A critical review on Li-Fi technology and its future applications

Conference Paper *in* AIP Conference Proceedings · March 2023

DOI: 10.1063/5.0121967

6 authors, including:

Devi Ganesan
RMK COLLEGE OF ENGINEERING AND TECHNOLOGY
12 PUBLICATIONS **38** CITATIONS
SEE PROFILE

Gokul Raghavendra Srinivasan
Steamax Envirocare Private Limited
62 PUBLICATIONS **502** CITATIONS
SEE PROFILE

A critical review on Li-Fi technology and its future applications

Cite as: AIP Conference Proceedings **2690**, 020061 (2023); https://doi.org/10.1063/5.0121967
Published Online: 24 March 2023

G. Devi, N. Jayanthi, S. Rahul, et al.

A Critical Review on Li-Fi Technology and its Future Applications

G. Devi[1], N. Jayanthi[1], S. Rahul[1], M. Saran Karthick[1], S. Gokul Raghavendra[2], M. Anand[3, a)]

[1]*RMK College of Engineering and Technology, Chennai, Tamilnadu, India*
[2]*R&D, Steamax Envirocare Pvt. Ltd, New Delhi, India*
[3]*R&D, Syntegrity Labs Pvt. Ltd*, *Hosur, Tamil Nadu, India*

[a)] Corresponding author: anandorgchem@gmail.com

Abstract. Lifi technology was introduced to face the increased demand of wireless applications caused by the drastic increase of users. Light from LEDs are used to transmit the signals. Unlike radio waves, the data transmission using visible light is more efficient with high security defense. Visible light can be used for free of cost is another major reason for its wide application. There is an increase in the usage of Lifi technology in hospital zones and security communications for its un harmful and data security reasons. Communication domain estimates a high increase in demand for Lifi technology in the near future which includes its usage in space and under water communications. Due to few limitations in Lifi technology; it cannot fully replace radio wave transmission technology. Anyway the hybrid model of bringing both wifi and Lifi technology is having a great future demand in the communication world. This review helps the Researchers in Lifi technology to expand their search in this communication technology.

Keywords: LiFi technology, data transmission, 5G, LED Drivers, Photo detectors.

INTRODUCTION

Optical Wireless Communication shortly known as OWC used optical waves for Data transmission These Optical waves are used for short range communication applications which usually works in the spectral range between 390 nm and 750 nm. Since this range is in the visible range of the electromagnetic spectrum, these are also called as Visible Light Communication system (VLC). This VLC used only LEDs for its data transmission, it has no impact on human eye.VLC can be send in wireless LAN, PAN and Vehicle to vehicle networking applications. This methodology can also be used in the terrestrial networking from point to point called as Free Space Optical System shortly called as FSO system which operates in the near Infra-Red Spectral range between 750 nm and 1600 nm. system offers a cost-effective transparent link which uses Laser transmitters. After the outcome of Laser, this OWC Play a prominent role in the transmission technology with various modulation schemes. In spite of less divergence of Laser property, still it could not cope up with the impact created by atmospheric effects. Hence the choice changed from laser beam to a low loss optical fiber system for long distance communications since 1970s [1].Recently photo detectors are used in the integrated CMOS Optical receivers. Thus, it can be used for long range communications to detect weak signals. The European Data Relay Satellite System (EDRS) is one of the examples for using ultra long OWC for intersatellite communication systems. Later this application extended to military and space applications for inter space ship wireless data transmission. After the knowing of its high secure transmission, radio waves have been replaced by optical waves in many confidential transmissions. The capability of using low power emitting LEDs called as smart lights for transmission is the best part of this Lifi technology [2]. Light Fidelity uses Visible light as well as Ultra Violet and Infra-Red Rays of the Electromagnetic spectrum. The principle behind its working is Visible Light Communication. For data transmission, light modulation has to be done. Three primary

ISET International Conference on Applied Science & Engineering (CASE 2021)
AIP Conf. Proc. 2690, 020061-1–020061-8; https://doi.org/10.1063/5.0121967
Published by AIP Publishing. 978-0-7354-4334-1/$30.00

modulation techniques are being used namely single carrier modulated transmission (SCMT),multi carrier modulated transmission (MCMT)and Pulse Based Transmission (PBT). SCMT uses a single sinusoidal wave whereas MCMT uses more than two waves which are modulated for data transmission. In PBT, the data is encoded on a pulsed wave [3].

