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Review: Li-Fi Future Technology, Architecture, and their Constraints

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Abstract
Light Fidelity (Li-Fi) is a network and mobile communication system that uses light to transmit data at fast speeds in both directions. Li-Fi is a wireless network made up of multiple light bulbs that provides a user experience that is very similar to Wi-Fi except that it uses the spectrum of light. Li-Fi is a type of Visible Light Communication (VLC) that uses light as a communication medium instead of wires. Li-Fi has recently advanced to address the disadvantages of Wi-Fi. This paper can be used as a reference and source of information for developing Li-Fi technology, it provides an overview of Li-Fi, covering the architecture of Li-Fi and its application environment, the differences between Wi-Fi and Li-Fi technologies, and the limitations of Li-Fi technology based on a review of numerous Li-Fi technology studies, as well as a brief discussion of Li-Fi efficiency and availability.

Key Words: Light Fidelity, Li-Fi, Wi-Fi, Visible Light Communication (VLC)

1. Introduction

Light Fidelity (Li-Fi) technology began in the 1990s in select nations when LEDs could be taught to be retrofitted for data transmission. Li-Fi may take several forms, including ultraviolet, visible light, and infrared. Some energy is carried by Li-Fi light beams, and this energy can be used for data transfer, according to researchers. With this notion, Li-Fi progresses, and many missions are completed, but it faces early challenges, such as locating gadgets that collect data from attached light sources [1-3]. As is generally known, wireless sensors are increasingly being employed in the high performance for building design. Once using sensors can be used wirelessly, the main challenges are energy supply and data transfer. Although the energy wireless sensors capture could self-produce by absorbing energy from the environment, the availability of energy supply to facilitate transmission through wireless is a significant barrier. The evolving technology of Li-Fi has been well-thought-out as a potential solution to this challenge. Li-Fi is a novel form of the system of wireless communication that uses light as a channel instead of typical radiofrequency radiation produced by electromagnetic waves. Harvested energy from Li-Fi technology is used to power wireless sensors, with the added benefit of generating electricity based on a regulated lighting system [4]. Since ancient times, when flames signaled linked urgent news over long distances, it has been considered that information might be transmitted by light. Modern uses include televisions that may be controlled remotely utilizing Infrared (IR) light to send commands to a television. Visible light communication (VLC) is a less common kind of communication in which communication frequencies must fall within the visible light spectrum. VLC approaches are less often used since the transmitted signals are visible to people who may be adversely affected by their surroundings [5-8]. The organization of this paper is formed as the following: in the rest of this section, we will explore the Li-Fi idea based on VLC. Section 2 focused on recent studies related to Li-Fi technology, and the architecture of Li-Fi with the applied environment in Section 3. In Section 4, Wi-Fi and Li-Fi technologies presented with differences between these technologies. From studying and analyzing recent study constraints of Li-Fi technology the efficiency and availability of Li-Fi are described in section 5. The efficiency and availability of Li-Fi technology, which is extracted from related research, are presented in Section 6. Concluding the key points from the works of literature are summaries with recommended future work in Section 7.

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2. Related Works

Professor Harald Haas of the University of Edinburgh in the United Kingdom was the first to propose and applied the concept of Li-Fi., he applied the concept of Li-Fi. Li-Fi is a method of data transport that eliminates the use of optical fibers by using an LED-light bulb to transmit data that fluctuates in concentration quicker than the naked eye can see [9, 10]. Many studies have been conducted on the usage of Li-Fi in the communication industry; the following studies are the most recent:

