Li-Fi (Light Fidelity): Data Communication Using Visible Light

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ABSTRACT

Li-Fi stands for light fidelity. Li-Fi is a bidirectional, high-speed and fully networked wireless communication technology similar to Wi-Fi. Li-Fi provides transmission of data through illumination by sending data through an LED light bulb that varies in intensity faster than human eye. The light which we are using in our daily life is not only used for providing light but also for communication by illumination. The Radio Frequency (RF) communication suffers from interference and high latency issues. Along with this, RF communication requires a separate setup for transmission and reception of RF waves. Overcoming the above limitations, Visible Light Communication (VLC) is a preferred communication technique because of its high bandwidth and immunity to interference from electromagnetic sources. Li-Fi is a latest technology that makes use of LED (Light Emitting Diodes) light which helps in the transmission of data much faster and flexible than data that can be transmitted through Wi-Fi. It refers to 5G VLC systems using LED as a medium to high-speed communication, Li-Fi provides better Capacity, efficiency, availability and security than Wi-Fi.

Keyword:-*Li-Fi (light fidelity), LED (Light Emitting Diodes), VLC (Visible Light Communication), WI-FI and5G Network.*

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1. INTRODUCTION

Light Fidelity or 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 [4]. 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 [2]. That is, it uses light instead of radio waves to transmit information and instead of Wi-Fi modems, Li-Fi would use transceiver-fitted LED lamps that can light a room as well as transmit and receive information [3]. Since simple light bulbs are used, there can technically be any number of access points. As there are more and more devices coming up day-by-day the signals are being clogged up due to heavy traffic, there arises a need for an error free transmission technology and the solution to this problem was the Li-Fi technology [1].

2. WORKING TECHNOLOGY

2.1 BASIC CONCEPT

An advance way to transfer information could drastically change path that systems can communication with each other called Li-Fi. Li-Fi uses visible light to transfer data between two devices which do not have physical connection. This idea is inspired from VLC (Visible light Communication) which uses visible light LED for transmitting data [4].

Li-Fi technology is a wireless communication system based on the use of visible light between the blue (670 THz) and red (480 THz). Unlike Wi-Fi which uses the radio part of the electromagnetic spectrum, Li-Fi uses the optical spectrum. The principle of Li-Fi is based on sending data by amplitude modulation of the light sources in a well-defined and standardized way. The principle is simple: the LED turns on and off at high speed and is not visible to humans. This ribbon of on and off signals is interpreted to create binary streams of 0 and 1. Because there are no battling light frequencies like that of the radio frequencies in Wi-Fi, Li-Fi is thought to be 80% more efficient.

2.2 WORKING MECHANISM

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 as shown in Fig.1 [2].

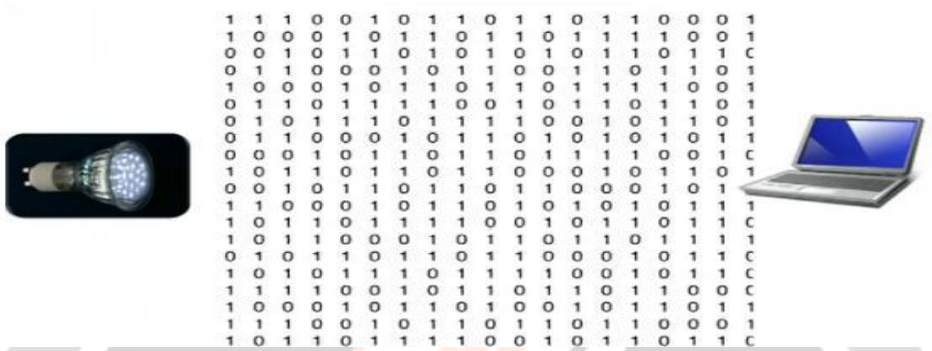

Fig -1: Li-Fi Works [13]

Hence all that required is some LEDs and a controller that a code data into those LEDs. All one has to do is to vary the rate at which the LEDs flicker depending upon the data want to encode. Further enhancements can be made in this method, like using array of the LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light's frequency with each frequency encoding a different data channel.

