposed in this paper is capable of transmitting data such as text, audio between two devices at the speed of a few kbps. The main requirement is line of sight between the sender and the receiver and hence it can be used to transmit data within a room.

AUDIO TRANSMISSION:

Li-Fi based Audio transmission is the live transmission of Audio signals without any signal loss. The sound clarity is clear and loud and using a focusing lens further enhances the output received.

The 4G audio streaming shows that Li-Fi can work as a complementary network with 4G or 5G. Most corporates and schools use internet to access video or text. By completing the 4G audio we can indicate that video streaming too can be done using Li-Fi. This would mean that educational institutions and organizations can utilize their illumination systems for data. This would give them the ability to access Videos and Audio files without use of cellular data and Wi-Fi.

The study of topology shows that multiple users can access the same luminary without data loss. This is an important aspect of Li-Fi, where each light in a room can cater to many users.

TEXT TO SPEECH:

The text to speech using Li-Fi can be directly implemented in Blind Indoor Navigation Systems.

Indoor navigation is convenient for everyone, and it is especially indispensable for the visually impaired. Such a navigation system for the visually impaired as shown in the below Figure. LED lights emit visible light with location data and by using embedded systems or smartphone instead of Arduino with a visible light receiver for receiving the data the Li-Fi enabled text to speech can be employed as an alternative for the blind. The embedded system or smartphone would calculate the optimal path to a designation and would speak to the visually impaired through a headphone. In a VLC-based system, a receiver in the headset would detect the signal from the nearest LED and play the relevant commentary.

TEXT TRANSMISSION:

Error Free transmission was achieved in both One- Way and Two-Way transmission. With off the shelf LED's a communication distance of 22cms was observed. Using better grade LED's and Photodiodes can enable two-way communication to much greater distances.

ONE WAY TRANSMISSION:

One-Way transmission can be proposed where the user will retrieve the one-time password through VLC on a LCD screen. Upon receiving this one-time password, the software will create a public key or an encrypted token for the user's computer/device for authentication. This token will act as an authentication key and the user will receive a new password for every log in. This can give more security and confidentiality.

TWO WAY TRANSMISSION:

VLC is a promising method of secured communication indoors. It applies to areas where sensitive information need to be transferred without the risk of leaks. Current communication techniques have vulnerabilities as discussed earlier in this paper which can be overcome using VLC. We have used this VLC technology in this paper to create an Arduino chat which can be made secure and independent of Wi-Fi vulnerabilities.

There are multiple options by which we can protect data in VLC. The VLC has two innate qualities which ensures security, the first being the fact that artificial lights cannot penetrate opaque materials and the second is that communication happens only when receiver and transmitter are in line of sight condition. This ensures that only those who are in the specific room and very close to the light source only receive the data. This protects the data from external threats or online hacking which can be circumvented.

There are ways to make the transmission more secure. This can be done by adding a predefined password on the transmitter and receiver terminals. So, when the system is accessed the system prompts the user to enter the password. Only then can the data be transmitted or received.

6. Conclusion and Future Scope

In this paper, a real-time audio broadcast prototype off the shelf LED's are used, it is envisaged that using commercial LED lamps would result in higher distances of transmission. It is shown that transmission of high quality audio with the distance of 1 m can be achieved

and improvements can be made by adding focusing lens between the transmitter and the receiver.

In the data transmission prototype, the encoding and decoding can be used in the transmitter part and receiver part to reduce the error in transmission. In addition, the data transmission rate could be enhanced by using fast switching multiple LED's. The tests were carried out indoors under ambient light conditions. Larger coverage of area for transmission can be obtained by using LED arrays.

VLC is still in a very early stage; however, it is a promising technology with a wide range of prospective applications. The interest in VLC is increasing throughout the world and we can soon expect many real-world applications.

Li Fi is a fast and cheap wireless-communication system. The increasing demand for higher bandwidths, faster and more secure data transmission as well as environmental and undoubtedly human friendly technology heralds the start of a major shift in wireless technology, a shift from RF to optical wireless technologies. The possibilities are numerous and research can provide us with many solutions. This technology can be used to make every LED bulb into a Li-Fi hotspot to transmit data wirelessly and will proceed to give us a safer, faster and a greener network.

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