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# **The Possibilities for Deployment Eco-Friendly Indoor Wireless Networks based on Li-Fi Technology**

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**ABSTRACT:** Li-Fi, short for Light Fidelity, is a groundbreaking technology introduced by German physicist Harald Haas during his 2011 TED Global Talk on Visible Light Communication (VLC). Utilizing light-emitting diodes (LEDs), Li-Fi enables wireless optical networking for data transmission. Essentially, Li-Fi operates similarly to Wi-Fi, but utilizes light as the medium for high-speed communication, adhering to the IEEE standard IEEE 802.15.7. This standard facilitates bidirectional, fully networked wireless communication, akin to Wi-Fi's IEEE 802.11. This paper delves into Li-Fi, exploring its applications, features, and comparative analysis with existing technologies like Wi-Fi. While Wi-Fi predominantly serves general wireless coverage within buildings, Li-Fi excels in providing high-density wireless data coverage in confined spaces, particularly in areas where radio interference poses challenges. Hence, Li-Fi and Wi-Fi are complementary technologies. Li-Fi boasts superior bandwidth, efficiency, connectivity, and security compared to Wi-Fi, achieving speeds exceeding 1 Gbps under laboratory conditions. Leveraging the cost-effectiveness of LEDs and lighting infrastructure, Li-Fi presents numerous opportunities for exploitation. Essentially, Li-Fi revolutionizes data transmission by utilizing LED light bulbs to transmit data, effectively eliminating the need for fiber optics.

**KEYWORDS:** Li-Fi, Wi-Fi, Visible Light Communication, Radio Spectrum.

## **I. INTRODUCTION**

In today's era of congested data communication, Li-Fi stands out as a novel and efficient wireless communication method. Li-Fi harnesses LED lights to transmit data wirelessly, offering a viable alternative to traditional radio wave-based systems. Current wireless networks often experience slowdowns when numerous devices are connected, compounded by the growing number of internet-enabled devices. Limited bandwidth availability further exacerbates the challenge of achieving high data transfer rates and maintaining network security. Unlike conventional methods that rely solely on radio waves, Li-Fi utilizes a broader spectrum for data transmission, specifically tapping into the visible light spectrum. The fundamental principle behind Li-Fi involves transmitting data through variations in LED light intensity, far beyond the detection capabilities of the human eye. By leveraging an underutilized portion of the electromagnetic spectrum, Li-Fi presents a promising solution for data transfer, bypassing the limitations of conventional gigahertz radio waves.

The concept of Li-Fi was first introduced by German physicist Harald Haas during his TED Global Talk on Visible Light Communication (VLC) in July 2011. He presented it as "data through illumination," demonstrating its potential by transmitting a video of a blooming flower using a table lamp with an LED bulb. In essence, Li-Fi can be seen as a light-based alternative to Wi-Fi, utilizing light rather than radio waves for data transmission. Li-Fi technology has the capacity to revolutionize how we access the internet, stream videos, and receive emails by communicating through visible light. Security is inherently integrated, as data transmission relies on the presence of light. This feature makes Li-Fi suitable for use in highly secured military environments, where Radio Frequency (RF) communication is vulnerable to eavesdropping. [Safwan Alfattani\*]

Li-Fi technology represents a paradigm shift in wireless communication, driven by its core values of speed, reliability, security, and sustainability. At the forefront of its justification lies its unparalleled speed capabilities, with laboratory tests demonstrating data transfer rates exceeding 1 gigabit per second (Gbps). This remarkable speed, several times