2.3ARCHITECTURE 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.

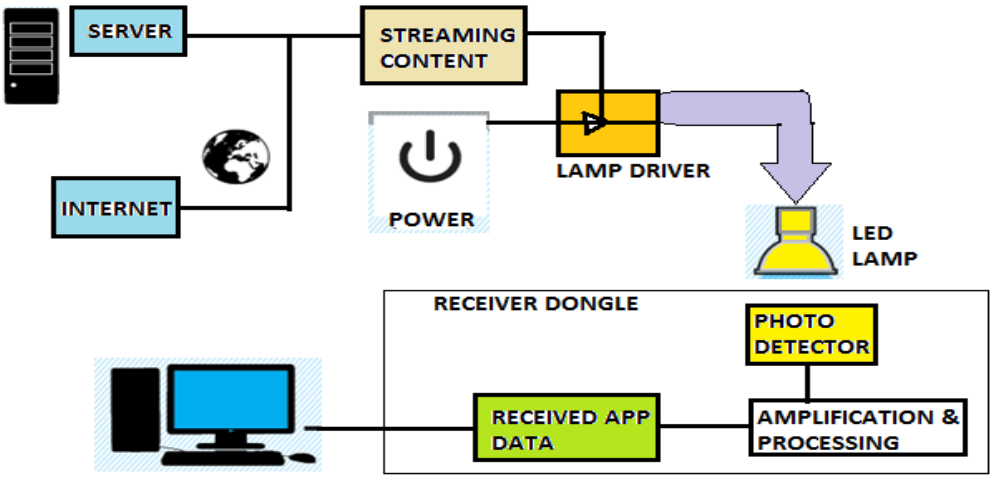

Fig -2: Architecture of Li-Fi [12]

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.

3. 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:

A. **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].

B. **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].

C. **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].

D. **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].

3.1 COMPARISON OF LI-FI AND WI-FI TECHNOLOGIES

Table -1: Comparison of Li-Fi and Wi-Fi Technologies.

PARAMETERS	LI-FI	WI-FI
SPEED	1-3.5 Gbps	54-250 Mbps
RANGE	10 meters	20-100 meters
IEEE STANDARD	802.15.7	802.11b
SPECTRUM RANGE	10000 times than WI-FI	Radio spectrum range
NETWORK TOPOLOGY	Point-to-Point	Point-to-Multi Point
DATA TRANSFER MEDIUM	Use light as a carrier	Use radio spectrum
FREQUENCY BAND	100 times of THz	2.4 GHz

3.2 MERITS OF LI-FI

- **Capacity:** The bandwidth of light is 1000 times wider than the bandwidth of radio waves. As the equipment are already available and the light sources are already installed so, it has got better capacity.
- **Efficiency:** Li-Fi works on visible light technology. Since homes and offices already have LED bulbs for lighting purposes, the same source of light can be used to transmit data.
- **Availability:** Wherever there is a light source, there can be Internet. Light bulbs are present everywhere – in homes, offices, shops, malls and even planes, meaning that high-speed data transmission could be available everywhere.
- **Security:** One main advantage of Li-Fi is security. Since light cannot pass through opaque structures.
- High data transmission rates of up to 10Gbps can be archived.

3.3 DEMERITS OF LI-FI

- LI-FI requires Line of Sight.
- One of the biggest potential drawbacks is the interception of signals outdoors. Sunlight will interfere the signals, resulting in interrupted Internet.
- If the apparatus is set up outdoors, it would need to deal with changing weather conditions.
- A whole new infrastructure for Li-Fi would need to be constructed.
- Light waves can easily be blocked and cannot penetrate thick walls like the radio waves can.
- Internet cannot be used without a light source. This could limit the locations and situations in which Li-Fi could be used.

3.4 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:

- **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].
- **Underwater**: 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 [3].
- **In 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 [3].
- **Petrochemical industry**: Since various radioactive chemicals are used for processing, the industry does not allow RF [3].
- **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].
- **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].

