LI-FI (LIGHT FIDELITY): A WAY TO EFFICIENT DATA COMMUNICATION BASED ON OFDM APPROACH

Bhaumik Gelani[1], Prof. Gayatri Pandi (Jain) [2],
Student (Master of Engineering) [1], H.O.D. PG Departments[2],
Computer Engineering,
L.J. Institute of Engineering and Technology, Gujarat, India.

Abstract: Li-Fi stands for Light-Fidelity. The technology is very new and was proposed by the German physicist Harald Haas in 2011. Li-Fi provides transmission of data through illumination by sending data through an LED light bulb that varies in intensity faster than human eye can follow. We discuss the technology in detail and a method is proposed to reduce noise from received data. Li-Fi is ideal for high density wireless data coverage in confined areas where there are no obstacles. Li-Fi is a wireless optical networking technology that uses light emitting diodes (LEDs) for transmission of data. The term Li-Fi refers to visible light communication (VLC) technology that uses as medium to deliver high-speed communication in a manner similar to Wi-Fi. Li-Fi provides better bandwidth, efficiency, availability and security than Wi-Fi and has already achieved high speeds in the lab. In this paper we will give a detailed study on Li-Fi technology, and method to achieve accuracy of data transmission. The experimental result shows that the proposed technique efficiently detects the noise and de-noising is achieved with a better accuracy.

Index Terms **- Light–Fidelity (Li-Fi), Light Emitting Diodes (LED), 5G networks, Visible Light Communication (VLC), OFDM encoding/decoding technique.**

I. INTRODUCTION

Transfer data from one place to another is one of the most important day-to-day activities. The current wireless networks that connect us to the internet are very slow when multiple devices are connected. As the number of devices that access the internet increases, the fixed bandwidth available makes it more and more difficult to enjoy high data rates and connect to a secure network. Nowadays, everyone is interested in using his mobile phone, laptop to communicate with other people through Wireless-Fidelity (Wi-Fi) systems, and this technology, Wi-Fi, is widely used in all public areas like home, cafes, hotels and airports by people, also the time usage of wireless systems is increasing exponentially every year; but the capacity is going down, due to the limitation of Radio Frequency (RF) resources, so we are going to suffer from severe problem such as Capacity, Efficiency, Availability, and Security.

This new technology is known as Light–Fidelity (LI-FI). It is a short range wireless communication system based on light illumination from LED, and use the visible light as a signal carrier instead of traditional RF carrier as in Wi-Fi. Professor Harald Haas coined the term "Light-Fidelity" and set up a private company, called “Pure Visible Light Communication”, to exploit that technology. He envisions a future where data for laptops and smart phones are transmitted through the light in a room in a secure way. [6]

Li-Fi basically outcome of twenty first century. Li-Fi is a Visible Light Communications (VLC) system running wireless communications travelling at very high speeds. Li-Fi uses common household LED (light emitting diodes) light bulbs to enable data transfer, boasting speeds of up to 224 gigabits per second. The basic ideology behind this technology is that the data can be transmitted through LED light whose intensity varies even faster than the human eye. As the transmission of the data takes place through the light emitting diodes (LED’s) the amount is comparatively small. In modern times, it is called as the optimized version of Wi-Fi. In simple terms, Li-Fi can be thought of as a light-based Wi-Fi. [7]

1.1 VLC frequency spectrum:

The limited radio frequency spectrum puts constraints on the increasing demand for ubiquitous connectivity and high capacity. The increase in the number of devices accessing the mobile networks is the primary reason for the drastic increase in mobile data traffic. Along with this, the development of online social services (such as Facebook and Twitter) has further increased the mobile data traffic. Apart from the spectrum deficiency issues in RF wireless communication, interference is another problem since most wireless devices are electromagnetic. The RF communication suffers from problems such as the following.

(a) Interference, according to Federal Aviation Administration (FAA) the use of mobile phones on aircraft causes interference with communication and navigational systems. Along with this, mobile phones on aircraft will also cause disruption with ground system towers as argued by the Federal Communication Commission (FCC).

(b) Regardless of the interference, it is clear that in a wireless communication system that needs very low latency requirements (such as in vehicular communication, safety system), the use of radio frequency is not suitable due to its bandwidth limitations.

(c) As RF waves easily penetrate the walls, they suffer from security issues.

(d) The increase in RF waves, transmission power beyond a certain limit results in risks to human health.

(e) RF communication suffers from power inefficiency, because we require a separate setup for communication of the RF waves. To overcome the drawbacks of the RF communication systems, it is imperative to design new communication technologies.

Visible Light Communication (VLC) systems employ visible light for communication that occupy the spectrum from 380 nm to 750 nm corresponding to a frequency spectrum of 430 THz to 790 THz as shown in Fig. 1. The low bandwidth problem in RF communication is resolved in VLC because of the availability of the large bandwidth as illustrated in Fig. 1. [4] The VLC receiver only receives signals if they reside in the same room as the transmitter, therefore the receivers outside the room of the VLC source will not be able to receive the signals and thus, it has the immunity to security issues that occurs in the RF communication systems. As a visible light source can be used both for illumination and communication, therefore, it saves the extra power that is required in RF communication. Keeping in view the above advantages, VLC is one of the promising candidates because of its features of non-licensed channels, high bandwidth and low power consumption. [13]