HISTORY AND ADVANCES OF LI-FI TECHNOLOGY

Wireless communication became essential during the past years in the twenty century and the early years in the twenty first century. At initial stages Radio Frequencies was mostly used. OWC is unguided with infrared, visible and ultraviolet radiation. In ancient days and even now in certain mountainous regions the beacon fires and smokes are used for signaling which is a way of communication. During the Roman and Greek era war, they used the sunlight as a signal by reflecting it with shields. In 1810, two pairs of mirrors were used for directing a beam of light rays of sun's beam to a distant station by Carl Friedrich Gauss. Alexander Graham Bell was the one who invented the photophone in 1880 which is the world's first wireless telephone and later Charles Sumner Tainter joined him in his invention. This was the first wireless technology that work on the light beams. The phenomenon changes the modulated light into modulated electrical signals as the results the sound waves duplicate the characteristics vibrations on the mirror which in turn makes the sound wave bones back to the receiver. This scope opened the door for many technologies including the fiber optics Lifi, VLC [5]. Bell's Photophone created an interest in Military field after his time. The Army of Germany in 1935 created a photophone using a tungsten filament lamp as the source of light and an Infra-Red transmitting filter for data transmission. Later American and German Army worked in their laboratories and developed high pressure Arc lamps for Optical Communications. Again, later in 1962, Lincoln laboratories were able to experiment optical wireless communication successfully using a Gallium Arsenide Light Emitting Diodes as transmitters. Using this they were able to transmit TV signals over a distance of 30 miles. Now modern Optical Wireless Communication are using Laser lights and other LEDs for transmitting signals. [6]

LIFI TECHNOLOGY STRUCTURE

The optical signals are converted in to ethernet compatible electric signals. These signals are then encoded into switching signals. These switching signals are then sent to a high speed LED driver. A lamp kept at the overhead carrying an LED which is designed with signal processing technology will stream the signals to the Photo detector. The detector which will then convert the changes in the amplitude in to electric signals. The control unit further converts these electrical signals into data stream and the final information is fed to the computer or mobile devices. [4] The basic structure of Lifi working methodology is shown in Figure 1.

WORKING OF LI-FI

Lifi technology is based on visible light between Violet and Red [29,35,36].Lifi uses the amplitude modulation technique for sending data. LEDs are used to carry the light signals. Since LEDs glow and switch off very fastly than the speed at which human eyes operate. If the LED glows, the signal is take as '1' and when the LED is off, it takes it as '0'. The working of Lifi is very simple which uses a LED transmitter and a Photo detector. The analog signals are encoded and fed into the Light. The transmitter is connected to a data network through a modem and on the other end, the receiver receives the data using a photo detector.

Various Modulation Techniques in Li-Fi

The radio waves and visible light waves, both being electromagnetic waves, the techniques used for modulation in radio wave technology can be used for lifi technology also. This means either single mode or multi mode techniques can be used [1].

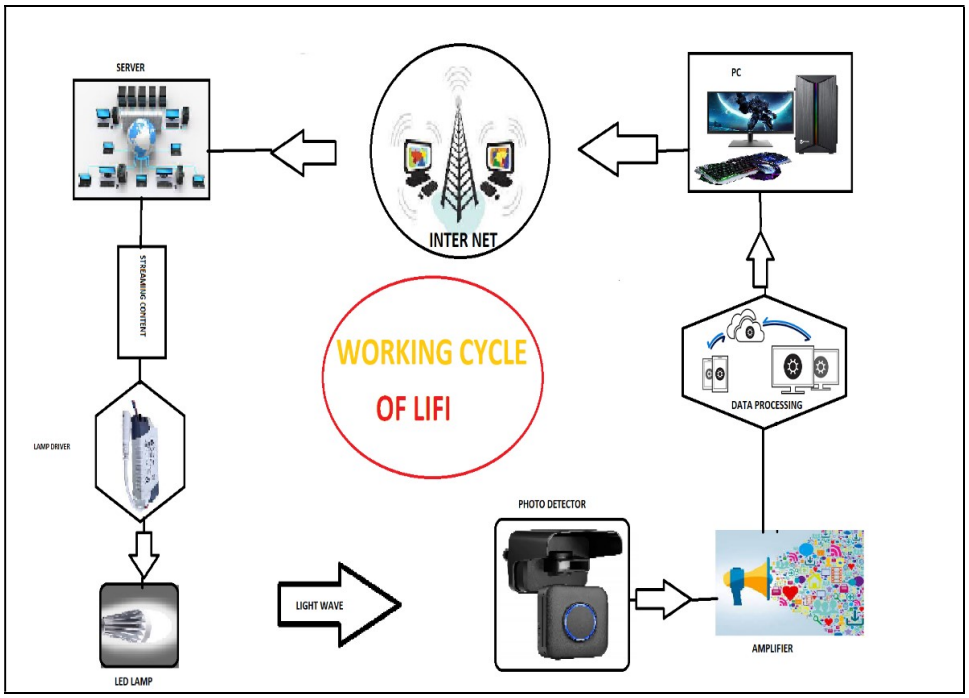

FIGURE 1. Basic working model of LIFI Technology

Single-Carrier Modulation (SCM)