- Khare et al [11], focused on the system of Li-Fi development and analyzed its achievement in comparison to current technology. The research moreover looks at the benefits and difficulties of utilizing Li-Fi to transfer info from one machine to another. They suggested that employing Li-Fi technology would alleviate many of the problems associated with data transfer technologies.
- Roma Jain in [5], addressed the scalability, availability, and security challenges of wirelessly delivering data by light using LEDs in their proposal for an interior visible transmission data system employing LEDs. Devices are utilized in their system not just for lighting rooms, but also for other purposes. An optical wireless communication system is implemented using devices.
- Hyung Jae Chang in [12], overcoming limitations in the level of implementation of the framework for data connection in the hospital utilizing Li-Fi technology The indoor wireless communication performance is much quicker than that of Wi-Fi because LED lights are used as the medium of transmission. People may still utilize LED light as a light source for each room since the flickering rate is quicker than the human eye can detect. Meanwhile, because Li-Fi uses light to communicate data, it does not interfere with the medical equipment required for surgeries.
- Liang Yin et al. in [13], exploited the interference multiuser by the usage of NonOrthogonal Multiple Access (NOMA) depending on Successive Interference Cancellation (SIC). A proportionate model is used to address residual interference caused by incomplete SIC in applicable states. The outcomes display that NOMA outperforms OMA by 5-10 dB on the comparable Signal to Interference plus Noise Ratio (SINR). When SIC is applied, the Bit Error Rate (BER) performance is greatly improved.
- Yunlu Wang and Xiping Wu [14] provided a viable communication scenario model that characterizes blockages, unpredictable Li-Fi receiver orientation, and the need for user data rate. For Li-Fi /RF hybrid networks, a new Load Balancing (LB) structure is proposed, which is centered on a modified theory of the game. The performance of the projected structure is thoroughly examined, and the findings show that it outperforms the current status of the art LB methods. The suggested structure importantly enhanced the level of user need while reducing computing complexity. Furthermore, in hybrid networks, optimal alignment of Li-Fi receivers and density of obstruction increased user quality of service.
- Mohammad Dehghani Soltani in [15] adapted two techniques, the first is feedback with a restricted scope method founded on limiting the contented of feedback info and the second is a feedback mechanism with a restricted frequency that is based on the update interval for minimizing the quantity of feedback in Li-Fi cellular networks. The best interval is updated, which gives the output of user equipment in both models of mobile waypoints directions at its maximum, which has also been calculated founded on the unsystematic waypoint mobility model. The results reveal that the altered methods outperform the benchmark one-bit feedback and full-feedback mechanisms in terms of average total throughput.
- Abdul Aleem Jamali et al. in [16] innovative technique for collision avoidance between the front and rear vehicles is presented in this study. The suggested Li-Fi-based Vehicular to Vehicular (V2V) communication system is a cost-effective, high-data-rate solution.
- Pradip Kumar Sharma et al. in [17], employed a Li-Fi communication schema to propose an IoT network with a human-focus architecture for a layered hybrid cloud computing to decrease bandwidth costs and latency. To fulfill present and future design requirements, the architecture of the local cloud is proposed to protect the cloud computing in private is proposed, plus offering a communication medium with a high speed at the edge of the network. It also includes a scenario in which the recommended model may be applied in the actual world.
- Bolli Jagadeeswari in [18] developed a Li-Fi-based system, where waves of radio are limited, for instance in Hospitals and aircraft, and several services. Li-Fi is a technology for wireless data transmission with high-density releasing intrusions without radio in limited zones, as a result of which it may be employed

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in biosensors that measure several factors of health. The technology of Li-Fi visualizes an upcoming, where files for PCs, smartphones, and tablets will be broadcast in the room using a cost-effective and environmentally friendly light-medium.