faster than traditional Wi-Fi, facilitates swift and seamless transmission of large volumes of data, catering to the ever-increasing demands of modern digital applications. Furthermore, Li-Fi leverages the vast potential of the visible light spectrum, offering an expansive bandwidth that far surpasses the congested radio frequency spectrum. With an additional frequency band estimated to be around 400 terahertz (THz), compared to the approximately 300 gigahertz (GHz) available in RF communication, Li-Fi extends the possibilities for high-speed wireless communication, accommodating the growing proliferation of internet-enabled devices. Li-Fi technology embodies sustainability principles by capitalizing on energy-efficient LED lighting infrastructure. LED bulbs, commonly used in Li-Fi setups, consume significantly less energy compared to traditional lighting sources. This not only reduces the operational costs but also contributes to environmental conservation efforts by minimizing energy consumption and greenhouse gas emissions. In summary, Li-Fi's values of speed, reliability, security, and sustainability are exemplified by its impressive performance metrics and practical applications. With its unparalleled speed capabilities, expanded bandwidth, enhanced security features, and environmental benefits, Li-Fi is poised to revolutionize wireless communication and pave the way for a more connected and sustainable future.

## II. MATERIAL AND METHODOLOGY

Li-Fi which can be the future of data communication, appears to be a fast and a cheap optical version of Wi-Fi. Being a Visible Light Communication (VLC), Li-Fi uses visible light of electromagnetic spectrum between 400 THz and 800 THz as optical carrier for data transmission and illumination. It uses fast pulses of light to transmit information in wireless medium. The main components of a basic Li-Fi system may contain the following: a) A high brightness white LED which acts as transmission source. b) A silicon photodiode with good response to visible light as the receiving element. Turning the LEDs on and off can make them generate digital strings with different combination of 1s and 0s. To generate a new data stream, data can be encoded in the light by varying the flickering rate of the LED. In this way, the LEDs work as a transmitter by modulating the light with the data signal. The LED output appears constant to the human because they are made to flicker at a phenomenal speed (millions of times per second) and it's impossible for human eye to detect this frequency. Communication rate more than 100 Mbps can be achieved by using high speed LEDs with the help of various multiplexing techniques. The Li-Fi transmitter system consists of four primary subassemblies: Bulb, Power Amplifier Circuit (PA), Printed Circuit Board (PCB), Enclosure, etc.

The Printed Circuit Board (PCB) controls the electrical inputs and outputs of the lamp, and houses the microcontroller used to manage different lamp functions. Radio Frequency (RF) signal is generated by the Power Amplifier and is directed into the electric field of the bulb, as a result of the high concentration of energy in the electric field.

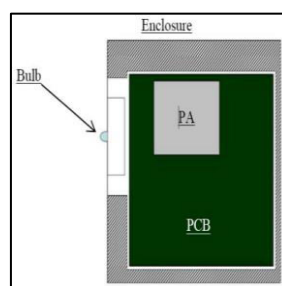


Fig 1: Block Diagram of Li-Fi sub-assemblies [2]

The working of Li-Fi is very simple. There is a light emitter on one end i.e. an LED transmitter, and a photo detector (light sensor) on the other. The data input to the LED transmitter is encoded in to the light (technically referred to as Visible Light Communication) by varying the rate at which the LEDs turns 'on' and 'off' to achieve different strings of 1s and 0s. The on-off activity of the LED transmitter which seems to be invisible (The LED intensity is modulated so fast that human eye cannot notice it, so the light of the LED appears constant to humans), enables data transmission in light form in accordance with the incoming binary codes: switching ON a LED is a logical '1', switching it OFF is a logical '0'. By varying the rate at which the LEDs turns on and off, information can be encoded in the light to different combinations of 1s and 0s. In a typical setup, the transmitter (LED) is connected plasma state at the bulb's center. And this controlled plasma in turn will produce an intense source of light. All of these subassemblies are contained in an

aluminum enclosure the data network (Internet through the modem) and the receiver (photo detector/light) [ Anurag Sarkar and Agarwal, et. al].

