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Analyzing Li-Fi Communication Benefits Compared to Wi-Fi

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Abstract

Li-Fi, or known as light fidelity, is a new technology that could alleviate some network congestion for the ever-increasing internet of things (IOT). The patent for Li-Fi was created by German physicist Harald Haas in 2011 around visible light communication. The purpose of the following research includes the capabilities of Li-Fi Technologies and how the implementation of a Li-Fi network can improve network infrastructure. A main point is to highlight the advantages that Li-Fi technology brings to the table in comparison to traditional Wi-Fi networks like the increased bandwidth frequency, faster transmission speeds, as well as not being affected by network latency due to high traffic. Benefits that Li-Fi technologies provide to network infrastructure include the use of less energy, the need for fewer components to operate, as well as the simplicity of only needing a light source to provide high-speed internet traffic. Some of our research shows the implementation of these systems and how they can provide different benefits to different types of needs of the consumer. The research gave a complete idea about hybrid indoor systems based on Li-Fi and Wi-Fi that indicates how Li-Fi technology raises the possibilities to fulfill the technological demand in the future. Also, the part explained the security concerns of Li-Fi technology and we can consider this technology secure by updating some system protocols. At present day, Li-Fi lacks the infrastructure that Wi-Fi has, which makes replacement unideal. Rather, Li-Fi can be seen as complementary to Wi-Fi and used to improve current technology.

Keywords

Next Generation Data Transmission, Light Fidelity, IEEE, LED, Network Congestion

1. Introduction

Li-Fi is an up-and-coming technology aiming to change the way networks are used by its consumers, "Li-Fi (light fidelity) is a bidirectional wireless system that transmits data via LED or infrared light based on the article written on https://www.iberdrola.com/. It was first unveiled in 2011 and, unlike Wi-Fi, which uses radiofrequency, Li-Fi technology only needs a light source with a chip to transmit an internet signal through light waves" [1]. Today's current wireless technology is Wi-Fi (wireless fidelity) works by using radio frequencies to send signals between devices. Li-Fi is a major advancement over today's wireless networks and could possibly be a replacement for Wi-Fi in many different applications. According to https://www.iberdrola.com/, "Li-Fi multiplies the speed and bandwidth of Wi-Fi, 3G, and 4G. The latter has a limited capacity and become saturated when the number of users surfing increases, causing them to crash, reducing speeds and even interrupting the connection" [1]. Li-Fi acquires a band frequency of 200,000 GHz compared to 5 GHz of traditional Wi-Fi. This comparison shows that Li-Fi is up to 100 times faster and can transmit substantially more information per second. A recent 2017 study by the University of Eindhoven acquired a download rate of 42.8 Gbit/s with infrared light with a radius of 2.5 meters. During this study, the best Wi-Fi connection would scarcely reach 300 Mbit/s. Below is a picture from The University of Edinburgh Li-Fi Research and Development Centre.

According to **Figure 1**, Li-Fi technology can change multiple ways of life that directly impact humans, animals, and even our ecosystems for beneficial purposes. Li-Fi will be able to connect to the internet in places where electromagnetic radiation is not accessible, LED headlights will be able to communicate with other cars and receive traffic information, and humans will be able to connect our refrigerators or dishwasher through light to create networks of electrical appliances, light waves can travel further in water than other waves, businesses handling sensitive information will be able to send and receive data more securely, and finally lighting in shops could give us more detailed information on products and discounts.

According to the report from https://www.iberdrola.com/, "This report estimates that the global market will reach a value of nearly $36 billion in 2028, and that over the next 10 years the compound annual growth rate will rise to 71.2%. The Asia-Pacific region will lead the global growth in Li-Fi technology up to 2028, overtaking Europe, which remained at the forefront in 2017" [1].

