5th IEEE International Conference on Recent Advances and Innovations in Engineering- ICRAIE 2020 (IEEE Record#51050)

A Review of LiFi Technology

Kanchan Tiwari Swami
Department of Information Technology
U.I.T, R.G.P.V.
Bhopal, India
Email-ktit27@gmail.com

Asmita A. Moghe
Department of Information Technology
U.I.T, R.G.P.V.
Bhopal, India
Email-aamoghe@rgtu.net

2020 5th IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE) | 978-1-7281-8867-6/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICRAIE51050.2020.9358340

***Abstract*—Light Fidelity (LiFi) is a wireless visible light communication technology, which answers the challenges of 5G. This paper explains the basic need of LiFi over WiFi. It describes the working methodology of LiFi and briefly discusses the various modulation techniques used in LiFi technology for data transmission. It also gives an overview of journey of visible light communication technology from ancient time to LiFi era. In this paper we have described the applications of LiFi in different domains which will help us to magnify the new research area in this technology.**

Keywords—LiFi, Visible Light Communication (VLC), Light Emitting Diode (LED), Photo Detector

I. INTRODUCTION

Wireless Data Communication has become an imperative part of our personal and professional life. In last few decades, the demand of wireless communication has increased exponentially, which makes the radio spectrum below 10 GHz inadequate [1]. If industry increases radio spectrum above 10 GHz then it results in path loss [1,2]. According to the Friis equation $L \propto f^2$ where L is Path Loss and f is Frequency. Two more problems can arise if radio frequency is increased i.e., blocking and shadowing [1,2]. To overcome such problems the radio waves are replaced by visual light [3]. LiFi uses LED for wireless communication, a single micro-LED can transmit 3 Giga bit per second [4].

LiFi term was first introduced by professor Harald Haas at the TED Global Talk 2011 [5]. Downside of Radio waves as compared to visual light that was pointed by Prof. Haas at the Global Talk includes the following:

1. **Capacity-** Spectrum of radio waves is ten thousand times less than spectrum of visual light [5] therefore the capacity of radio waves is less than visual light.
2. **Availability-** In some sensitive places like hospitals, planes etc. mobile phones are prohibited [5] because of electromagnetic waves mainly radio waves as they are harmful to human body [6]. So, in place of radio waves if we use visual light it would solve the problem since light does not harm the human body but is a part of life. We don't need to install separate infrastructure, as visual light is already present in our homes in the form of electric bulbs, we only need to replace normal bulbs by LED [5]. Moreover, we can use headlight and tail light of vehicles for data communication on road [7].
3. **Efficiency-** 1.4 Billion radio wave stations are used for wireless communication [7], in which most of the energy is used to cool down the base stations [5], as radio waves emit heat. On the other hand, LEDs will not only provide light to the rooms but can also transmit data at the same time [8].
4. **Security-** Visual lights are more secure than radio waves as radio waves can travel beyond the wall which makes them insecure, on the other hand, visual lights cannot penetrate the walls [9].

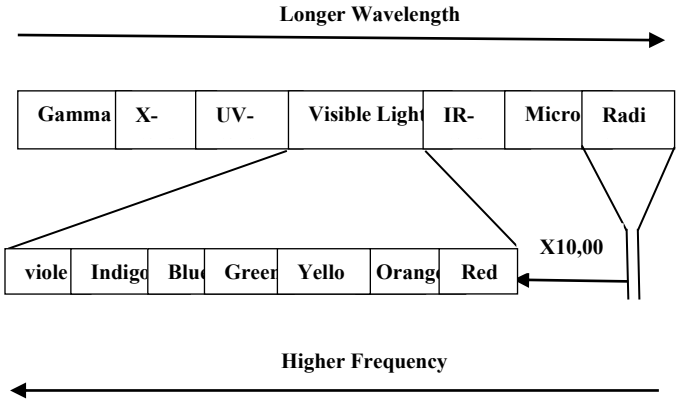

Figure 1. Electromagnetic Spectrum

Above four points describes the need of LiFi over WiFi.

II. EVOLUTIONOF VISUAL LIGHTCOMMUNICATION

In primordial times the visual light was used to send messages in the form of fire [10]. This section briefly describes the evolution of light communication technologies from semaphore line based optical communication system to LiFi.