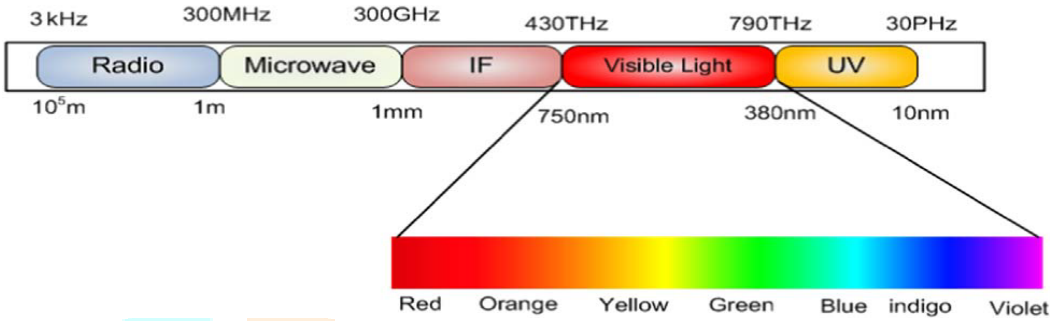


Figure 1. VLC frequency spectrum. [13]

Potential applications of VLC include Li-Fi, vehicle to vehicle communication, and robots in hospitals, underwater communication and information displayed on sign boards. The Li-Fi uses visible light for communication to provide high speed internet up to 10Gbits/s. VLC can be used in vehicular communication for lane change warning, pre-crash sensing and traffic signal violation warning to avoid accidents. These applications require communication with low latency which is provided by VLC because of its high bandwidth and easier installation due to the existing presence of vehicle lights and traffic signals. VLC also has applications in areas that are sensitive to electromagnetic waves, such as aircrafts and hospitals where the radio signals interfere with the waves of other machines. Visible light is used to provide both lighting and information using VLC techniques. For example, we use lighting in the room to provide the room number identification and other information about the building.

II. ARCHITECTURE OF LI-FI

2.1 Architecture of Li-Fi

Li-Fi architecture consist numbers of LED bulbs or lamps, many wireless devices such as PDA, Mobile Phones, and laptops. Important factors we should consider while designing Li –Fi as following:

1. Presence of Light must be line-of-sight.
2. Lamp driver where internet connection, switch and LED lamp connected.
3. for better performance use LED bulbs.
4. A photo detector received data.

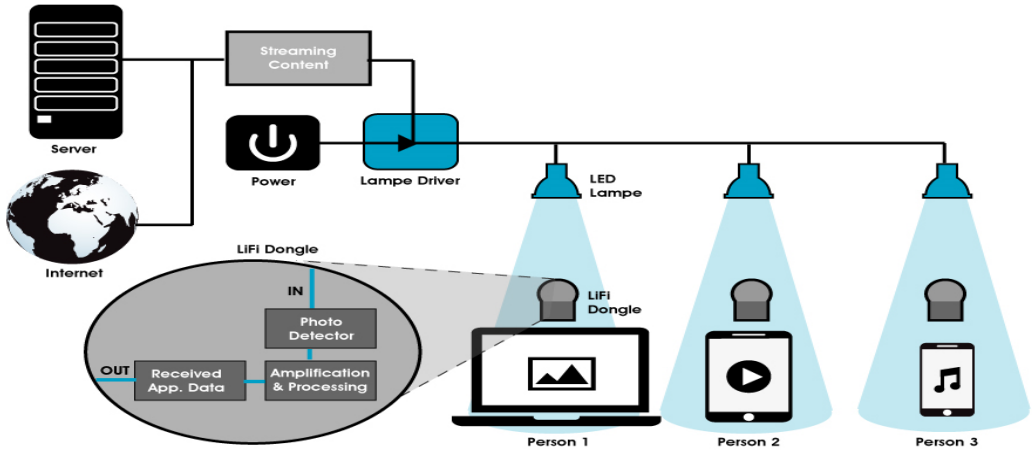


Figure 2. Architecture of Li-Fi [13]

Fig.2 shows Architecture of Li-Fi. In Figure an internet connection is connected to the lamp driver. A switch connected with lamp driver and LED lamp also connected this lamp driver through fiber optics cable. Now a receiving device named photo detector is using for receive signal and processing, this device is connected with PC or Laptop's LAN port. On one end all the

data on the internet will be streamed to a lamp driver when the LED is switched on the microchip converts the digital data in form of light. The light sensitive device photo detector receives the signal and converts it back into original data. This method of using rapid pulses of light to transmit information wirelessly is technically referred as Visible Light Communication.

The working procedure is very simple, if the light is on then transmits a digital 1; if it's off transmit a 0. The LEDs can be switched on and off very quickly which gives nice opportunities for transmitting data. [2]

2.2 Layered architecture of VLC

The two integral parts of the VLC system: the transmitter and receiver generally consist of three common layers. They are the physical layer, MAC layer and application layer. The reference model of the VLC communication system is shown in Fig. 3. In IEEE 802.15.7, only two layers (such as PHY and MAC) are defined for simplicity

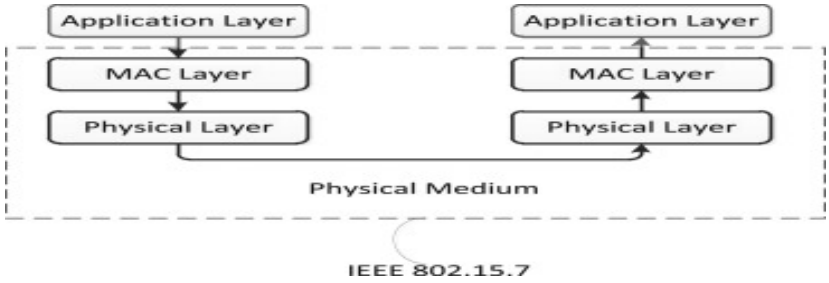


Figure 3. Layered architecture of VLC. [13]

2.2.1 MAC layer

The tasks performed by Medium Access Control (MAC) layer include:

- Mobility support,
- Dimming support,
- Visibility support,
- Security support,
- Schemes for mitigation of flickering,
- Colour function support,
- Network beacons generation if the device is a coordinator,
- VPAN disassociation and association support,
- Providing a reliable link between peer MAC entities.