- S. M. Tanvir Abid et al. in **[19]**, used a concave mirror and the placement of LEDs, the range of each LED may be increased independently. A smarter manner of placing light results in higher light coverage, which extends the LED's range. Concave mirrors provide a bigger picture with a greater angle, increasing the area covered by the light and the image formed ahead of the LED, increasing the light's horizontal range. Though it is no longer feasible to extend the range from one room to another, the technology may still be used to cover large areas.
- Balaji K and S.Shakthivel Murugan in [20], used for communication the underwater Li-Fi module. However, owing to the exclusive characteristics of acoustic systems and the underwater channel, using a Li-Fi module underwater poses significant obstacles. After a thorough examination of distinguishing characteristics, several clarifications are presented. MATLAB software is used for simulations to detect the appropriate color of Light Emitting Diode (LED) for communication underwater. Results determined that appropriate for underwater communication is (Blue_ Cyan_ Green) Spectral range of wavelength 490 nm to 560 nm. Low preoccupation, handful, and decreased loss in the Blue – Cyan Green Spectral range are obtained. The presentation of this paper is advanced for the fisherman to detect the number and diversity of fishes obtainable in a specific position.
- In [21, 22], they suggested an indoor navigation system is for people with visual disabilities that employ Visible Light Communication (VLC) technology. VLC technology is referred to as Light Fidelity. VLC is built on the concept of using observable light as a means of communication, allowing for a quicker flow of data. Regarding their flow, VLC offered accurate locational directions.
- Mohamed Amine Arfaoui et al. in [23], for indoor Li-Fi systems, a realistic and measurement-based channel model was provided. For the scenario of the station and mobile Li-Fi devices which randomly oriented, channel gain statistics are calculated. Two-channel models are adopted for stationary employers: the modified truncated Laplace (MTL) model and the modified Beta (MB) model. Two-channel models for Li-Fi operators have been proposed: the sum of the Modified Truncated Gaussian (SMTG) model and the sum of the Modified Beta (SMB) model. The influence of random orientation and geographical distribution of Li-Fi users is investigated using the resultant models, and it is shown that the above-mentioned elements have a significant impact on the gain of channel and performance of the system.
- Ahmet Burak Ozyurt [24] presented a two-tier Li-Fi network, with the cross-tier handover rate between the cells (primary and secondary) being examined. Three distinct attention models are offered for the secondary cells for varied semi-angle at partial luminance conditions of the main and secondary cells. Closed-form formulas for the Ping-Pong handover rate, cross-tier handover rate, and duration in terms of received optical signal intensity, time-to-trigger, and mobility, there has been a sojourn of customers are determined using stochastic geometry. The simulation results are used to confirm the analytical models.
- Trang Nguyen et al. [25] introduced innovative line codes and optical orthogonal frequency division multiplexing using direct current (DCO-OFDM). National Instruments PXIe-1085 and NI-7966R Field the Programmable Gate Array(FPGA) is applied to examine the system's performance. The suggested iDim provided different profits as associated with existing dimming technologies such as Amplitude Modulation (AM) dimming, according to implementation findings. Particularly, the iDim method's lowermost power of optical power is recorded at 20 W, which is ten times less than the reported limit of AM dimming. The SNR of the iDim system is 22.5 dB at all brightness levels, whereas the SNR of the AM-lowering approach drops drastically when light is lowered. iDim has a greater transmission rate than DCO-OFDM.

3. The Architecture of Li-Fi and its Applied Environment

The technology of the (Li-Fi) scheme is concerned with the construction of the transmitter, and the construction of and receiver construction respectively. When it comes to the design of a transmitter, many components must be assembled to achieve their roles. Bulb's architecture is one of the most important of these

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assemblies. The dielectric substance is connected to light. This alliance is capable of performing two functions: It is employed as a concentrator of an electric field to focus the energy into the bulb and directs the radiofrequency energy waves delivered by the amplifier of the power [26, 27]. In physical noise flow, the degree of regularity should be considered when determining the interfering effect of noise through communication[28]. The technology of Li-Fi is increasingly expanding into a variety of tasks for humans, such as:

- **Mobile Device Communication:** Li-Fi enabled several of the next-generation mobile and ubiquitous computing devices. It is ideal for mobile communication infrastructure in many respects, including delivering a high level of mobility, conserving energy, reducing space, lowering deployment costs, also lowering maintenance costs. It also can be used to keep the greenly of the human environment, smart, and safe; it will complete and outline upcoming technology by promoting a more maintainable way of existence for humanity [29, 30].
- **Deepwater Communications:** The majority of distantly functioned underwater vehicles (ROVs) use cables to communicate commands; however the cable's length has restricted the region ROVs can determine. However, because light waves can pass through water, Li-Fi might be used to signals receiving and transmitting aboard automobiles. While Li-Fi may potentially be utilized in applications underwater, the distance light can penetrate water limits its usefulness. Important volumes of light do not go beyond 200 meters. There is no light beyond 1000 meters [31, 32].
- **The Hospital:** Wi-Fi is utilized because of its intrinsic radiation, and the potential for intrusion with observing equipment such as Magnetic Resonance Imaging (MRI) and scanners [33-36].
- **High-Risk Environments**: Facilities of petrochemical, plants of power, and other high- [37], which employed waves of radio for high-risk spaces communication due to great flammability.
- **Smart Street Lighting**: This development's major goal is to develop an IoT system for lighting streets automatically. Because when the traffic gradually dropped over the hours of the night, caused gradually lowered intensity for saving the energy until morning, and the street light automatically turns on at dark and turn off at dawning. Every day, the process is repeated [38, 39].