TABLE I. HISTORY OF VLC

YEAR	DESCRIPTION
1790	Semaphore line based optical communication system was developed in France [10] during the French Revolution for faster and dependable military communication.
1792	Claude Chappe of France invented the first visual telegraph system along with four of his brothers [11,12].

978-1-7281-8867-6/20/$31.00 ©2020 IEEE

Early 1800s	US military invented a wireless solar telegraph known as Heliograph [10], which reflect the sunlight in flashes with the help of moveable mirror [13].
1880	First wireless telephone was developed by Alexander Graham bell, which sent voice signal with the help of light beams [14], the device was named Photophone.
1930	Heinrich Lamm sent an image from a bundle of optical fibers but this idea was given by John Logie Baird in 1920 [15].
YEAR	**DESCRIPTION**
1970	Corning Incorporate (An American Multinational Technology Company) developed a single mode optical fiber [15]. GaAs (Gallium Arsenide) semiconductor laser was also developed around the same time which was used for long distance communication [10].
2003	The transmission of data using LED was first demonstrated at Nakagawa Lab, Keio University, Japan [10].
2011	LiFi term was first given by Prof. Harald Haas in TED Global Talk [5].

Table I describes the journey of visual light communication.

III. Working Principle Of LiFi Technology

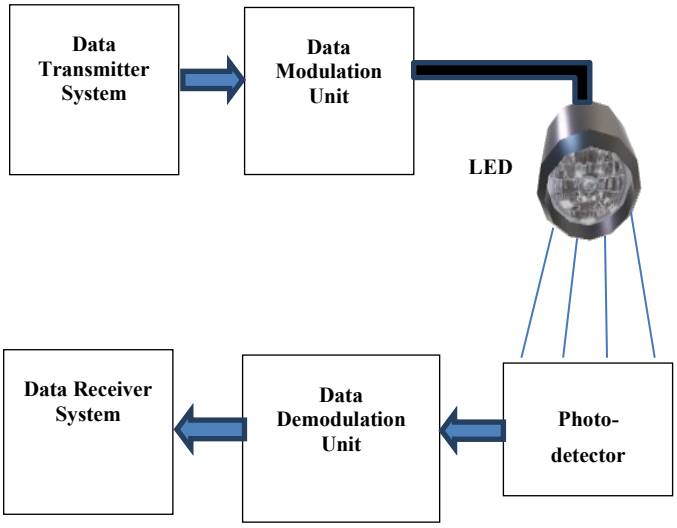

Figure 2. Basic Working Methodology of LiFi

LiFi uses visual light spectrum for optical wireless communication. The range of visual spectrum varies from 300 GHz to 700 GHz [2]. Among all electromagnetic waves the wavelength of only visual light is visible to human eye therefore visual lights are used in our daily routine. Visual light communication is based on binary system, when LED is on it conveys '1' and when off it conveys '0' [16]. The phenomenon of LED on and off is too brisk therefore it cannot be noticed by human eye and the core functionality of LED is not muddled [7].

Figure 2 shows that the information is transmitted in the form of signals from transmitter to the data modulation unit where it is converted to digital signal by using different modulation techniques, then LED transfers the information in binary form by using visual light. This visual light is captured by photodetector where the light signal is converted to electric signal [8] and this electric signal is demodulated in the demodulation unit and then finally received by the receiver.

IV. Modulation Techniques Used In LiFi

Many modulation techniques that are developed for radio wave communication are modified for optical wireless communication [17].

A. **Single Carrier Modulation-** In this type of modulation the data is carried by single main carrier. This technique is more energy efficient than multi carrier modulation [1]. Mostly used single carrier modulation techniques for wireless communication [1] are;

- ON-OFF Keying (OOK)
- Pulse Position Modulation (PPM)
- Pulse Amplitude Modulation (PAM)

OOK is one of the prominent modulation techniques which is also known as Amplitude Shift Keying. In OOK if no signal is transmitted then it indicates *0* bit and if signal is transmitted then it indicates *1* bit. There are two stumbling blocks of OOK; (a) it is sensitive for additive white Gaussian noise [2], (b) high data rate cannot be attained [17].