Light Fidelity (Li-Fi) technology is a wireless communication system based on the use of visible light between the violet (800 THz) and red (400 THz). Unlike Wi-Fi which uses the radio part of the electromagnetic spectrum, Li-Fi uses the optical spectrum i.e. Visible light part of the electromagnetic spectrum. The principle of Li-Fi is based on sending data by amplitude modulation of the light source in a well-defined and standardized way. LEDs can be switched on and off faster than the human eyes can detect since the operating speed of LEDs is less than 1 microsecond. This invisible switching activity enables data transmission using binary codes. If the LED is on, a digital signal '1' is transmitted and if the LED is off, a digital signal '0' is transmitted. Also, these LEDs can be turned on and off very quickly which gives us a very nice opportunity for transmitting data through LED lights, because there are no interfering light frequencies like that of the radio frequencies in Wi-Fi. Li-Fi is thought to be 80% more efficient, which means it can reach speeds of up to 1Gbps and even beyond. Li-Fi differs from fibre optic because the Li-Fi protocol layers are suitable for wireless communication over short distances (up to 10 meters). This puts Li-Fi in a unique way of extremely fast and efficient wireless communication over short distances. Among the above possible solutions, visible light communication (VLC), which uses wireless optical in the wavelength interval of 380–780 nm has received much research interests recently.

The first wireless communication prototype using visible light was far back as 1880, when Alexander Graham Bell developed a photo-phone that allowed for the transmission of both sounds and normal human conversations on a beam of light. However, the research of optical wireless communication did not receive much attention for several years. As the development of the semiconductor technology, this situation has been changed. It is possible that visible light communication (VLC) uses off-the-shelf white light emitting diodes (LEDs) as signal transmitters and off-the-shelf p-intrinsic-n (PIN) photodiodes (PDs) or avalanche photo-diodes (APDs) as signal receivers [7].

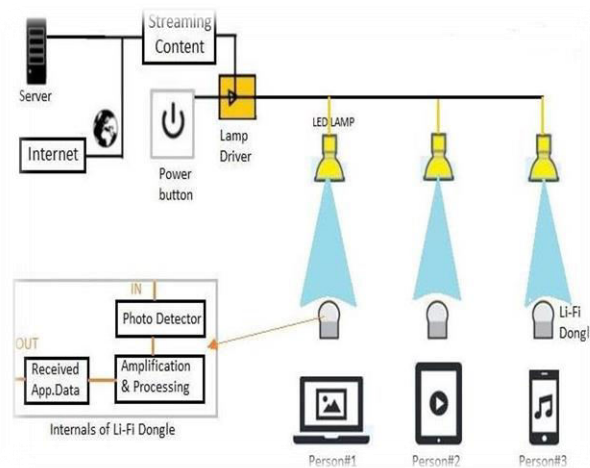


Fig 2: Block Diagram of Li-Fi Working [6]

In simpler terms, all you need for a Li-Fi system is a set of LEDs and a controller to manage them. The controller encodes data into the LEDs, controlling how fast they flicker based on the input data. To increase data rates, you can use multiple LEDs in parallel for simultaneous transmission or mix different colored LEDs to encode multiple data channels using different light frequencies. This approach allows for efficient data transmission through light signals. The figure below illustrates how a Li-Fi system can connect devices within a room, demonstrating its practical deployment. Many of us are familiar with Wi-Fi, the technology that allows us to access the internet wirelessly using radio waves in the 2.4-5GHz frequency range. Wi-Fi is commonly used in homes, schools, offices, and public places, providing convenient internet access. However, Wi-Fi has its limitations. While it can cover a whole house, its bandwidth is typically limited to 50-100 megabits per second (Mbps) using the IEEE 802.11n standard. This bandwidth is often insufficient for tasks like streaming high-definition movies, storing large media libraries, or playing video games. As our reliance on cloud services and media servers grows, the need for higher bandwidth and faster speeds becomes more pressing. RF-based technologies like Wi-Fi may not be the most efficient solution for meeting these

demands. Additionally, Wi-Fi may not be well-suited for emerging capabilities such as indoor positioning or gesture recognition. [R.Karthika1 , S.Balakrishnan2]