On –off keying and pulse position modulation are examples of single carrier modulation in which On –off keying is a very simple modulation techniques [2]. Pulse position modulation is more power efficient than On –off keying scheme. Another new modulation scheme called as Optical Spatial modulation is bothe power efficient and band width efficient [3].

Multi-Carrier Modulation (MCM)

MCM uses many frequencies enabling it to create many channels. Its attenuation is minimum comparing with SCM which makes it more popular among the users. It has also less signal interference and less impulse noise and also least affected by synchronization problems. Due to its multi-channel facility high speed data transmission can be done more efficiently using MCM. Orthogonal frequency division multiplexing (OFDM) is the most commonly used technique in MCM.DC biased optical OFDM (DCO – OFDM), asymmetrically clipped DC biased optical OFDM (ACO-OFDM) and asymmetrically clipped DC biased optical OFDM (ADO-OFDM) [6].

LiFi Unique Modulation

Lifi technique needs illuminating parameter in the transmitters which the wifi technique does not require. Multicolour LEDs are used for this purpose. The Scheme known as Color – Shift keying (CSK) transmits information using the colour variation in the output signal [7]. Metametric modulation is a specific color light modulation technique used in CSK technique [8]. To compensate the color matching requirements and additionally to improve the efficiency Color Intensity modulation (CIM) is used [9,37]

MERITS OF LIFI TECHNOLOGY

During network traffic times, Wifi find difficult in transmitting data due to its limited bandwidth whereas Lifi technology has a good band width with which multiple file data transfer can be done with a high speed. It is hundred times faster than Wifi and its speed reaches 224 Gigabits per second. [12] Positioning or locating an object is also

possible using this technology. This GPS system which was initially used by only military purpose is now being used in our everyday life. The current GPS system is also difficult for indoor situations as radio waves uses multiple pathways. In Lifi technology, the LEDs can be modulated with higher frequencies to get the positioning accurately. Apart from this mobile Robot navigation, Vehicle to vehicle communication, baby monitoring system, smart Lifi car parking system, Blind indoor navigation system. [13] Since the LED light bulbs are already used in homes and offices, the same light source can be used for transmitting signals. Hence there is no need of additional cables like Wi-Fi transmission systems. [28] This also means that wherever there is light, there is network connection. The main advantage of all is the security that we get while using this technology. As light cannot pass through walls, opaque objects, the data is secured within the room itself. [14,32]

Capacity

The primary advantage of using Lifi is the capability to transmit signals at high data rate. Visible light has high frequency and thus it provides high bandwidth and henceforth high data rate. The bandwidth using light waves is 10,000 times wider than radio waves, hence Lifi technology achieves data rate more than gigahertz .

Free Spectrum

The enormous usage of wireless applications have created a higher demand for networking and there is a scarcity of spectrum whereas visible light is a free spectrum and it can be used to its maximum limit.

Efficiency

The Radio frequency communication networking needs cool platform stations whereas Lifi technology needs only less energy with higher transmission efficiency.

Availability

In places like hospitals and security based domains, Radio wave transmissions are restricted for health safety and security safety purposes whereas LEDs are harmless, hence Lifi networking can be used anywhere.

Security

Light waves donot penetrate through the walls and hence data security is highly maintained in Lifi transmission techniques [30]

Complexity

Like Radio frequency transmission, Lifi does not need complex circuits and moreover it depends on simple modulation techniques[16]

No fading

When multi channels are used, signal fading occurs due to the propagation of data though multi paths whereas light signals does not allow any fading [16]

Safety

Recent studies have proved that Radio waves are harmful to brain when exposed for a longer duration. Especially children get affected more due to the over exposure to signals because of the frequent usage of mobiles[17]Addition to this it also causes insomnia[18,23].It also affects normal growth of fetus and its ‘cell growth

[19,20,25].Fertility problems and cardiac problems also arise due to long exposure to Radio signals[21,22,26,27].All the above said problems do not occur in Lifi technology[33].