Li-Fi technology has tremendous potential that can enhance and improve our use of data, the internet, and our overall civilization. Li-Fi is faster, cheaper, and more secure than Wi-Fi. One major advance is that Li-Fi is faster and has been proven to reach 224 Gbit/s. An example is that a 1.5 Gbit film could be downloaded in thousandths of a second. To compare this with traditional Wi-Fi, the current speed swings between 11 and 300 Mbit/s. Li-Fi is also 10 times cheaper than Wi-Fi, the technology only needs fewer components, and overall,

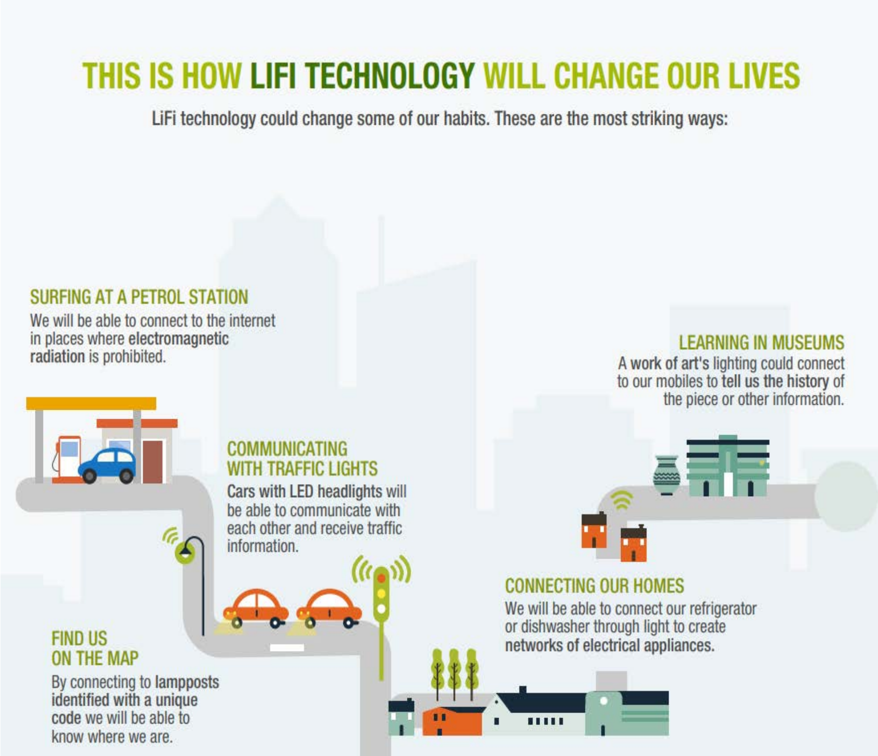

Figure 1. How Li-Fi technology will change our lives.

Li-Fi technology uses less energy. To use Li-Fi technology a user simply has to turn on a light source. Another benefit of Li-Fi is that there is absolutely no interference with radio communications or interaction with other systems such as ships, aircrafts, etc. The final benefit of Li-Fi is that it is wireless and invisible. Li-Fi utilizes lights and dispenses with a user's router, thus the user will not need any cables for Li-Fi. Li-Fi can also operate with infrared light and to humans this is invisible. This technology can operate in low LED light at very low intensity to avoid disturbances as well. **Figure 2** below shows a real-life example of how Li-Fi can work in an everyday office from Boston University [2].

The rest of this paper is organized as follows. In Section 2 we review related work and will go over our results and analysis. The paper concludes in Section 3. Section 4 is the references.

2. Related Work

Li-Fi, which has been seen as being the future of data communication, has the possibility of being a fast and cheap optical version of Wi-Fi. Li-Fi is considered a Visible Light Communication or VLC. Li-Fi takes the visible light from the electromagnetic spectrum from the range of 400 THz to 800 THz to use as the optical carrier for data transmission and illumination [3]. Li-Fi uses fast pulses of light to transmit data through a wireless medium. The main components of a basic Li-Fi system contain the following:

- High Brightness white LED which acts as the transmission source.