Figure 3: - Li-Fi integrated conference rooms

Visible Light Communication (VLC) encompasses technologies that utilize visible light to transmit data. One notable project in this field is the D-Light project at Edinburgh's Institute for Digital Communications, which received funding from 2010 to 2012 and helped promote VLC technology through a TED Global talk in 2011. Pure Li-Fi, previously known as Pure VLC, is a company that manufactures Li-Fi products, which use LED lights for wireless data transmission. The Li-Fi Consortium, formed in October 2011, aims to advance optical wireless systems like Li-Fi to overcome limitations of radio-based wireless communication. While some companies offer unidirectional VLC products using visible light for communication, Li-Fi specifically refers to bidirectional communication systems that use visible light for data transmission. VLC technology was exhibited in 2012 using Li-Fi. By August 2013, data rates of over 1.6 Gbps were demonstrated over a single-color LED. In September, Li-Fi technology use a part of the electromagnetic spectrum that is still not greatly utilized. Light is in fact a very much part of our lives for millions and millions of years and does not have any major ill effect. Moreover, there is 10,000 times more space available in this spectrum and just counting on the bulbs in use, it also multiplies to 10,000 times more availability as an infrastructure, globally.

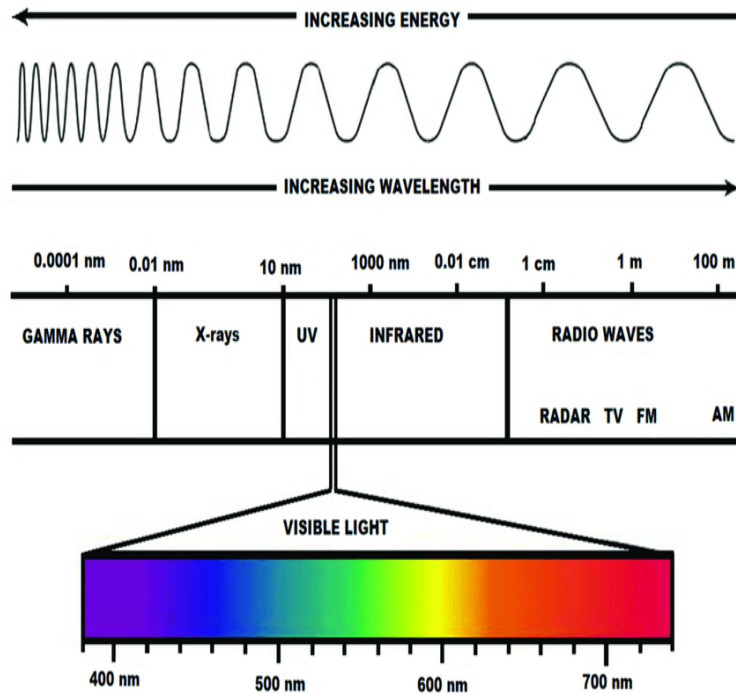


Fig 4: - The visible spectrum

Table 1: Comparison Between Li-Fi and, Wi-Fi:-

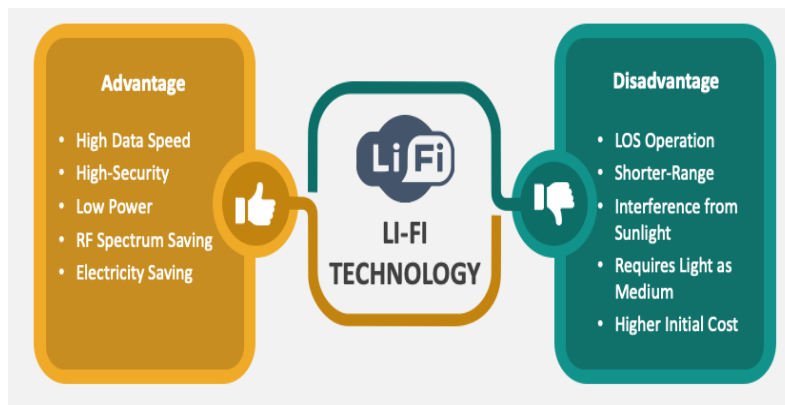
Li-Fi	Wi-Fi
Uses visible light of electromagnetic spectrum	Uses radio waves of electromagnetic spectrum
Cannot penetrate through walls	Can penetrate through walls
Li-Fi covers distance of about 10 meters	Wi-Fi has a range of 30 meters
Lesser interference from other devices	Has interference issues from nearby devices and routers
Speed of 1 Gbps is in use commercially	Speed up to 2 Gbps can be achieved commercially
A range of 10,000 times more than radio waves	Short frequency range of 2.4GHz to 5GHz
Consumes less power	Takes up more power to operate