Cost-Effective

Comparing with Radio frequency transmission, Lifi Transmission needs less components, LED light bulbs being the primary.It does not have complex circuits like Radio transmission and this makes it cheaper[16]

VARIOUS APPLICATIONS OF LI-FI TECHNOLOGY

The unique features of Lifi technology enables its wider usage in future.

Under Water Application

Radio waves are characteristic of getting absorbed in water, which does not give a good signaling transmission but light waves can penetrate through water and gets easier for communication from one object to another under water. Signals received from the satellites are received by the buoys attached to the ships. These signals are then transmitted from one ship to another ship using light signals. [7]

Blind Navigation

Lifi facilitates blind people to navigate inside a room. The data transmission happens when somebody enters a room and gives them audio message. Hence it makes blind people to confidently move around inside the room. This lifi assistance can to blind people can also be given in hospitals, airports, museum and restaurants. [8]

Defense and Security

The existing Wi-Fi communication has no security in which there are provisions for capturing the confidential information and hence there is a threat always. In Lifi technology the data transmission is highly secure and safe because of which it is used in defense service as well for preventing the communications being seized by external attackers. [9]

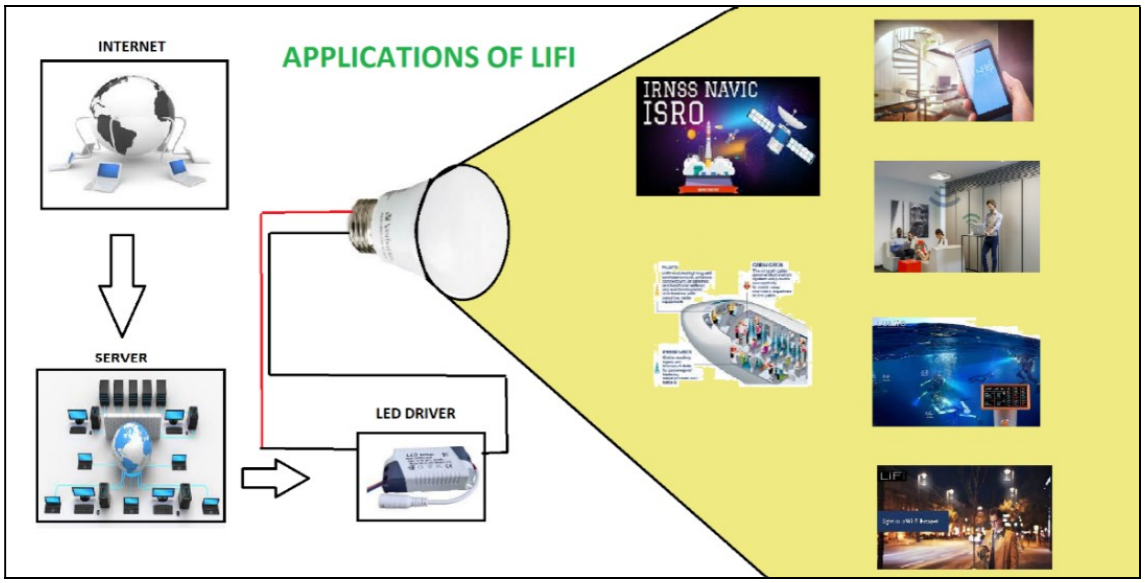

FIGURE 2. Lifi Applications

Health Care

Inside an environment where medical Sensitive devices are being operated, the use of cell phones are sometimes restricted as it may interfere the device signals. But when Lifi networking is used there is no need of this constraint as light signals will not interfere with the other networking**.** In fact, this technology can be used for device-to-device communication without any hindrance at less cost with secured transmission. [10]

Satellite Communication

Optical wireless communications can be used for satellite-to-satellite networking in a secured manner. From one spaceship to another spaceship data transmission can be made through Lifi technology [11].