4. RELATED WORKS

4.1 LITERATURE REVIEW

4.1.1 Enabling 5G Wireless Access Using Li-Fi Technology: An OFDM Based Approach

- In [1] Walid Abdallah and Noureddine Boudrigapaper, the light fidelity (Li-Fi) technology is one of the promising solutions to increase transmission capacity in the indoor scenario. It is based on light emitting diodes (LEDs) to enable high speed communication with fully networking capabilities. In this paper, the author investigate orthogonal frequency division multiplexing (OFDM) to reach targets using 5G optical wireless access in terms of data rates and transmission delays. Specifically, the author propose a Li-Fi access-point architecture that implements a novel OFDM encoding/decoding technique based on delaying optical pulses in a vector of optical delay lines loops (ODLs).

4.1.2 Integrated Li-Fi (Light Fidelity) For Smart Communication through Illumination

- In [2] R.Mahendranpaper, wireless communications have become important in communication process. The main way to transmit wireless data is by using electromagnetic waves i.e. radio waves. However, radio waves can support less bandwidth because of compact spectrum availability and intrusion. Solution to this is data transmission using Visible Light Communication (VLC).In Li-Fi basically we focus to transmitting multimedia data between two terminals using LED's. Li-Fi is a transmission of data through illumination, in which data can be sent through a LED light bulb that varies in intensity faster than human eye can follow. The light used in our daily life is not only used for providing light but also for communication by illumination.

4.1.3 LiFi –the Path to a New Way of Communication

- In [3] Monica Leba, Simona Riurean and AndreeaIonicapaper, Due to the latest improvements, the optical wireless communication (OWC) proves to be a viable alternative solution to the issues of forthcoming radio frequency RF spectrum crisis, especially in certain places and situations. Currently, most mobile data traffic

is consumed indoor, where light fidelity (Li-Fi) which is related to visible light communication (VLC) offers lots of specific advantages, and effective solutions to the many issues of wireless communication. The current paper summarizes most of the research, developments and applications achieved so far and looks at the different aspects of the strengths and weaknesses, implementations, challenges and data modulation techniques of the VLC and specific Li-Fi new coined optical wireless communication technology.

4.1.4 High sensitivity universal Li-Fi receiver for enhance data communication

- In [4] Zashi P. Choudhariand Satish R. Devanepaper, wireless data communication between two systems through visible light. This approach creates a way which can make data transmission faster than current wireless communication technology. Use of visible light for wireless communication can solve issue of lack of radio wave spectrum space that will increase the data transmission rate. This paper describes the design, fabrication, and capabilities of visible light-based data communication, as well as the development of the LED and photo sensor based optical wireless communication system.

4.1.5 Using Mobile Phone Based Camera to Read Information from a Li-Fi Source

- In [5]Sreesha Damodaran, Talal Shaikh and Prof. Nicholas K Taylor paper, this paper investigates the use of LED light to act as a Li-Fi source in order to transmit data. The data is captured using the CMOS (Complementary metal–oxide–semiconductor) camera of an Android smart phone. The experimental setup is tested using two different Android devices and the results are compared.

4.2 COMPARATIVE TABLE

Table -2: Comparative Table

Sr. No.	Paper Title	Method Used	Advantages	Disadvantages
1	Enabling 5g Wireless Access Using Li-Fi Technology: An OFDM Based Approach	OFDM encoding/decoding technique	Increasing the data rates provided to users, Reducing transmission delays	Due to the limited transmission range of the VLC
2	Integrated Li-Fi (Light Fidelity) For Smart Communication Through Illumination	Communication by illumination	Li-Fi provides secured, low cost, easy data transmission and provides reliable communication.	The communication is done in direct line of sight manner by deploying transmitter and receiver
3	Li-Fi – The Path to A New Way of Communication	Signal carrier modulation communication-with pulse width modulation	High data transmission rates of up to 10Gbps can be archived	A whole new infrastructure for Li-Fi would need to be constructed.
4	High Sensitivity Universal Li-Fi Receiver for Enhance Data Communication	OOK: On-off keying	Eco friendly transmission is feasible through light fidelity	Lights ON: Light sources totally need to be on for VLC communication.
5	Using Mobile Phone Based Camera to Read Information from A Li-Fi Source	Color detection technique	Li-Fi sources are intolerant to noises and disturbances	Li-Fi only works in Line of Sight.