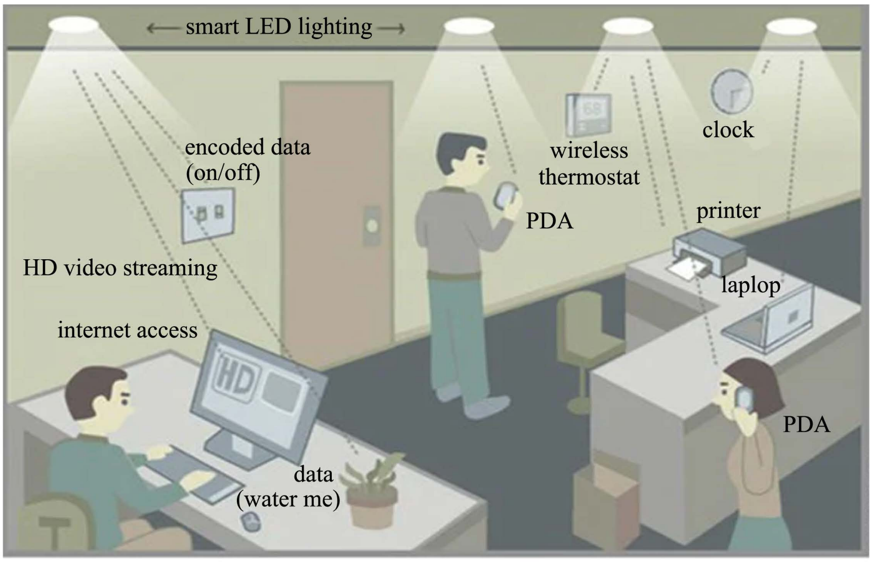

Figure 2. 2009 Boston University [2].

- A silicon photodiode with good response to visible light as the receiving element [3].

One main benefit to using Li-Fi capable technology is that simply turning LED lights on and off can generate a sufficient wireless signal to use. The LED lights are seen as a transmitter by taking the light along with the data signal and sending those back out across the network. Along with all of these possibilities that Li-Fi can introduce to networks, it can also achieve extremely high communication rates at more than 100 megabytes per second, with the use of high-speed LEDs, or with the use of parallel technology speeds can achieve the rates of up to 10 gigabytes per second with each LED array projecting different data streams [3].

Primary advantages from using Li-Fi over Wi-Fi are seen with the capabilities Li-Fi can provide that Wi-Fi can't. First is the efficiency, energy consumption can be minimized with the use of LED lights which are already used by many homes, offices and other different areas that Li-Fi may be seen as advantageous [3]. This means that Li-Fi would not require an extra power source to transmit data across small areas like an office or a home network which can help reduce costs over time the longer it is implemented. Next is the high speed due to the low interference because it is used on the IEEE 802.15.7 standard which does not have nearly as much traffic as the standard that Wi-Fi uses which is IEEE 802.11. Due to the low interference this allows Li-Fi to transmit data over 1 gigabyte per second [3]. Li-Fi also increases the availability of internet connectivity due to the fact that the only thing needed is electricity and light sources are everywhere in homes and workplaces. With Li-Fi wherever there is a power source or light source there can be internet, which can use things like light bulbs as a medium for data transmission. Li-Fi also has fewer components than traditional networking setups, and only needs a small amount of power for it to properly work.

Lastly is the security aspect since light cannot pass through walls, doors, mountains, etc. This means that the internet access is confined to users in a small, confined area and cannot be intercepted by outside threats or agents [3].

The main disadvantages of Li-Fi include the points that without a light source, there will be no internet connectivity, and when it is used, the system requires a near or perfect line-of-sight to properly transmit data [3]. Opaque obstacles can interfere with the transmission of data, as well as sunlight and normal electric light can weaken the signals. As well as the fact that light waves cannot go through walls, it is harder to implement a large-scale system and due to this fact, it has yet to be developed for mass scale adoption [3].

The Architectural Structure of Li-Fi Technology:

For visible light communications, optical fidelity is the primary application, as wireless communication technology transmits information by directing optical signals at approximately 400 The main advantage of Li-Fi technology is the ability to reuse the existing lighting infrastructure. Along with lighting, this recycling can provide indoor wireless data transmission. Li-Fi relies on the modulation of light at high frequencies imperceptible to the human eye for data transformation. Figure 3 below shows the basic block diagram of the VLC (Visual Optical Communication) system [4].