4. Wi-Fi and Li-Fi Technologies

Since is well known, restricting the process of Wi-Fi to exclusively indoor settings is a challenging undertaking, as it is hard to adequately screen all of the buildings where network access points are installed; as a result, networks also run outdoors in part (difficulties with the coverage configuration). All of this shows the disadvantages of using Wi-Fi networks safely [40]. The pressing need for research in the realm of wireless technology is the hunt for novel ways to improve and keep safe communication channels both the information and levels of physical [41].

Wi-Fi is good for building-wide wireless coverage, whereas the technology of Li-Fi is better for wireless data high density, the data inside a limited space or area is covered, as well as for reducing radio intrusion. The differences between these technologies are detailed in the table below:

Table 1. Show differences between Wi-Fi and Li-Fi Technology [42, 43].

Factors	Wi-Fi Technology	Li-Fi Technology
IEEE Standard	802.11b	802.15.7
Frequency Band	2.4 GHz	100 times of Tera Hz
Cost	Expensive	Cheaper
Data Transfer Medium	Radio spectrum	Light radio
Network Topology	Point-to-point	Point-to- point
Spectrum Range	Radio spectrum range	visible light
Range	20-100 meters	10 meters
Speed	54-250 Mbps	1-3.5 Gbps (100 times faster than current average WiFi speeds)

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Security	Medium	High because the signal doesn't pass through walls so outsiders cannot hack into the network
Power Energy	Less available	Available

5. Constraints of Li-Fi Technology

Li-Fi is simple to set up, quick, non-harmful, and has a high data transmission rate for internet applications. It also uses less power to operate, making it ideal for IoT applications. Light Fidelity (Li-Fi) offers a considerable speed advantage in transmitting data, as well as more-secure connections and decreased device interference. Many constraints of using Li-Fi are determined in this review through studying the Li-Fi features, architectures, environments, and applications; the next is a summary of these constraints:

1. **Physical Barriers:** For the reason, that visible light cannot flow through buildings, trees, or obstructions, and because light cannot pass through walls and has a mounted field procedure, the signal will be switched off instantaneously, limited range of the signal.
2. **Power of Light and Rang**: The type of light source has a direct influence on the speed that a Li-Fi solution can reach, therefore if the power of light is turned off, there is no Li-Fi. The range of beams of light is limited (about 5 to 10 meters).
3. **Interference Environment**: Signal intrusion from external light sources such as sunshine and ordinary bulbs, as well as opaque objects in the transmission channel, and this caused communication to be disrupted.
4. **Line-of-sight technology (LOS):** As is well known, the technology named Line-of-Sight (LOS) is beneficial to any system for improved communication. Li-Fi isn't precisely a LOS technology since, even while the changeover isn't in a direct line of sight, data is still sent, although at a slow rate.
5. **Reliability of Li-Fi:** It is necessary to have light present. The availability and alignment of LOS connections are critical to the dependability of an OWC channel.
6. **Compatibility Limitation:** As the technology of Li-Fi is considered new, there are a small number of gadgets are well-matched with this technology. Many devices are currently relied on communication using a Wi-Fi network, and Li-Fi which permitted particular gadgets is unlikely to materialize in the following years.