In PPM the amplitude and width are unchanged and position of pulse varies according to reference pulse of input signal [2]. PPM is more power efficient and poor spectral efficient than OOK [1].

PAM map the signal data for selection of LED [17]. It is a safe and secure modulation technique in optical communication system due to the following reasons [18]; (a) benefits in less complexity, (b) flexible in implementation, (c) has simple structure.

B. **Multi Carrier Modulation-** OOK, PPM and PAM are not suitable for high data rate, when data rate is increased over LiFi network all above mentioned techniques will suffer from some problems [1] like Non-Linear Signal Distortion and Inter Symbol Interference [19]. So due to such reasons multi carrier modulation technique is spot lighted for high-speed communication [17], moreover it is more bandwidth efficient as compared to single carrier modulation [1]. Mostly used multi carrier modulation techniques for optical wireless communication are [17];

- Orthogonal Frequency Division Multiplexing (OFDM)
- Wavelength Division Multiplexing (WDM)

- Multiple Input- Multiple Output Technique (MIMO)

OFDM technique is based on fast Fourier transformation [20], due to this reason the signal processing implementation is computationally effective. In OFDM the data stream is transmitted simultaneously with the help of orthogonal sub-carriers [1,16]. The communication channel is divided into sub-channels which are equal to orthogonal sub-carriers [16].

C. **Specific Modulation for LiFi-** Color Shift Keying (CSK) modulation is specific intensity modulation technique for visual light communication [19]. When white light is produced by using yellow phosphor and blue LED then switching ability of Led slows down [10]. Another method to produce white light is by using three different LEDs, i.e.; red, blue and green [1,10]. The privilege of CSK over traditional intensity modulation technique [1] includes;

- continuous illuminous flux and no flickering effects
- ameliorate LED reliability.

This modulation technique improves the data rate as compared to other modulation techniques.

V. Literature Review

In this section a few existing researches on LiFi technology have been discussed, which will help us to better understand the latest growth of LiFi.

The image transmission approach using visible light was proposed by Mahendran [8]. He used ARM microcontroller which has serial communication capacity for data transfer

Image transmission using LiFi technology was also proposed by Mohit Vasuja, A.K Mishra et al. [2]. The authors had used InfraRed (IR) light for transmitting and photodiode for receiving the image. The selected image is first converted to black and white format, resized according to the size of Graphical Liquid Crystal Display (GLCD). The Micro-Controller uses OOK modulation technique to convert the image data into binary form. IR-LED transmits the binary data, which is received by photo-diode. In the decode unit again the micro-controller will convert the binary data and display the image on GLCD. The performance is evaluated by calculating the Bit Error Rate (BER) and Bit rate, which is 76,800 bps.

The Vehicle to Vehicle(V2V) communication is possible with help of head-light and tail-light of vehicles on road. By using V2V communication the emergency vehicles like ambulance, fire brigade, police vehicle etc. are detected and an alert message is sent to traffic signal which will help in traffic clearance mechanism. If this system is designed in real world then the emergency vehicles may reach on time and will save many lives. The paper [7] had proposed an emergency vehicle detection and traffic clearance system.

Now-a-day many researchers are exploring different areas where the visible lights communication is more efficient than WiFi M.S Mekala, P. Viswanathan et al [21] had proposed a Human Safety Management Algorithm to avert the causality during some environmental peril in an underground mining process. Many people are injured/die in mines due to many reasons like rock fall, omission, bangs etc. If these people get an alert on time then many tragedies can be avoided. Communication through radio waves is not suitable for mines because there are many environmental issues which can interrupt the radio waves. Therefore, the authors of this paper proposed a Decision-Making System which uses different sensors for taking correct decision and conveying that decision to end person in mines with the help of Light Fidelity. The combination of IoT and LiFi technology is growing very rapidly. IoT is a framework where physical devices are embedded with sensors to gather the data and send it over the network. These days the LiFi technology is preferred to share data rather than WiFi technology. Jayant, Swapnaja and Roopali [22], had proposed a system which work as a mediator for cloud service provider and organization using cloud to store data. To make better business decision and to increase customer satisfaction the real time and continuous data is collected with the help of IoT devices. In the given system the data stored on cloud is encrypted by using ASE algorithm, it is 128-bit symmetric key cryptography algorithm. The role-based access control approach is used, so that the data can be accessed only by authorized client.