The topologies supported by the MAC layer are peer-to-peer, broadcast and star as illustrated in Fig. 4. The communication in the star topology is performed using a single centralized controller. All the nodes communicate with each other through the centralize controller as shown in Fig. 3.

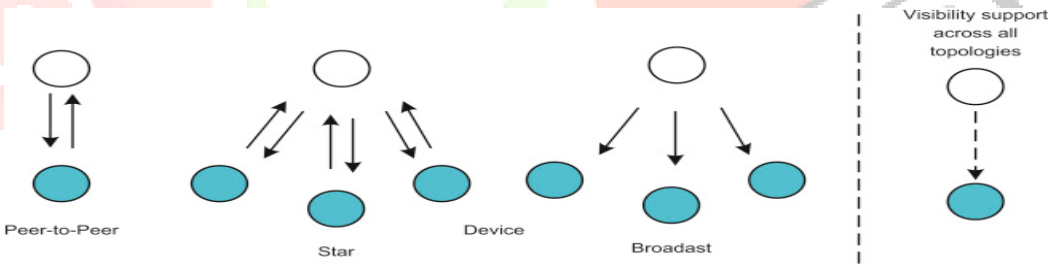


Figure 4. Supported MAC topologies by IEEE 802.15.7

2.2.2 Physical layer

The Physical layer provides the physical specification of the device and also, the relationship between the device and the medium. Fig. 5 shows the block diagram of the general physical layer implementation of the VLC system. First of all, the input bit stream is passed through the channel encoder (optional). Linear block codes, Convolution codes and the state of the art turbo codes can be used to enhance the performance of the VLC system. Then, the channel encoded bit stream is passed through the line encoder to yield the encoded bit stream.

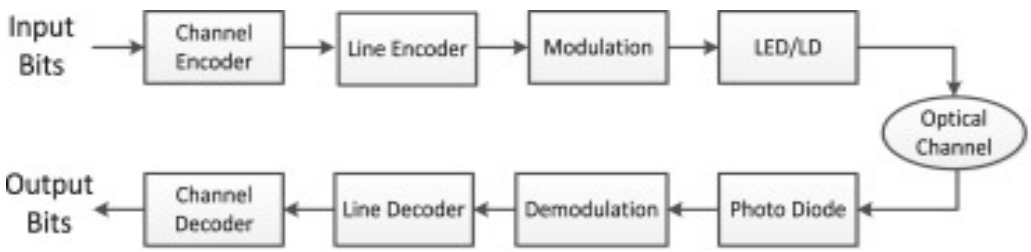


Figure 5. Typical physical layer system model of VLC.

III. MODULATION TECHNIQUES FOR VLC

Modulation in VLC differs from that of RF communication because of the non-encoding feature of information in phase and amplitude of the light signal. Therefore, it is clear that we cannot use amplitude and phase modulation in the case of VLC. Modulation in VLC is achieved using variations in the intensity of the light corresponding to the information in the message signal.

3.1. Factors affecting the modulation in VLC

Two factors to be considered in the design of the modulation scheme for VLC include:

a) Dimming and
b) Flickering.

(a) Different activities require different illuminances, such as 30–100 lux that is required for normal visual activities in public locations. There is a non-linear relationship between the measured light and perceived light and their relation is given by:

$$\text{Perceived Light}(\%) = 100 \times \sqrt{\frac{\text{Measured Light}(\%)}{100}} \qquad (1)$$

(b) The changes in brightness of the modulated light should be done in a way that it should not result in human-perceivable fluctuations. According to IEEE 802.15.7, the switching should be done at a rate faster than 200 Hz for avoiding harmful effects.

3.2. Modulation techniques

Since Li-Fi uses visible light for sending data, it is necessary to modulate the data into a signal which can be transmitted. These signals consist of light pulses. Some of the common modulation techniques used in Li-Fi is discussed below:

3.2.1 OFDM:

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme at a low symbol rate, maintaining total data rates similar to conventional *single-carrier* modulation schemes in the same bandwidth. [9]

3.2.2 OOK:

On-off keying (OOK) denotes the simplest form of amplitude-shift keying (ASK) modulation that represents digital data as the presence or absence of a carrier wave. In its simplest form, the presence of a carrier for a specific duration represents a binary one, while its absence for the same duration represents a binary zero. Some more sophisticated schemes vary these durations to convey additional information. It is analogous to unipolar encoding line code. It is very easy to generate and decode but is not very optimal in terms of illumination control and data throughput. [9]

3.2.3 PWM:

Pulse-width modulation (PWM) is a technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. Pulse Width Modulation transmits the data by encoding the data into the duration of the pulses. More than one bit of data can be conveyed within each pulse. [9]

3.2.4 PPM:

Pulse-position modulation (PPM) is a form of signal modulation in which M message bits are encoded by transmitting a single pulse in one of possible required time-shifts. This is repeated every T seconds, such that the transmitted bit rate is bits per second. It is primarily useful for optical communications systems, where there tends to be little or no multipath interference. [9]

3.2.5 CSK:

Colour Shift Keying **(**CSK) was proposed in IEEE 802.15.7 to enhance the data rate which was low in other modulation schemes. The switching ability slows down by producing white light utilizing yellow phosphor and blue LEDs. Therefore, an alternate way to produce the white light is the utilization of three separate LEDS such Green, Blue and Red. Modulation in CSK is performed using the intensity of the three colors in an RGB LED source.