6. Efficiency and Availability of Li-Fi

Although there are several drawbacks to adopting Li-Fi technology, such as the receiver's restricted range and line of sight, there are several advantages. Without producing interference, Li-Fi might be utilized in settings that are sensitive to electromagnetic fields, such as aircraft or hospitals. Publics have come to be reliant on light to access the internet. If the light source fails, you will be unable to access the internet. Every source of light can connect to the internet with Li-Fi. When Li-Fi technology is widely offered, street lights, building lights, and transit lighting will all be able to interact wirelessly, and the internet will be accessible from everywhere. Due to the nature of LED lights, which are effective on their own when it’s used as energy, Li-Fi has the potential to be more cost-effective and energy-efficient. Connection is the have additional use for the technology of Li-Fi because it can work without the need of components for electrical devices such as antennas, routers, modems, repeaters of signal, and amplifiers of the wave, it will consume less cost in the home environment and offices. As a result, these devices must be connected to power 24 hours a day, 7 days a week to function. Due to the information that many structures LED lights are already installed, The Li-Fi technology would not be an added cost. Additionally, pure LiFi is functioning on cells of solar as light detectors to allow simultaneous wireless battery charging and Internet connectivity.

7. Conclusion and Future Works

A large number of academics and institutions are now working on this notion of li-Fi, which has the potential to alleviate radio spectrum shortages, space constraints, and slow internet connection speeds. Though there is still a long way to go before this technology is commercially feasible, it offers a lot of promise in the wireless internet sector. Since it offers a true and agile alternative to wireless devices that rely on the radio spectrum, the Li-Fi concept has aroused people's interest. It is well known that it is superior to Wi-Fi and other technologies in terms of performance and usability in a range of fields. As a result, Li-Fi technology is usually

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regarded as being more secure than Wi-Fi. LiFi systems may be enhanced with a variety of security mechanisms to make them extra safe. Transmission speed and data dependability are already good. This paper presented a sight about Li-Fi, including the architecture of Li-Fi and its applied environment, differences between Wi-Fi and Li-Fi Technologies is presented, also the constraints of Li-Fi technology are determined with a brief description of the Efficiency and availability of Li-Fi. In the future, work on analyzing security threats based on the architecture of Li-Fi, analyzing will done by conducting a study about the Li-Fi technology's difficulties concerned with data security

References

[1] J.-P. Linnartz, C. R. B. Corrêa, T. B. Cunha, E. Tangdiongga, T. Koonen, X. Deng, M. Wendt, A. Abbo, P. J. Stobbelaar, and M. Müller, "ELIoT: New features in LiFi for next-generation IoT," in *2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*, 2021, pp. 148-153: IEEE.

[2] R. Badeel, S. K. Subramaniam, Z. M. Hanapi, and A. Muhammed, "A review on LiFi network research: Open issues, applications and future directions," *Applied Sciences*, vol. 11, no. 23, p. 11118, 2021.

[3] D. Choudhary, "Next Generation Communication Li Fi Technology," *International Journal of Engineering Research Technology*, vol. 2, no. 11, 2013.

[4] Q. Huang, X. Li, and M. Shaurette, "Integrating Li-Fi wireless communication and energy harvesting wireless sensor for next generation building management," 2014.

[5] R. Jain, V. Kandekar, and P. Kadam, "Wireless Data Communication Using Li-Fi Technology," *IOSR Journal of Electrical Electronics Engineering*, vol. 2, no. 2, pp. 65-68, 2016.

[6] N. R. Saadallah, M. M. Fathi, and R. Arwa, "The efficiency of Li-Fi (Light–Fidelity) security and data transmission compared to Wi-Fi," *Materials Today: Proceedings*, 2021.

[7] N. A. Jasim, H. TH, and S. A. Rikabi, "Design and Implementation of Smart City Applications Based on the Internet of Things," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 13, pp. 4-15, 2021.

[8] A. M. Alaidi, I. A. Aljazaery, and S. H. Abbood, "Dark web illegal activities crawling and classifying using data mining techniques," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 16, no. 10, 2022.

[9] R. Vikkram, M. Kumar, and J. S. K. FG, "Efficient Transmission Using a Visible Light Technology for Data Communication-A LIFI Approach," *Annals of the Romanian Society for Cell Biology*, pp. 2644-2652, 2021.

[10] D. Khandal and S. Jain, "Li-fi (light fidelity): The future technology in wireless communication," *International Journal of Information Computation Technology*, vol. 4, no. 16, pp. 1687-1694, 2014.