One more application which is based on VLC was developed by Xiaoxuan Qi, Li Du et al [23]. They had designed the glasses for blind people to deal with the problem of indoor items positioning. The micro-controller unit is used to store the position coordinates of indoor items. LED send these coordinates in the form of optical signal. The optical signal is converted to electrical signal by receiver and actual position is recorded in it. The glasses are embedded with voice player which guides the blind person about the position of indoor items. Headphone facility is provided in glasses to avoid the outside noise. Charging port is also available in it for artificial charging, moreover it can be charged using solar energy. Energy can be harvested with the help of LiFi technology, as solar panels are used to receive the light in this technology. P.K. Sharma, Y.S. Jeong and J.H. Park [19], had proposed a communication model for smart home and industries based on the combination of Energy Harvesting Wireless Sensor Network (EH-WSN) and Hybrid LiFi/WiFi communication techniques. It is named as EH-HL Model. In this model the energy is harvested from renewable resources like thermal energy, solar energy, wind etc. and used for wireless sensor network. Data is transmitted at high speed for bidirectional multi-devices by using the combination of LiFi and WiFi techniques.

In enhancement of LiFi technology the modulation techniques play an important role. As described in section IV there are different modulation techniques have been developed. M.D Soltani, Harald Haas et al. [17] had proposed bidirectional

optical spatial modulation technique for mobile user. In their research they studied the effect of mobility, random orientation and blockage on the performance of LiFi network. Issues with high channel correlation had been overcome by use of Multi-directional Receiver (MDR) for downlink and Multi-directional Transmitter (MDT) for uplink. The result analysis of this paper shows that MDR/MDT gives better performance in terms of Signal to Noise Ratio (SNR), Bit Error Rate and Energy Efficiency. The LED is not only used for communication but also for illumination at the same time, therefore the light quality of LED should be good. After applying different modulation techniques, the quality of light can be measured in three aspects [24]: -

- Correlation Color Temperature (CCT).
- Chromaticity.
- Color Rendering Index (CRI) metrics.

Evangelos and Waisu [24], had evolved a framework for finding the effect of modulation technique on light quality of LED. The authors also described the relationship between driving current and light quality of LED.

VI. Challenges Of LiFi Technology

Everything in this world has two sides one is success and other is filled with challenges, similarly the concept of LiFi also have two sides to it. On one hand it is useful for data transfer with efficiency and security however on other hand there are some issues which are needed to be resolved.

Through review of available literature on LiFi we observe following challenges in LiFi concept.

A. FLICKERING –It is an effect which occurs due to turning ON and OFF of LED, since LED plays two roles simultaneously of Illumination and communication [25]. When data is transfer from LED the fluctuation occurs due to ON-OFF mode which affects the illumination process of LED. It is one of the major challenges of LiFi which has to be overcome because flickering affects human vision.
B. Line of Sight – The efficiency of LiFi can be achieved only with Line-of-Sight communication. If either receiver/transmitter moves from its desired position then miscommunication may occur [7].
C. Interference of external light source can interrupt the communication process [26].
D. Separate LED should be used for each room because light cannot penetrate thought the wall or any solid object.

Above challenges are need to be short out for better future of LiFi technology. This technology is one of developing technology for data transfer. Researcher are taking huge interest to solve all the above problem of LiFi technology to make it efficient and successful.

VII. Applications Of Lifi In Different Areas

LiFi is an alternative of WiFi, as it provides high speed Internet than WiFi. So, all the areas where WiFi is used can be replaced by LiFi, but in this section we will discuss only such areas where either WiFi is not allowed or it fails to give service.

A. In Hospitals: WiFi is not allowed in sensitive area of hospitals because of following reasons: -

- Radiations of radio frequency may affect the patients' health.
- It may also interrupt the medical equipment.

LiFi uses light for data transmission therefore LiFi can replace WiFi in medical applications for safety purpose.

B. In Aircrafts: When we travel in airplanes, the crew member of plane asks us to keep our mobile phone on airplane mode because the radio frequency may interfere with navigation system of plane. Thus, LiFi is a safe alternative to WiFi in aircrafts.