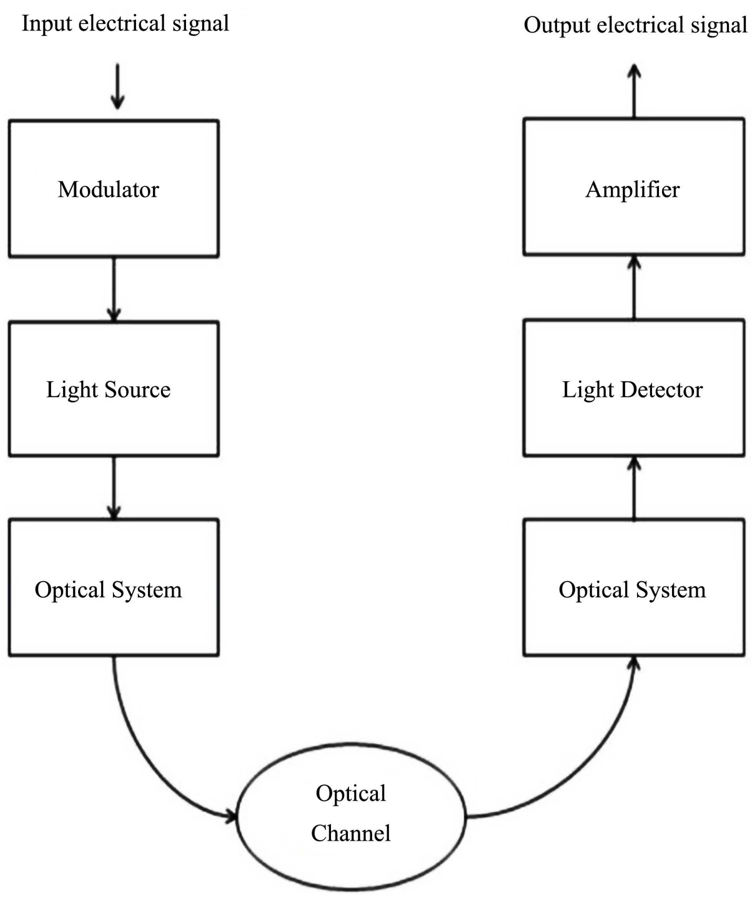

Figure 3. Block diagram of VLC system.

In a Li-Fi communication system, a compact digital signal processor with LED drivers regulates the transmission of digital data through the optical medium of the network/server. The LED driver transducers digital data bit-stream into an optical signal that is usually transmitted at a very high frequency. These signal frequencies stay in the visible light spectrum, which helps to avoid congestion in the existing radio frequency spectrum. The decoder module such as a smartphone, computer or any device in the receiving terminal translates regulated signals into meaningful data for the end-user. The proposed Li-Fi module must decode the modularized data, transmit it via the downlink, and upload the signal via the uplink via Li-Fi. Visual light communication is considered as a one-way, point-to-point optical communication technology. On the other hand, Li-Fi can create two-way communication over multiple frequencies for several networked connections. The latter is a hybrid version of visual light communication and R talk. Li-Fi modules can be classified broadly into sections like transmitter, receiver, Optical Channel, Modulator, and LED driver. Usually, LEDs are the main components in the Transmitter section and the receiver section composes a demodulator unit and photodiode. **Figure 4** shows the typical Li-Fi system structure in [4].

The Li-Fi communication system involves a full-duplex communication method. The downlink in Li-Fi technology transmits using the visible spectrum through intensity modulation of LEDs in solid state lighting systems. However, uplink connections in Li-Fi systems are designed using I-communication, as uplinks in the visible spectrum may cause interference to downlink Data Streams. In the current work, a downlink connection from the access point to the edge devices of the Li-Fi system is established [4].