[11] Y. Khare, V. P. Tiwari, A. B. Patil, and K. Bala, "Li–Fi Technology, Implementations and Applications," *International Research Journal of Engineering Technology*, vol. 3, no. 04, pp. 1391-1394, 2016.

[12] H. J. Chang, "Framework for data communication in the hospital using Li-Fi technology," *International Journal of Scientific Engineering Research*, vol. 7, no. 8, pp. 637-639, 2016.

[13] L. Yin, M. S. Islim, and H. Haas, "LiFi: transforming fibre into wireless," in *Broadband Access Communication Technologies XI*, 2017, vol. 10128, p. 1012802: SPIE.

[14] Y. Wang, X. Wu, and H. Haas, "Load balancing game with shadowing effect for indoor hybrid LiFi/RF networks," *IEEE Transactions on Wireless Communications*, vol. 16, no. 4, pp. 2366-2378, 2017.

[15] M. D. Soltani, X. Wu, M. Safari, and H. Haas, "Bidirectional user throughput maximization based on feedback reduction in LiFi networks," *IEEE Transactions on Communications*, vol. 66, no. 7, pp. 3172-3186, 2018.

[16] A. A. Jamali, M. K. Rathi, A. H. Memon, B. Das, and S. Ghanshamdas, "Collision avoidance between vehicles through LiFi based communication system," *IJCSNS*, vol. 18, no. 12, pp. 81-87, 2018.

[17] P. K. Sharma, J. H. Ryu, K. Y. Park, J. H. Park, and J. H. Park, "Li-Fi based on security cloud framework for future IT environment," *Human-centric Computing Information Sciences*, vol. 8, no. 1, pp. 1-13, 2018.

ISSN NO: 2770-4491
Date of Publication:07-07-2022

[18] B. Jagadeeswari, C. S. Anusha, D. Monisa, and M. Preethi, "Audio Transmission using Li-Fi Technology," *IJTSRD, March-April*, 2019.

[19] S. T. Abid, M. Shiam Khabir, A. Hasan, A. Saha, and M. Masuduzzaman, "Li-Fi technology: increasing the range of Li-Fi by using mirror," *International Journal of Information Technology Computer Science*, vol. 11, no. 1, pp. 50-57, 2019.

[20] K. Balaji and S. S. Murugan, "Implementing IoT in underwater communication using Li-Fi," *Int J Recent Technol Eng*, vol. 8, 2019.

[21] N. Al Abdulsalam, R. Al Hajri, Z. Al Abri, Z. Al Lawati, and M. M. Bait-Suwailam, "Design and implementation of a vehicle to vehicle communication system using Li-Fi technology," in *2015 International Conference on Information and Communication Technology Research (ICTRC)*, 2015, pp. 136-139: IEEE.

[22] H. K. Yu and J. G. Kim, "Smart navigation with AI engine for Li-Fi based medical indoor environment," in *2019 International Conference on Artificial Intelligence in Information and Communication (ICAIIC)*, 2019, pp. 195-199: IEEE.

[23] M. A. Arfaoui, M. D. Soltani, I. Tavakkolnia, A. Ghrayeb, C. M. Assi, M. Safari, and H. Haas, "Measurements-based channel models for indoor LiFi systems," *IEEE Transactions on Wireless Communications*, vol. 20, no. 2, pp. 827-842, 2020.

[24] A. B. Ozyurt and W. O. Popoola, "Mobility management in multi-tier LiFi networks," *Journal of Optical Communications Networking*, vol. 13, no. 9, pp. 204-213, 2021.

[25] T. Nguyen, M. S. Islim, C. Chen, and H. Haas, "iDim: Practical implementation of index modulation for LiFi Dimming," *IEEE Transactions on Green Communications Networking*, vol. 5, no. 4, pp. 1880-1891, 2021.

[26] M. U. Farooq, M. Waseem, S. Mazhar, A. Khairi, and T. Kamal, "A review on internet of things (IoT)," *International journal of computer applications*, vol. 113, no. 1, pp. 1-7, 2015.