C. Underwater: WiFi technology completely fails in underwater communication because radio frequency is comfortable to travel underwater. Un Tethered Remotely Operated Vehicle (UTROV) is used for underwater communication [10]. UTROV is an application of VLC technology.

D. In Disaster Management: WiFi may fail during natural disasters like earthquakes, tsunami, cyclones etc. because tower may get distorted during natural disaster. As a single tower cover large area. If LED blubs are used in street light then LiFi can easily replace WiFi. Since Street lights are placed in few meters apart from each other. So, the communication system will be alive after natural disaster. The idea of using street light for data transmission can be used in building the smart cities.

E. In Defense: Defense is fourth pillar of developing India. It is very essential to provide a secure communication system for defense. Jammer can block the signal of radio frequency which leads to failure of communication system. In LiFi technology light is used, which cannot be blocked by jammer.

In all the above areas, LiFi is safest and effective alternative to WiFi.

VIII. COMPARISION OF LiFi AND WiFi

In this section we will discuss the comparison between LiFi and WiFi in technical terms: -

- **IEEE Standard: -**802.15.7 is IEEE standard of LiFi and 802.11b is IEEE standard of WiFi [27].
- **Network Topology:** LiFi uses point to point topology whereas WiFi uses point to multi-point topology.
- **Frequency Band:** The frequency band of LiFi is 100 times of Terahertz and frequency band of WiFi is only 2.5 Gigahertz [27].
- **Range:** LiFi can be use within the range of 10 meters but the range of WiFi is approx. 100 meters, which is larger than LiFi.

- **Speed:** The speed of LiFi is approx. 1 Gbps to 3.5 Gbps. And the speed of WiFi is approx. 5 Mbps to 250 Mbps [27].

CONCLUSION

From the study of existing research on LiFi technology we conclude that the visible light can be used as a medium for wireless data communication. It is more secure and efficient than WiFi technology. If this technology is accepted globally and challenges are overcome then we will move towards faster, greener and safer future of wireless communication.

REFERENCES

[1] H. Haas, L. Yin, Y. Wang and C. Chen, "What is LiFi?," Journal of Lightwave Technology, vol. 34, no. 6, pp. 1533-1544, 2016.

[2] M. Vasuja, A. Mishra, U. S. Chauhan, D. Chandola and S. Kapoor., "Image Transmission Using Li-Fi," Second International Conference on Inventive Communication and Computational Technologies (ICICCT), 2018.

[3] S. Dimitrov and H. Haas, Principles of LED Light Communications: Towards Networked Li-Fi, Cambridge: Cambridge University Press, 2015.

[4] D. Tsonev, H. Chun, S. Rajbhandari, J. J. D. McKendry, S. Videv, E. Gu, M. Haji, S. Watson, A. E. Kelly, G. Faulkner, M. D. Dawson, H. Haas and D. O'Brien, "A 3-Gb/s Single-LED OFDM-Based Wireless VLC Link Using a Gallium Nitride μLED," IEEE Photonics Technology Letters, vol. 26, no. 7, pp. 637-640, 2014.

[5] H. Haas, "wireless data from every light blub," TEDGlobal Talk, Edinburgh, 2011.

[6] S. Ghnimi, J. Ben Romdhan Hajri, F. Harrathi and A. Gharsallah, "Statistical study on the effect of the use of mobile phone technology on human body health," 17th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Sousse, 2016, pp. 675-678, 2016.

[7] R. Shanmughasundaram, S. P. Vadanan and V. Dharmarajan, "Li-Fi Based Automatic Traffic Signal Control for Emergency Vehicles," in Second International Conference on Advances in Electronics, Computers and Communications (ICAECC), Bangalor, 2018.

[8] R. Mahendran, "Integrated LiFi(Light Fidelity) for smart communication through illumination," International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), Ramanathapuram, pp. 53-56, 2016.

[9] I. Demirkol, D. Camps-Mur, J. Paradells, M. Combalia, W. Popoola and H. Haas, "Powering the Internet of Things through Light Communication," IEEE Communications Magazine, vol. 57, no. 6, pp. 107-113, June 2019.

[10] L. U. Khan, "Visible light communication: Applications, architecture, standardization and research challenges," Digital Communications and Networks, vol. 3, no. 2, pp. 78-88, May 2017.