### (A) Advantages of Li-Fi

- 1) Efficiency: Energy consumption can be minimized with the use of LED illumination which are already available in the home, offices and malls etc. for lighting purpose. Hence the transmission of data requiring negligible additional power, makes it very efficient in terms of costs as well as energy.
- 2) High speed: Combination of low interference and high bandwidth and also high-intensity output, help Li-Fi provide high data rates i.e. 1 gbps or even beyond.
- 3) Availability: Availability is not an issue. A light source is present everywhere. Wherever there is a light source, there can be Internet. Light bulbs are present almost everywhere – in homes, offices, shops, malls and also in planes, which can be used as a medium for the data transmission.
- 4) Cheaper: Li-Fi not only requires fewer components for its working, but also uses only a negligible additional power for the data transmission.
- 5) Security: One main advantage of Li-Fi is security. Since light cannot pass through opaque structures, Li-Fi internet is available only to the users within a confined area and cannot be intercepted and misused, outside the area under operations.
- 6) Li-Fi technology has a great scope in future. The extensive growth in the use of LEDs for illumination indeed provides the opportunity to integrate the technology into a plethora of environments and applications [1]

### (B) Limitations of Li-Fi

1. Internet cannot be accessed without a light source. This could limit the locations.
2. Situations in which Li-Fi could be used. It requires a near or perfect line-of-sight to transmit data.
3. Opaque obstacles on pathways can affect data transmission.
4. Natural light, sunlight, and normal electric light can affect the data transmission speed.
5. Light waves don't pass through walls and so Li-Fi has a much shorter range than Wi-Fi.
6. High initial installation cost, if used to set up a full-fledged data network.
7. Yet to be developed for mass scale adoption.



**Fig 5: - Advantages & Disadvantages**

### (C) Application of Li-Fi

The applications of visible light communication to location-based services and new graphical user interfaces that combine visual imagery with visible light communication have potential widespread use. For these applications, users are able to know the information associated with a transmitter. If a transmitter is attached to a building or a fixed place, location information will be obtained.

**a) Indoor Navigation:** A typical application of visible light communication for location-based services is where a user uses a cellular phone with a photo diode, which detects signals from an LED light. This application is especially useful indoor

Because (GPS) receivers do not work well indoors even though they work well outdoors. Indoor navigation is convenient for everyone, and it is especially indispensable for the visually impaired. Such a navigation system can be proposed for the visually impaired as shown in Fig. LED lights emit visible light with location data and a smart phone

with visible light receiver receives the data. The smart phone calculates the optimal path to a designation and speaks to the visually impaired through a headphone. [aSLD Laser, Inc., Goleta, CA, USA 93117 bLi-Fi R&D Centre, the University of Edinburgh, Etol]

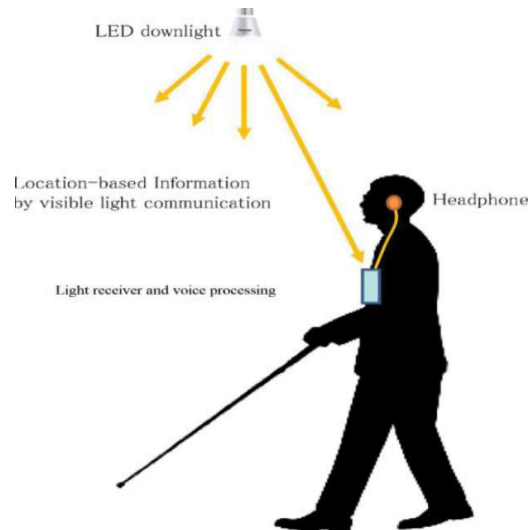


Fig.6 Li-Fi Used in Indoor Navigation

**b) Education systems:** Li-Fi is the latest technology that can provide fastest speed for Internet access. So, it can augment/replace Wi-Fi at educational institutions and at companies so that the people there can make use of Li-Fi with the high speed.