[27] L. I. Albraheem, L. H. Alhudaithy, A. A. Aljaser, M. R. Aldhafian, and G. M. Bahliwah, "Toward designing a Li-Fi-based hierarchical IoT architecture," *IEEE access*, vol. 6, pp. 40811-40825, 2018.

[28] M. K. Abdul-Hussein and H. Alrikabi, "Evaluation of the Interference's Impact of Cooperative Surveillance Systems Signals Processing for Healthcare," *International journal of online and biomedical engineering*, vol. 18, no. 3, pp. 43-59, 2022.

[29] N. V. Swami, N. B. Sirsat, and P. R. Holambe, "Light fidelity (Li-Fi): In mobile communication and ubiquitous computing applications," in *Advances in Computing Applications*: Springer, 2016, pp. 75-85.

[30] H. T. S. AlRikabi, A. H. M. Alaidi, A. S. Abdalrada, and F. T. Abed, "Analysis of the efficient energy prediction for 5G wireless communication technologies," *International Journal of Emerging Technologies in Learning*, Article vol. 14, no. 8, pp. 23-37, 2019.

[31] R. Pradeep, M. Kowsalya, and A. Aarthy, "A Review on under water data transfer and detection of water leakage system using LI-FI," *Gorteria Journal*, 2021.

[32] V. V. Nair, N. Sridhar, and K. Venkateswaran, "Li-Fi based Data Transmission for Underwater Communication," in *2021 6th International Conference on Communication and Electronics Systems (ICCES)*, 2021, pp. 925-929: IEEE.

[33] W. Ayara, M. Usikalu, M. Akinyemi, T. Adagunodo, and K. Oyeyemi, "Review on Li-Fi: an advancement in wireless network communication with the application of solar power," in *IOP Conference Series: Earth and Environmental Science*, 2018, vol. 173, no. 1, p. 012016: IOP Publishing.

[34] I. A. Aljazaery, and A. H. M. Alaidi, "Encryption of Color Image Based on DNA Strand and Exponential Factor," *International Journal of Online Biomedical Engineering*, vol. 18, no. 3, pp. 101-113, 2022.

[35] N. Alseelawi, H. T. Hazim, and H. T. Salim ALRikabi, "A Novel Method of Multimodal Medical Image Fusion Based on Hybrid Approach of NSCT and DTCWT," *International Journal of Online Biomedical Engineering*, vol. 18, no. 3, 2022.

ISSN NO: 2770-4491
Date of Publication:07-07-2022

[36] S. H. Abbood, H. N. Abdull Hamed, M. S. Mohd Rahim, and A. H. M. Alaidi, , "DR-LL Gan: Diabetic Retinopathy Lesions Synthesis using Generative Adversarial Network," *International Journal of Online Biomedical Engineering*, vol. 18, no. 3, 2022.

[37] O. H. Yahya, H. T. Salim, R. a. M. Al_airaji, and M. Faezipour, "Using Internet of Things Application for Disposing of Solid Waste," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 13, pp. 4-18, 2020.

[38] A. Strelnitskiy, V. Shokalo, E. Yagudina, and M. K. Abdul-Hussein, "Method of calculating the detection zone boundaries of the Rayleigh Wi-Fi wireless channel with quasi-static fading," *Radioelectronics Communications Systems*, vol. 55, no. 10, pp. 452-457, 2012.

[39] A. H. M. Alaidi, I. A. Aljazaery, H. TH., I. N. Mahmood, and F. T. Abed, "Design and implementation of a smart traffic light management system controlled wirelessly by arduino," *International Journal of Interactive Mobile Technologies*, Article vol. 14, no. 7, pp. 32-40, 2020.

[40] H. T. ALRikabi and H. T. Hazim, "Enhanced Data Security of Communication System Using Combined Encryption and Steganography," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 16, 2021.

[41] V. M. Shokalo, A. Strelnitsky, M. Abdul-Hussein, and E. Yagudina, "Refined model for calculation of limiting secret efficiency of Wi-Fi communication channel," *Telecommunications Radio Engineering*, vol. 71, no. 16, 2012.

[42] A. T. Mohammed, "Evaluation Study Li-Fi Vs Wi-Fie," 2016.

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