[11] "semaphore-world-first-telegraph.html," [Online]. Available: https://www.amusingplanet.com. [Accessed 20 May 2020].

[12] G. J. Holzmann, in The early history of data networks, Los Alamitos, California, IEEE Computer Society Press, 1995, pp. 251-252.

[13] H. Elgala and H. Haas, "A Study on the Impact of Nonlinear Characteristics of LEDs on Optical OFDM," IRC-Library, Information Resource Center der Jacobs University Bremen, 2010.

[14] J.H. Ku, "Between Invention and Discovery: A. G. Bell's Photophone and Photoacoustic Research," The Journal of the Acoustical Society of Korea, vol. 31, no. 2, pp. 73-78, February 2012.

[15] History Of Fiber Optics- Timbercon.," [Online]. Available: https://www.timbercon.com/resources/blog/history-of-fiber-optics/. [Accessed 20 May 2020].

[16] R. Kizer, A. Mantica, N. McNeill, J. Tobin and S. Jones ,"Li-fi-an-overview-part-1-purpose-and-function.," "IEEE Internet Policy Newsletter, June 2018. [Online]. Available: https://internetinitiative.ieee.org/newsletter/june-2018/ . [Accessed 26 May 2020].

[17] M. D. Soltani, M. A. Arfaoui, I. Tavakkolnia, A. Ghrayeb, M. Safari, C. M. Assi, M. O. Hasna and H. Haas, "Bidirectional Optical Spatial Modulation for Mobile Users: Toward a Practical Design for LiFi Systems," IEEE Journal on Selected Areas in Communications, vol. 37, no. 9, pp. 2069-2086, September 2019.

[18] N. Chi, M. Shi, C. Wang and M. Zhang, "High speed visible light communication based on pulse amplitude modulation," 16th International Conference on Optical Communications and Networks (ICOCN), Wuzhen, pp. 1-3, 2017.

[19] P. K. Sharma, Y. Jeong and J. H. Park, "EH-HL: Effective Communication Model by Integrated EH-WSN and Hybrid LiFi/WiFi for IoT," IEEE Internet of Things Journal, vol. 5, no. 3, pp. 1719-1726, June 2018.

[20] D. DINEV, V. ALEKSIEVA and H. VALCHANOV, "Comparative Analysis of Prototypes Based on Li-Fi Technology," 16th Conference on Electrical Machines, Drives and Power Systems (ELMA), Varna, Bulgaria, pp. 1-4, 2019.

[21] M. Mekala, P. Viswanathan, N. Srinivasu and G. Varma, "Accurate Decision-making System for Mining Environment using Li-Fi 5G Technology over IoT Framework," International Conference on contemporary Computing and Informatics (IC3I), Singapore, pp. 74-79, 2019.

[22] J. D. Bokefode, S. A. Ubale and R. M. Gaikwad, "Retrieving Real Time Data Through IOT Devices and Storing Securely on Cloud Using Li-Fi," 3rd International Conference for Convergence in Technology (I2CT), Pune, pp. 1-5, 2018.

[23] X. Qi, L. Du, S. Wang and J. Liu, "Design of the Indoor Positioning Glasses for the Blind Based on the LiFi Technology," IEEE 4th International Conference on Computer and Communications (ICCC), Chengdu, China, pp. 744-747, 2018.

[24] E. Pikasis and W. O. Popoola, "Understanding LiFi Effect on LED Light Quality," 2018 IEEE Photonics Conference (IPC), Reston, VA, USA, pp. 1-2, 2018.

[25] F. Aftab, "Potentials and Challenges of Light Fidelity Based Indoor Communication System," International Journal of New Computer Architectures and their Applications (IJNCAA), vol. 6, no. 3, pp. 92-102, 2016.

[26] P. Kuppusamy, S. Muthuraj and S. Gopinath, "Survey and challenges of Li-Fi with comparison of Wi-Fi," International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai, pp. 896-899, March 2016.

[27] S. Chatterjee, S. Agarwal, A. Nath, "Scope and Challenges in Light Fidelity(LiFi) Technology in Wireless Data Communication," International Journal of Innovative Research in Advanced Engineering(IJIRAE), vol. 2, no. 6, june 2015.