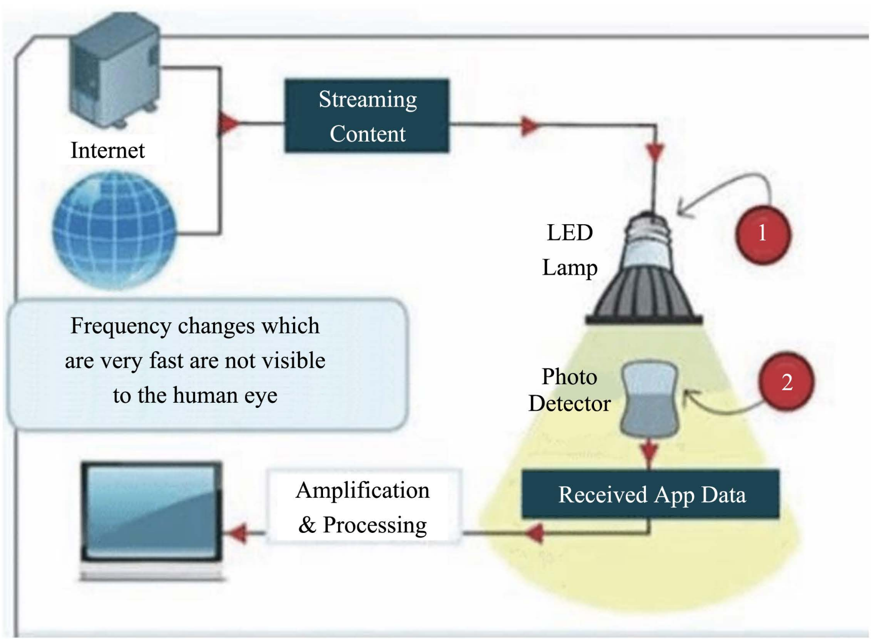

Figure 4. Typical Li-Fi system (6).

Modulation:

In visual light communication, the data that needs to be transmitted is stored in the optical medium. Visible light communication can be detected as a direct detection or intensity modeling system, which can connect a unipolar modulated signal (real value). According to the article, "this limits the modulation schemes of application to the techniques for instance On-Off Keying, Pulse Position modulation, Pulse Width Modulation, and Unipolar Pulse Amplitude Modulation. Since these modulation schemes introduce Inter Symbol Interference (ISI) in the communication channel, Orthogonal Frequency Division Multiplexing technique is considered in the Li-Fi system". The OK modulation technique has been used for data modulation at the transmitter to cover the system. In this article, there is a prototype design proposed and evaluated with white LED lights for maintaining a short-range optical communication system. According to the paper, "Off-the-shelf arrays of white LEDs and single photodiodes (PD) are utilized for analog circuitry design. Investigations into the influence of Signal-to-Noise Ratio (SNR) of communication signal and channel coding on the Bit-Error Rate (BER) performance are performed using the prototype". However, the effect of incident LED beam angle, the relative position of the emitter relative to the receiver on horizontal coverage will be used for performance analysis [4]. The Li-Fi system has a transmitter and a receiver block with associated software block, Figure 5 below shows how the Li-Fi transmitter block works.

Optical Channel:

Optical Channel: In the present work, we choose the optical channel theoretical model given by Barry for analysis [4].

Receiver Block:

At the end of the receiver, the photodiode changes as a transducer that converts the light modulations into electrical impulses. This procedure turns into a

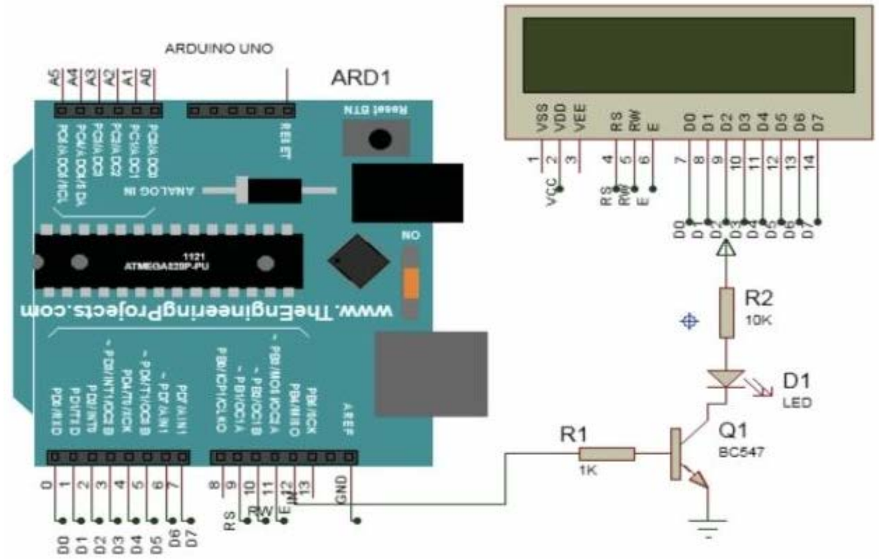

Figure 5. Li-Fi transmitter block.

system processor protocol. According to the article, "Transistor-based ampLi-Fier circuitry is designed to enhance the signal strength. Atmega328P microcontroller is used in the work as a system processor for demodulation and processing of encoded data bits" [4].

Receiver Block:

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Software Block:

Usually, the demodulation and the modulation of data bits are performed in software blocks. According to the diagram above, "the transmitter doing the encoding has been implemented by Manchester encoding the data bits. This process occurs through modulation techniques, in which the LEDs are constantly switched. The encoding algorithm is implemented using C++ on Arduino IDE" [4].