IV. APPLICATIONS OF LI-FI

Many areas where Li-Fi system provide a reliable, secure, cheaper and ultra-high-speed communication infrastructure have already been launched worldwide, so we can summarize some of them as follows:

1) **Vehicle and traffic lights**: LED devices can be installed as headlights and tail-lights developing an intelligent transport system. Traffic lights can also move to LED with the benefit of road safety and traffic control. [3]
2) **Underwater communication:** Light propagate underwater where radio frequencies cannot be used because of salty, high conductivity and high attenuation environment. Since cables creates threads in communication undersea water, can be replaced with Li-Fi transmitters. Also, they can send data to submarines, to surface as well as to divers with their head lights. [13]

3) **Home and office appliances**: Li-Fi system can be integrated in home appliances such as: secure systems, freeze, central heating systems, TV's, clocks and so on to reduce energy consumptions for an intelligent energy management. Hotspots and monitoring lighting and data can be used to the same communications and sensor infrastructure. [12]

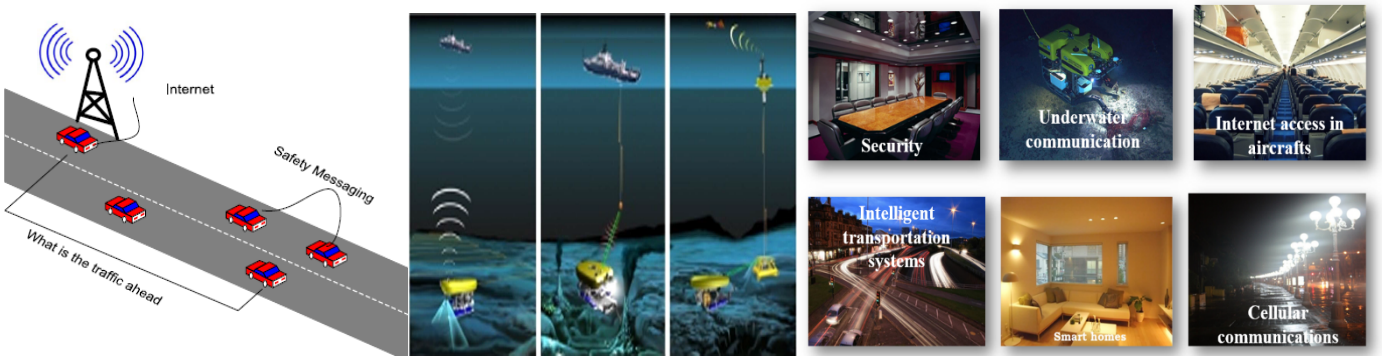


Figure 6. A.VLC for vehicular networks. [3] B. Operation of UTROV. [13] C. Some of viable applications for Li-Fi. [12]

4) **Airplanes**: Since Wi-Fi during flights with most of airlines is forbidden, and therefore limited, Li-Fi can be a suitable replacement for wireless communication. The use of this technology within aircraft cabin has more advantages since significant amounts of cabling can be saved resulting in cost saving, reduced weights and flexible layout design. [3]
5) **Petrochemical industry**: Since various radioactive chemicals are used for processing, the industry does not allow RF.
6) **Nuclear power plants**: Li-Fi can be a useful replacement of Wi-Fi in electromagnetic sensitive areas such as nuclear power plants as it does not cause any electromagnetic interference. [3]