LIMITATIONS

Light cannot pass through obstacles hence there should not be any hindrances in terms of obstacles in the path of the light wave. In case of any other source of light entering into the system, the data transfer process gets obstructed due to interference in signals. [31], another main drawback is its short-range communication. Another main drawback is if there is no light, there is no connectivity. [15]

FUTURE PROSPECTS

There were lot of projects done with li-fi technology in many countries in air crafts, air force and air communication. Father of li-fi Shuji Nakamura have done the research on CES consumer electronics, to show the real time working of his project in Las Vegas This project transmits the data at 20 Gbit/sec where speed is 20 times faster than 5G net speed. [16] LIFIMAX 1G is used to replace the network for the Internet-of-Things (IoT) communications and also for machines and robotics. This technology will work at the distance of 5km, and still researchers are working on it to expand the range. Aura Light Italia is one of them to expand the li-fi range up to 10 km. This research is focusing on safety and more secure networking facility. They are using light-based, materials in this project also concentrating on cost control to get work in lower price for commercial usage. Another company named Technology Research Institute in their research got a record result of 5.1 Gbit/sec. OWNII Coin Global is a private company, planning to launch their wings in 2 phases. [17] The Oppo smart phone brand got the patent on the LET'S GO DIGITAL, which signifies using li-fi technology instead of using the wi-fi technology. Using this, they are going to create very fast networking. [18] In 2020, Signify, new company got interested in the indoor project called indoor Visible Light Communication (IVLC). Signify company has created new intelligent language for the li-fi, that will connect and convey the meaning in full message, and they are also part of the "Enhance Lighting for the Internet of Things" (ELIOT). EPFL is the first company for creating the working model of under- water military modem, for endless communication in under water up 6,000 meters. ZND CEO of HYDEROMEIA says that their normal li-fi will also support under water communication where Blue light is used for under-water communication. [19] In October 2020, the light rider company worked on the project connecting li-fi and quantum physics to create the super natural code for the unparalleled encryption products which got patented. GETAC is another company who got patent in 2019, for Pure li-fi to public which is a fast and powerful sensor. [20] The International Conference on Li-Fi Technology held on August 2021 in New York, United States has tagged on many decisions on the li-fi tech and planned projects for the next five years. The inter net speed will change rapidly worldwide at a Compound Annual Growth Rate (CAGR) of 31.5% from 2020 to 2025. [21]

CONCLUSION

The next generation is ready now to use this Lifi Technology as the current method has its own disadvantages. Hence very soon the bulbs that we use in homes and offices will be Lifi Bulbs for transmitting efficient Data. Since optical waves are ten thousand times wider in band width than the Radio waves, large data transmission can be

done. Due to its high secure data transmission ability, this is going to lead in communication networking in the near future. Traffic management application is one of the versatile applications where accidents can be controlled in a greater number and this technology is going to be a gift for blind people for whom Lifi is going to give vision.

REFERENCES

1. Do Ky Son, EunByeol Cho, Inkyu Moon, Zabih Ghassemlooy, Soeun Kim and Chung Ghiu Lee, EURASIP Journal on Wireless Communications and Networking, 1-8 (2013).
2. Angayarkanni S, Arthi R, Nancy S,Sandhiya, International Journal of Engineering Science and Computing ,**8**, 3, 1-3 (2018).
3. Sandip Jadhav, Aniket Rathod, Vikram Shind, Priyanka Patil, Journal of Contemporary Issues in Business and Government, **27**, 5137-5150 (2017).
4. Porselvi S, Bhagyalakshmi L, Sanjay Kumar Suman, Innovare Journal of Engineering & Technology, **5**, 2, 1-4 (2017).
5. Anwesha Chakraborty, Trina Dutta, Sushmita Monda, Asoke Nath, International Journal of Advance Research in Computer Science and Management Studies, **5**, 12, 1-7 (2017).
6. Maninder Kaur Madhok, Simarpreet Kaur Mehra, Interject Singh Madhok, International Journal of Advanced Computational Engineering and Networking, **4**, 10, 1-5 (2016).
7. Sarkar, Anurag & Agarwal, Shalabh Nath, Asoke, International Journal of Advance Research in Computer Science and Management Studies,**3**, 1-10 (2015).
8. Haas H, Yin L, Wang Y, Chen C, Journal of Light Technology, **34**, 1533–1544 (2016).
9. C. Soumya, B. Deepanraj, J, Ranjitha, "A Review on Solar Photovoltaic Systems and Its Application in Electricity Generation", AIP Conference Proceedings, **2396,** 020011 (2021).
10. Mesleh R, Elgala H, Hammouda M, Stefan I, Haas H, Journal of Opt Commun Netw., **3,** 1–4 (2011).
11. Afgani MZ, Haas H, Elgala H, Knipp D, 2006, 2nd International Conference Testbeds Res Infrastructures Dev Networks Communities, TRIDENTCOM, 129–134 (2006).
12. Komine T, Haruyama S, Nakagawa M, International Symposium Wirel Pervasive Comput Conf Progr. **456–61**(2006).
13. Dissanayake SD, Armstrong J, J Light Technology, **31**:1063–1072 (2013).
14. Monteiro E, Hranilovic S, IEEE Globecom Work GC Wkshps.1224–1228 (2012).
15. Butala PM, Chau JC, Little TD, IWOW.1–3 (2012).
16. Ahn KI, Kwon JK, IEEE Photonics Technol Lett., **24**, 2254–2257 (2012).
17. Haas H. Wireless data from every light bulb. TED Website. TEDGlobal, Edinburgh, Scotland (2011).
18. S. Shanmugan, N. Saravanan, V. Chithambaram, B. Deepanraj, G. Palani, "Investigation on single crystal by tartaric acid–barium chloride: growth and characterization of novel NLO materials", Bulletin of Materials Science, **43**, 202 (2020).
19. Ravi Prakash, Prachi Agarwal, International Journal of Advanced Research in Computer Engineering & Technology, 3, 1-9 (2014).
20. Jitender S, Vikash, International Journal of Recent Development in Engineering and Technology, **2(6),** 1-9 (2015).
21. Karthika R, Balakrishnan S, SSRG International Journal of Electronics and Communication Engineering (SSRG-IJECE), **2(3)**, 1-5 (2015).
22. Dinesh Khandal, Sakshi Jain, International Journal of Information & Computation Technology, **4,** 1-5 (2014).
23. Cunnington D, Junge MF. Insomnia: prevalence, consequences and effective treatment. Med J Aust. **199(8),** 36–40 (2013).
24. Pyrpasopoulou A, Kotoula V, Cheva A, Hytiroglou P, Nikolakaki E, Magras IN, et al. Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. Bioelectromagnetics. **25(3),** 216–227 (2004).
25. Lv B, Chen Z, Wu T, Shao Q, Yan D, Ma L, et al. The alteration of spontaneous low frequency oscillations caused by acute electromagnetic fields exposure. Clin Neurophysiol. **125(2),** 277–286 (2014).