Fig.7 Li-Fi Used in Education System [4]

**c) Aircraft:** The passengers travelling in aircrafts get access to low speed internet at a very high rate. Also Wi-Fi is not used because it may interfere with the navigational systems of the pilots. In aircrafts Li-Fi can be used for data transmission. Li-Fi can easily provide high speed internet via every light source such as overhead reading bulb, etc. present inside the airplane. In aircraft, the overhead lights can be used for data transmission. It can also be used in petroleum or chemical plants where other transmission or frequencies could be hazardous. Airline Wi-Fi wants captive audience to pay for the "service" of dial up on the plane. And also they are very expensive. Passengers will soon be offered a "high-speed like —connection on some airlines. Li-Fi could easily introduce that sort of speed to each passengers reading light. It would be interruption free to and from other wireless signals on the board.





Fig 8. LIFI Used in Aircraft [4]

**d) Public Hotspot:** Public Li-fi Hotspot There are around 14 billion bulbs worldwide, they just need to be replaced with LED ones that transmit data as we reckon VLC at a factor of ten, cheaper than Wi-Fi. In streets for traffic control. Cars have LED based headlights, LED based backlights, and cars can communicate with each other and prevent accidents in the way that they exchange such information. Traffic light can communicate to the cars and so on. By implementing this technology worldwide every street lamp would be a free access point. In traffic signals fig.9 Li-Fi can be used which will communicate with the LED lights of the cars which can help in managing the traffic in a better manner and the accident numbers can be decreased. Also, LED car lights can alert drivers when other vehicles are too close.



Fig 9. LIFI Used in Public Hotspots [4]

**e) Underwater Communication:** In recent days, Underwater Communication is used to keep track of obstacles and ocean species. Wi-Fi cannot be used in underwater communication because in water the radio Waves are get absorbed. Li-Fi can be used underwater because light can penetrate deep into water. In this paper, we present a real-time video transmission using Li-Fi (Light Fidelity) transmitter. The audio and video transmission achieve a maximum distance of 200m. The Li-Fi transmitter and receiver are used to analyze the performance and various conditions such as quality, intensity, and distance. The key advantage of Li-Fi is low power consumption and very high data rates. The software is implemented in Keil software.

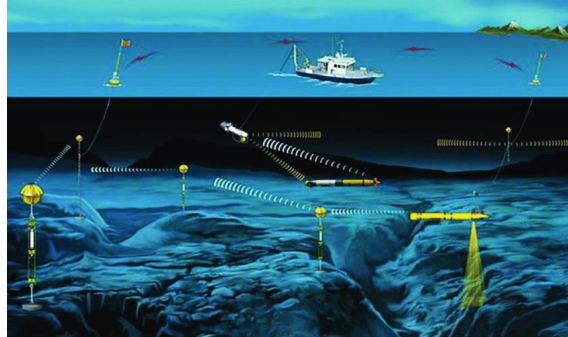


Fig.10 LIFI Used in Underwater [4]

#### **(D) Li-Fi Future Scope**

Li-Fi technology, rooted in the principle of visible light communication (VLC), represents a paradigm shift in wireless communication. By harnessing light waves emitted by LED bulbs, Li-Fi enables high-speed data transmission at gigabit speeds, surpassing conventional Wi-Fi. Its utilization of the visible light spectrum results in reduced interference and enhanced security, making it suitable for environments where electromagnetic interference is a concern, such as hospitals and aircraft. Moreover, Li-Fi's integration potential with the Internet of Things (IoT) promises seamless connectivity in smart homes, cities, and industrial settings. Energy-efficient LED bulbs serve a dual purpose, illuminating spaces while transmitting data, thus contributing to energy savings. Li-Fi's precision in indoor positioning and navigation systems further extends its utility, offering accurate navigation in complex indoor environments. As technology progresses, Li-Fi's integration with 5G networks presents opportunities for network optimization and capacity enhancement. While challenges such as limited range and environmental factors persist, ongoing research endeavors aim to address these limitations, paving the way for broader adoption and application of Li-Fi across various sectors.