V. PROPOSED STRATEGY

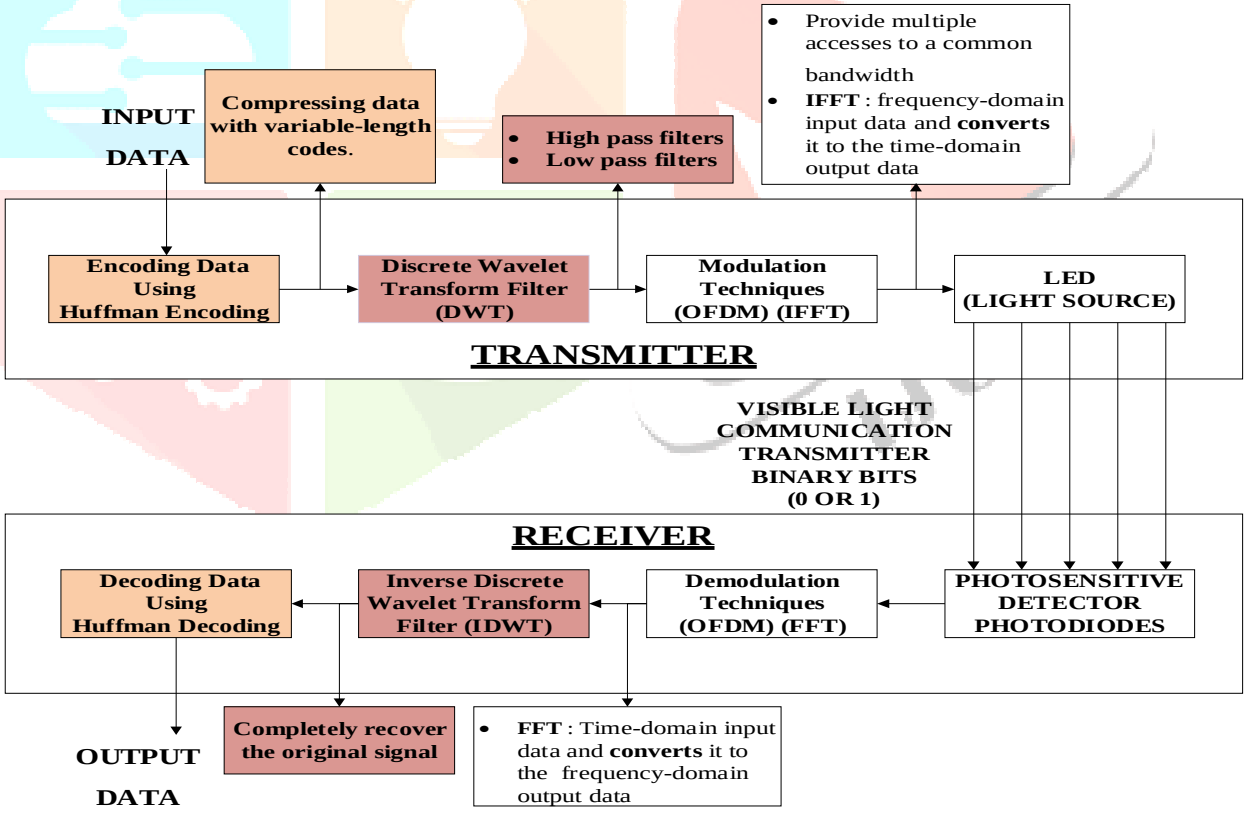


Figure 7. Proposed Model

1. Encoding Data Using Huffman Encoding:

Encoding is the process of converting data into a format required for a number of information processing needs, including:

- Program compiling and execution Data transmission,
- storage and compression/decompression
- Application data processing, such as file conversion

A Huffman code is a particular type of optimal prefix code that is commonly used for lossless data compression. "Encode" a sequence of Characters into a String of 0's and 1's using the Huffman Tree.

2. Discrete Wavelet Transform (DWT):

DWT used for De-noising process. The DWT of a signal x is calculated by passing it through a series of filters in Fig. 8

- "g" low-pass filter, and
- "h" high-pass filter.

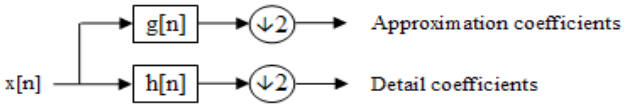


Figure 8. Filter Analysis

The outputs giving the detail coefficients (from the high-pass filter) and approximation coefficients (from the low-pass). At each level in diagram the signal is decomposed into low and high frequencies. Due to the decomposition process the input signal must be a multiple of 2^ n where, n is the number of levels. [14]

3. Orthogonal Frequency Division Multiplexing (OFDM):

OFDM is based on the well-known technique of Frequency Division Multiplexing (FDM). In FDM different streams of information are mapped onto separate parallel frequency channels. [1]

The OFDM is a very efficient modulation technique that can achieve very high throughput by transmitting on a great number of carriers simultaneously. [1]

OFDM is not only a great modulation method, also can provide multiple accesses to a common bandwidth or channel to multiple users. [1]

4. VLC Communication:

Visible light communication (VLC) is a data communications variant which uses visible light between 400 and 800 THz (780–375 nm). VLC is a subset of optical wireless communications technologies. LED lights can be used to transmit data. Visible Light Communication Transmitter Binary Bits (0 or 1)

VLC = Illumination + Communication

Figure 9. VLC Communication [12]

5. Photo-detector or Photodiode:

At the receiver side, the receiver (such as a silicon photo diode and PIN photodiode) received the optical signal. A photodiode is a semiconductor device that converts light into an electrical current. The current is generated when photons are absorbed in the photodiode. Photodiodes may contain optical filters, built-in lenses, and may have large or small surface areas. Photodiodes usually have a slower response time as their surface area increases

6. Demodulation OFDM:

Demodulation is extracting the original information-bearing signal from a carrier wave. A demodulator is an electronic circuit (or computer program in a software-defined radio) that is used to recover the information content from the modulated carrier wave.

7. IDWT:

IDWT is reverse process of DWT, completely recover the original signal form, no information is lost in this transformation.

8. Decoding Data Using Huffman Encoding:

Decoding is the reverse process of encoding which is to extract the information from the converted format.