26. Shahin S, Singh VP, Shukla RK, Dhawan A, Gangwar RK, Singh SP. 2.45 GHz microwave irradiation-induced oxidative stress affects implantation or pregnancy in mice, musmusculus. Appl Biochem Biotechnol. **169(5),** 1727–1751 (2013).
27. Havas M, Marrongelle J. Replication of heart rate variability provocation study with 2.45 GHz cordless phone confirms original findings. ElectromagnBiol Med. **32(2),** 253–266 (2013).
28. Rani J, Chauhan P, Tripathi R. Li-Fi (Light Fidelity)-the future technology in wireless communication. Int J ApplEng Res. **7,** 1517–1520 (2012).
29. Jaiswal NS, Chopade PS. Technology- light bulb to access the InternetReview of Li-Fi Technology: new Future. Int J SciEng Res. **4,** 36–40 (201).
30. Gupta SU. Research on Li-Fi technology & comparison of Li-Fi/ Wi-Fi. International Journal of Advanced Research in Computer Science and Software Engineering. **5(6),** 429–433 (2013).
31. Chatterjee S. Scope and challenges in light fidelity (LiFi) technology in wireless data communication. Int J Innov Res Adv Eng. **2,** 1–9 (2015).
32. Ayyash M, Elgala H, Khreishah A, Jungnickel V, Little T, Shao S, et al. Coexistence of WiFi and LiFi toward 5 G: concepts, opportunities, and challenges. IEEE Commun Mag. **54,** 64–71 (2016).
33. Mishra P, Poddar J, Priya S, A review on LiFi: the green WiFi. Int Res J Eng Technol. **3,** 99–103 (2016).
34. Li-Fi Internet solution from Russian company attracting foreign clients, Russia and India Report (2014).
35. Shao S, Khreishah A, Ayyash M, Michael B, Rahaim HE, Jungnickel V, et al. Design and analysis of a visible-light communication enhanced WiFi system. IEEE/OSA J Opt CommunNetw. **7(10),** 960–973 (2015).
36. Dimitrov S, Haas H. Principles of LED Light Communications (Towards Networked Li-Fi). Cambridge University Press, United Kingdom (2015).
37. Saito Y, Kishiyama Y, Benjebbour A, Nakamura T, Li A, Higuchi K Non-orthogonal multiple access (NOMA) for cellular future radio access. In: IEEE Vehicular Technology Conference. Dresden, Germany (2013).