#### **(E) LIFI Market Size**

As of recent estimates, the Li-Fi market has been burgeoning, albeit from a relatively modest starting point. In 2021, its global valuation hovered around \$454 million, reflecting a promising trajectory. Forecasts indicate a robust compound annual growth rate (CAGR) surpassing 70% through 2027, propelling the market size into the billions. This surge is propelled by several key factors. Firstly, the escalating demand for high-speed data transmission, driven by the proliferation of data-intensive applications and Internet of Things (IoT) devices, is a significant catalyst. Secondly, mounting concerns regarding data security have positioned Li-Fi favorably, given its inherent advantages over conventional radio-based technologies like Wi-Fi. Thirdly, advancements in light-emitting diode (LED) technology have rendered Li-Fi implementations more feasible and cost-effective, widening its appeal. Moreover, Li-Fi's versatility extends its reach across diverse sectors, including healthcare, retail, automotive, and aerospace, where its attributes, such as rapid data transmission and precise indoor positioning, find practical applications. Additionally, its compatibility with emerging technologies like 5G networks and IoT ecosystems augurs well for its integration and interoperability. While the Li-Fi market remains comparatively small in contrast to established wireless technologies, its upward trajectory underscores its potential to revolutionize wireless communication in the coming years [7].

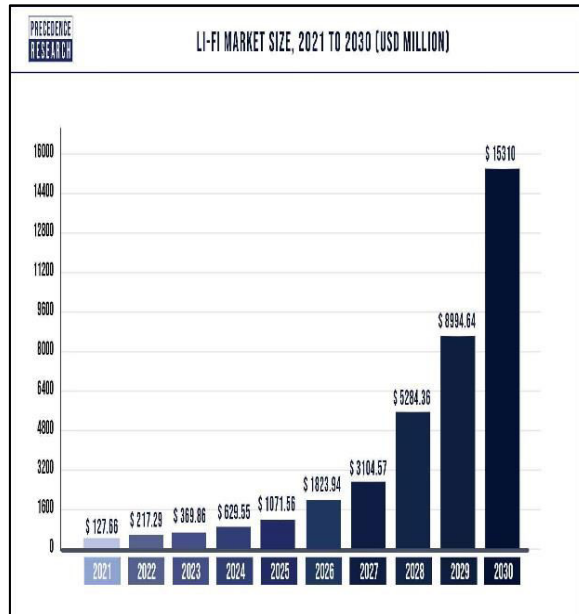


Fig 11. LIFI Market Size [4]



Fig.12 LIFI Market Size in Future [2]

### III. CONCLUSION

The potential applications of Li-Fi are vast and warrant further exploration. If this technology can be effectively implemented, every light bulb could serve as a Wi-Fi hotspot, transmitting wireless data and leading us towards a cleaner, greener, safer, and brighter future. The concept of Li-Fi is currently gaining significant attention because, with its advanced capabilities, more people and their myriad devices can access wireless internet and transmit data at higher rates, all at a lower cost compared to Wi-Fi. While Li-Fi may not completely replace conventional radio technologies, it has the potential to greatly enhance the development of wireless television and simplify the distribution of wireless signals throughout a home. Currently, positioning a wireless router optimally can be challenging, but using visible light communication (VLC) to transmit signals within a home from one point to another could enable the deployment of small local routers at strategic points, reducing the likelihood of interference. In areas saturated with radio signals or

where security concerns prohibit their use, Li-Fi could serve as a high-speed wireless network solution. While Li-Fi has limitations, such as requiring direct line of sight to light, it presents a viable solution to address the shortage of radio frequency spectrum. The integration of both light and radio waves for data transfer represents a significant advancement in technology and science. Overall, the growing interest in Li-Fi stems from its potential to offer an efficient alternative to traditional radio-based wireless systems.

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