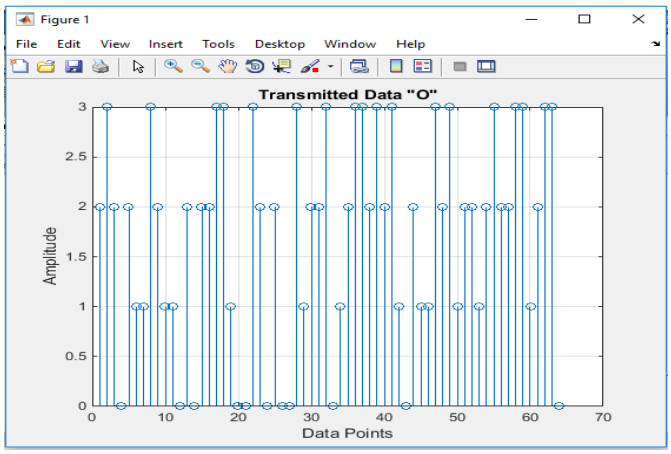
VI. SIMULATION RESULT

6.1 Evolution Parameters:

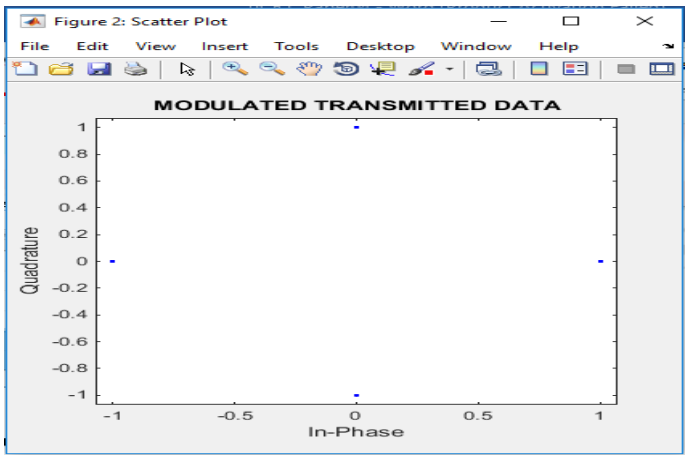
- BER (Bit Error Rate):
  BER=Number of error bits / Number of total bits
- SNR (Signal-to-Noise Ratio):
  $SNR = P_{signal} / P_{noise}$
  Where, P is average power,
  Signal is meaningful information,
  Noise is unwanted signal.
- It means, the less the BER result is the higher the SNR and the better communication quality.

6.2 Implementation Results:

Senders send data through line of sight (LOS) communication channel model with lamberient radiation, the data is shown in Figure 10 (a). Then transmitted data is modulated as shown in Figure 10 (b), this modulated data is shown in OFDM signal in Figure 10 (c), after OFDM Signal, HPA (High Performance Addressing) is added to the signal using DWT filter as shown in Figure 10 (d). then this signal is pass through LOS channel to receiver, after receiving data receiver check the error in modulated data as shown in Figure 10 (e), then receiver demodulate the data and the noise in data is shown in Figure 10 (f).



(a)



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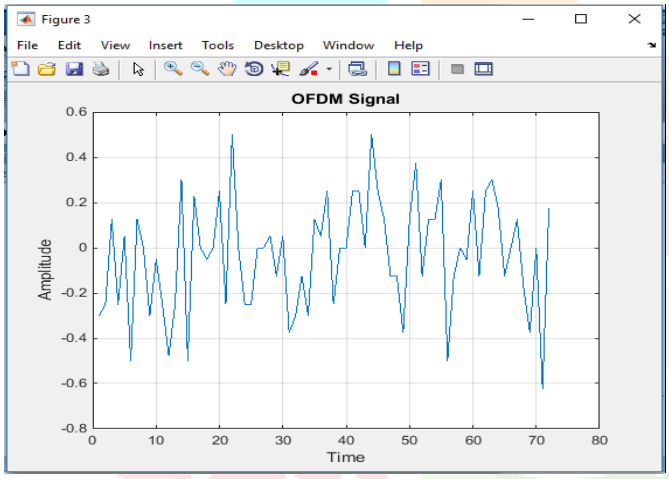

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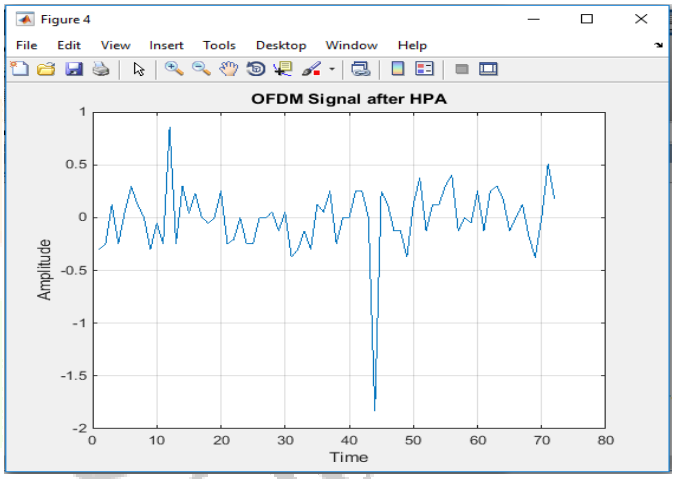
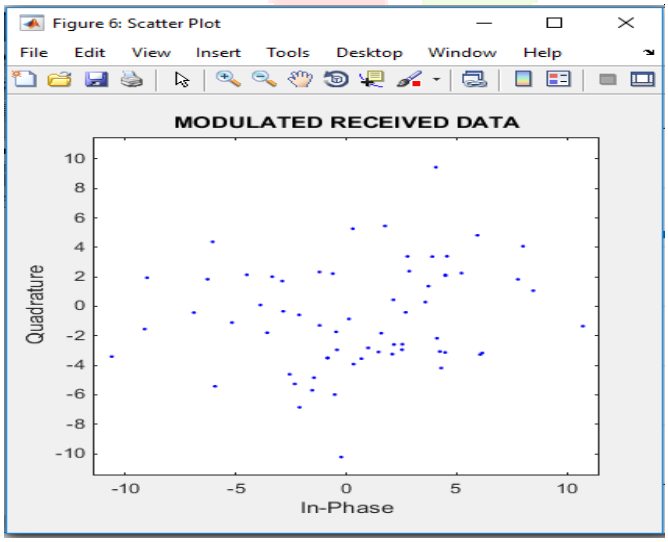
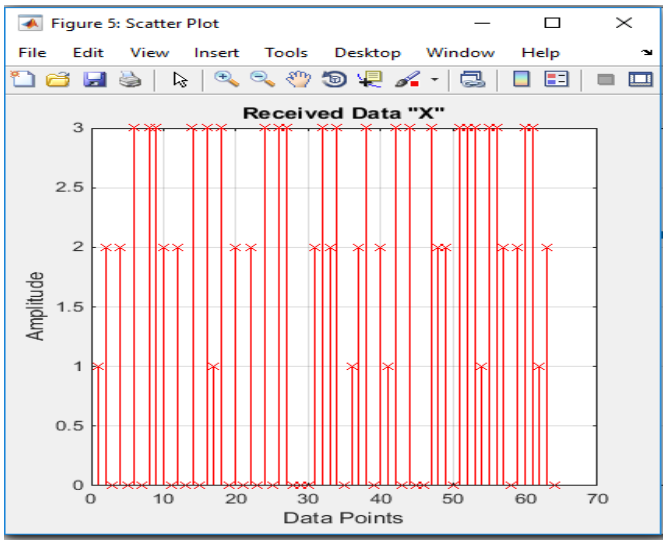