4.3 CURRENT ISSUES IN LI-FI TECHNOLOGY

According to the literature review there are some problems related to Li-Fi wireless data communication between two systems such as: Delaying optical pulses, Noisy data, Speed, and Capacity for accessing multiple users etc. The proposed model's main focus is to improve accuracy. That is main goal is to reduce Noisy data and improve accuracy.

4.4 PROPOSED MODEL

Wireless data communication between two systems and accuracy for different technique has been proposed for Li – Fi transmitting data as shown in Fig.3

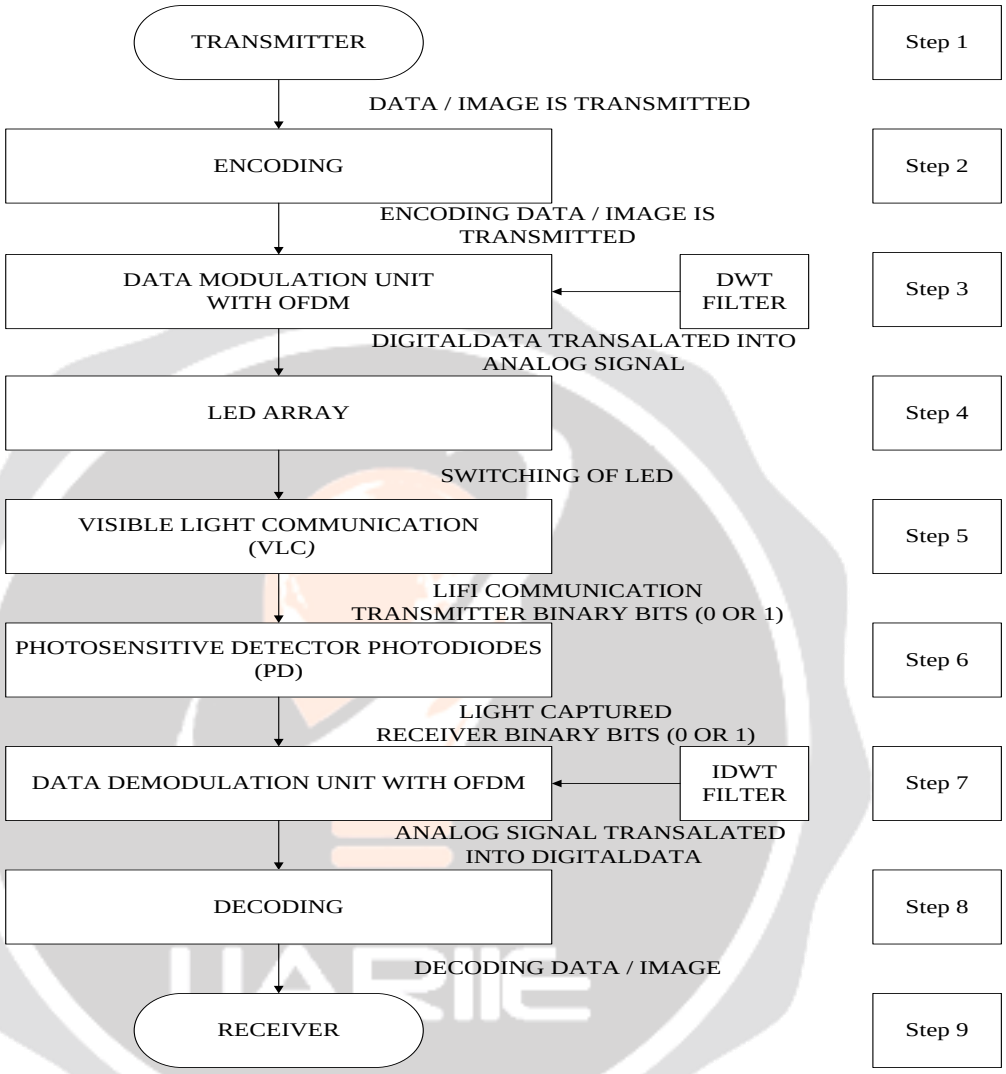

Fig - 3: Li-Fi Proposed Model

In order to enhance the wireless data communication between two systems and accuracy for different technique has been proposed and following are the steps.