(d)



(e)



(f)

Figure 10. (a) Input transmitted data after encoding, (b) tranmitted data is modulated, (c) Data in OFDM Signal, (d) Data in OFDM signal after HPA, (e) Modulated Data at receiver side and (f) Received data

- **Error Detected in Each Bit at Receiver Side**

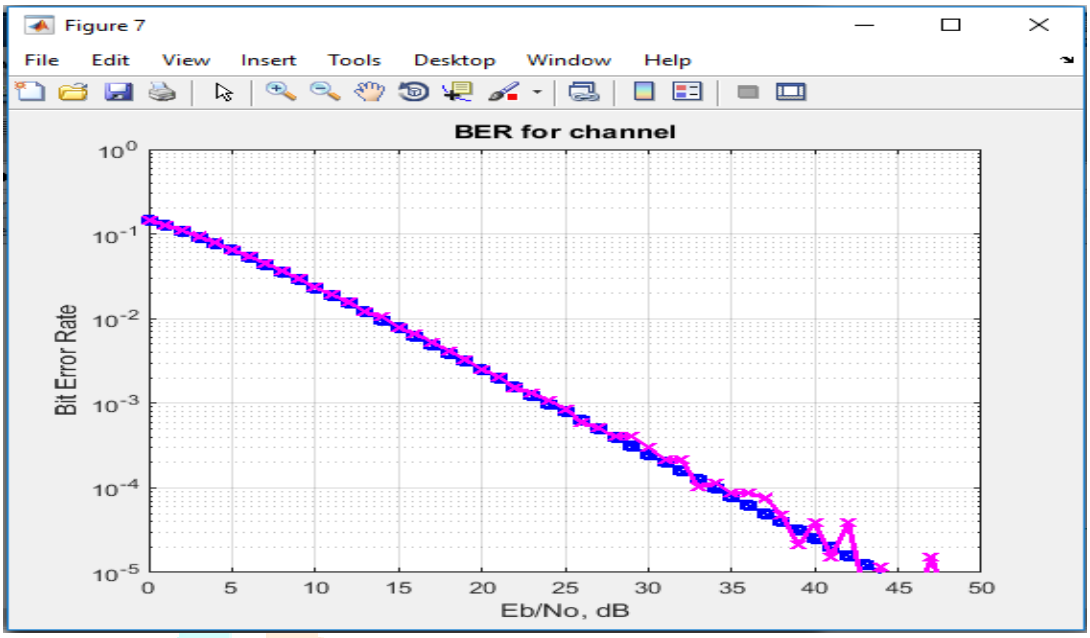


Figure 11. Error Detected in Each Bit at Receiver Side

From Figure 11, its shows the effect on transmitted data after noise is added while traversing through Line of sight with lambertian Radiation. This figure show that proposed strategy is able to detect different noise effect efficiently.