Step 1: Transmitter: Transmitters are devices that are used to send out data as radio waves in a specific band of the electromagnetic spectrum in order to fulfill a specific communication need, Send the original data/ image. For example, many modern devices that have communication capabilities have transmitters such as mobile phone, pc, and laptop.

Step 2: Encoding: Encoding is the process of converting the data or a given sequence of characters, symbols, alphabets etc., into a specified format, for the secured transmission of data.

Step 3: Modulation Technique and DWT filter: After encoding, modulation (such as ON–OFF keying, OFDM, PPM and PWM, etc.) is performed.

- **OFDM:** The OFDM is a very efficient modulation technique that can achieve very high throughput by transmitting on a great number of carriers simultaneously. It is also very spectrally efficient because of the proximity of the subcarriers. OFDM is not only a great modulation method; it also can provide multiple accesses to a common bandwidth or channel to multiple users.

- **DWT Filter:** The DWT (Discrete Wavelet Transform), simply put, is an operation that receives a signal as an input (a vector of data) and decomposes it in its frequential components. By this description, it may be confused with the also very important DFT (Discrete Fourier Transform) but the DWT has its tricks. First, DFT has a fixed frequency resolution (eg: It can separate frequential components lineally along the whole frequency range), on the other hand, DWT can separate frequential components with an increasing frequency resolution as the frequency increases. This means that at bigger frequencies, the number of components that can be distinguished is larger [14].

Step 4: Start LED Array: Finally, the data is fed to the LED for transmission through the optical channel. In, different implementations of the visible light communication systems are given. In, a full-duplex bi-directional VLC system utilizing RGB LEDs and a commercially available phosphor-based LED in downlink and uplink, are proposed respectively.

Step 5: Visible Light Communication (VLC): 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.

VLC = Illumination + Communication

Optical Wireless communication (OWC) is a general term which refers to all types of optical communications where cables (optical fibers) are not used. VLC, FSO, Li-Fi and infra-red remote controls are all examples of OWC.

Step 6: Photo Diode (PD): 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.

Step 7: Demodulation technique and IDWT filter: 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.

Step 8: Decoding: Decoding is the reverse process of encoding which is to extract the information from the converted format.

Step 9: Receiver: After demodulation and decoding, the bit stream passed through the channel decoder to yield the output bits. The receiving end of a communications channel

5. CONCLUSIONS

The Li-Fi technology will become one of the major technologies in near future. It overcomes the limitations of radio spectrum and provides high data transfer rate. Li-Fi technology promises to provide a faster, safer, greener, better and healthier future for wireless communication system. This technology is an effective not only for wireless but also underwater communication. Eco friendly transmission is feasible through light fidelity. Li-Fi provides secured, low cost, easy data transmission and provides reliable communication. Every light bulb can be used something like a Wi-Fi hotspot. It can also be used in industrial, medical, military applications.

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7. 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, AmoghDarekar, Pavan Joshi "A Survey on Li-Fi Technology" IEEE WiSPNET 2016 conference. 978-1-4673-9338-6/16/ © 2016 IEEE. pp. 1624-1625.

[9] AnshuAdwani ,SmitaNagtode "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] Yunlu Wang and Harald Haas "Dynamic Load Balancing with Handover in Hybrid Li-Fi and Wi-Fi Networks"Journal of Lightwave Technology VOL. 33, NO. 22, NOVEMBER 15, 2015, 0733-8724 © 2015 IEEE.

[12] 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.

[13] http://www.eng.ed.ac.uk/drupal/hxh accessed on 24th October 2017

[14] https://www.dsprelated.com/showarticle/115.php accessed on 18th November 2017

BIOGRAPHIES

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