6.2 Result Analysis:

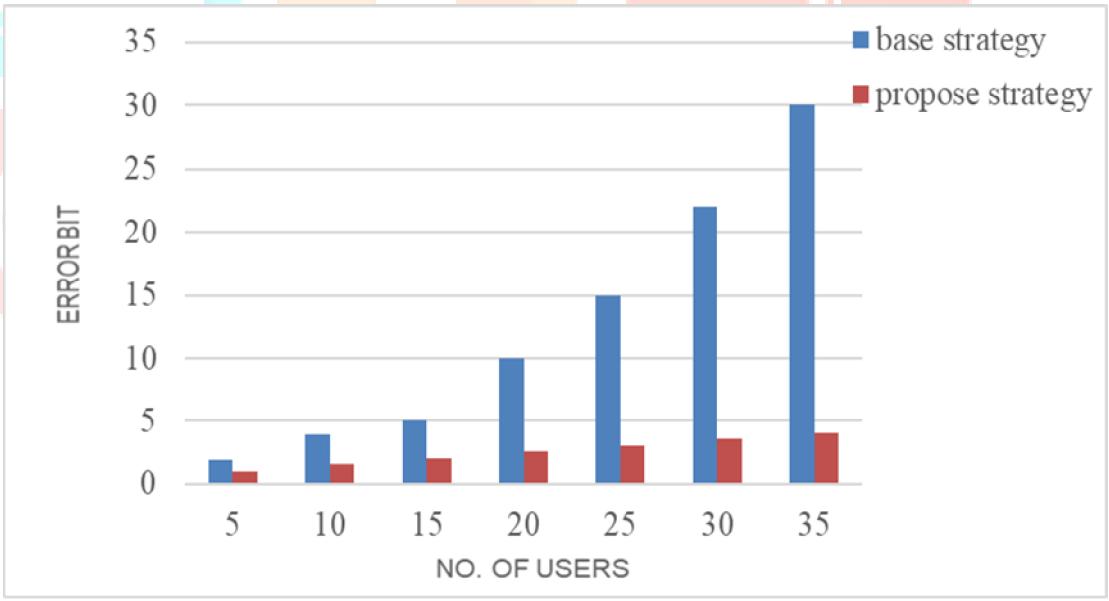


Figure 12. Error bit vs no. of users

The experimental result shown in Figure 12, error bits for users calculated in proposed strategy is less than the base strategy. Thus proposed strategy is efficient.

VII. CONCLUSION

This research paper analyses the shortcoming of previously defined OFDM technique that is previous technique does not consider the accuracy parameter while designing the Li-Fi structure. We work on detecting the noise in received data and also on De-noising process while working with DWT technique. The final result shows that it will efficiently work on de-noising process.

VII. ACKNOWLEDGEMENTS

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REFERENCES

[1] Walid Abdallah and Noureddine Boudriga "Enabling 5G Wireless Access Using Li-Fi Technology: An OFDM Based Approach" 978-1-5090-1467-5/16/ ©2016 IEEE. pp. 1-6.

[2] R.Mahendran "Integrated Lifi(Light Fidelity) For Smart Communication Through Illumination" ISBN No.978-1-4673-9545-8 © 2016 IEEE. pp. 35-56.

[3] Monica Leba, Simona Riurean, Andreea Ionica, "LiFi – the Path to a New Way of Communication" © 2017 IEEE.

[4] Zashi P. Choudhari, Satish R. Devane, "High sensitivity universal Lifi receiver for enhance data communication" 978-1-5090-4556-3/16/ ©2016 IEEE

[5] Sreesha Damodaran, Talal Shaikh, Prof. Nicholas K Taylor "Using Mobile Phone Based Camera To Read Information From A Li-Fi Source" 978-1-5090-5527-2/16© 2016 IEEE. pp. 165-170.

[6] Harald Haas, Liang Yin , Yunlu Wang and Cheng Chen "What is Li-Fi ? " JOURNAL OF LIGHTWAVE TECHNOLOGY VOL. 34, NO. 6, MARCH 15, 2016, 0733-8724 © 2015 IEEE.

[7] Manoj V. Bhalerao , Dr. S. S. Sonavane "Visible light communication: A smart way towar wireless communication" 2014 International Conference on Advances in Computing,Communications and Informatics (ICACCI) 978-1-4799-3080-7/14/ © 2014 IEEE. pp. 1370-1375.

[8] Shivaji Kulkarni, Amogh Darekar, Pavan Joshi "A Survey on Li-Fi Technology" IEEE WiSPNET 2016 conference. 978-1-4673-9338-6/16/ © 2016 IEEE. pp. 1624-1625.

[9] Anshu Adwani , Smita Nagtode "Li-Fi: Information Transferring Through Led's" 978-1-4673- 9939-5/16/ © 2016 IEEE.pp. 2125-2127.

[10] Noof Al Abdulsalam, Raya Al Hajri, Zahra Al Abri, Zainab Al Lawati, and Mohammed M. Bait- Suwailam "Design and Implementation of a Vehicle to Vehicle Communication System Using Li-Fi Technology" 978-1-4799-8966-9/15/ ©2015 IEEE.

[11] Mrs. Padmini Mishra, Jyoti Poddar, SonuPriya and Minu kumari"A Review on Li-Fi: The Green Wi-Fi" International Research Journal of Engineering and Technology Volume: 03 Issue: 03, Mar-2016, © 2016, IRJET.pp.99-103.

[12] "What is Li-Fi?", accessed on 24th October 2017 http://www.eng.ed.ac.uk/drupal/hxh

[13] "VISIBLE LIGHT COMMUNICATION: APPLICATIONS, ARCHITECTURE, STANDARDIZATION AND RESEARCH CHALLENGES", ACCESSED ON 14TH NOVEMBER 2017 HTTP://WWW.SCIENCEDIRECT.COM/SCIENCE/ARTICLE/PII/S2352864816300335

[14] "DISCRETE WAVELET TRANSFORM FILTER BANK IMPLEMENTATION (PART 1)", ACCESSED ON 25 OCTOBER 2017, HTTPS://WWW.MATHWORKS.COM/SUPPORT/SYSREQ.HTML

[15] "System Requirements for MATLAB", accessed on 30 October 2017, https://www.mathworks.com/support/sysreq.html

[16] "Concepts of OFDM", accessed on 30 October 2017, http://rfmw.em.keysight.com/wireless/helpfiles/89600b/webhelp/subsystems/wlanofdm/content/ofdm_basicprinciplesoverview.htm