Hybrid Indoor System Based on Li-Fi and Wi-Fi:

Li-Fi networks can deploy many APs and achieve high throughput. That can consider the special convenience of the information rates because of the CCI. The networks expand the framework execution and maintain the high caliber similar services among all the clients. The Wireless-Fidelity (Wi-Fi) can over deploy. Li-Fi uses different bands of frequency spectrum and compared to Wi-Fi there are no barriers among these frameworks. However, a hybrid system that correlates with Wi-Fi and Li-Fi networks is capable of achieving the expecting

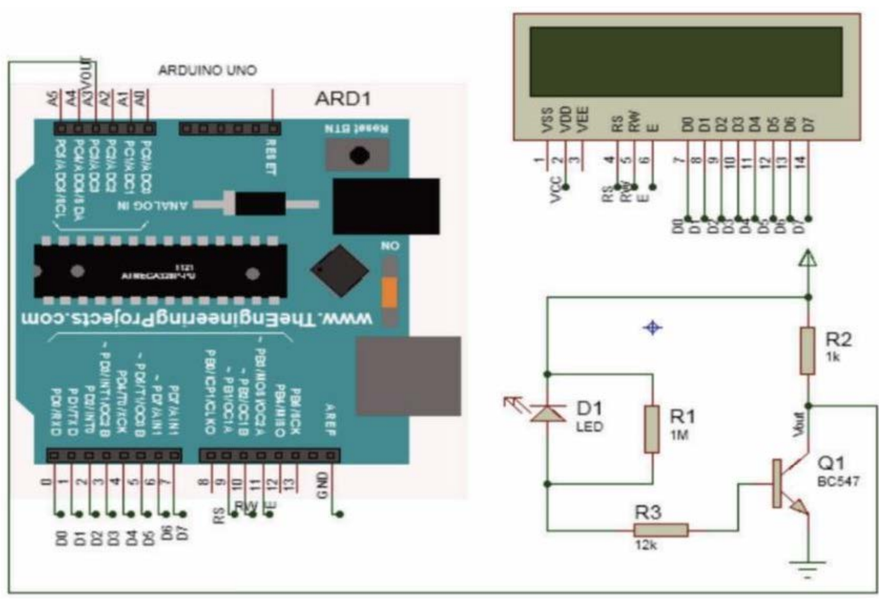

Figure 6. Li-Fi receiver block.

output. One of the latest members of the Wi-Fi family is Wireless Gigabit Alliance (WiGig) that is used for hybrid networks. This upgraded protocol can operate on three different bands of frequency at the same time with some latest modern advanced features. If we consider it as a half-breed connection between Wi-Fi and Li-Fi, all potential areas inside an expanded inclusion territory of clients can benefit by throughput. This hybrid system helps to reduce spectrum efficiency and gives benefits of reduction. Li-Fi technology can offload the present Wi-Fi system and provide additional benefits and give coverage to dead spots to achieve frequent network experiences [5].

Hardware/Software Setup:

In the Li-Fi system, the main part consists of a transmitter and receiver module. For pre-process and modulation data at the transmitter there is a system controller that controls demodulation at the receiver end [5].

Transmitter Block:

In the transmitter, the microcontroller acts as a system processor ii for preprocessing and modulation of the data to be transmitted over the downlink. The data to be transmitted may contain images, text, sounds, etc. Further conversion to the digital domain and data modulation/encoding is performed in the controller. The LED driver circuit is designed to convert the modulated data into an optical signal for transmission through the optical channel [5].

Li-Fi as Intelligent Lighting:

The sensors can monitor several parameters like intensity of light, blinking level of LED and the colors of the light. By using and controlling the dimming level of a transmitter, we can also cover the area of light emitting (LED). This intelligent lighting system can give us a smart solution to control the power consumption of LEDs. These networks can be useful to operate smart home systems powered by LED based lighting. This system can provide illumination and data communication at the same period to achieve the user's goal. According to the article, "In these smart home devices which are used for data communication such as laptop, cell phone, and other smart devices can also perform short distance communication at high-speed using a visible light spectrum".

Analyzing Security Issues in Li-Fi-Based Communication Systems:

Li-Fi-based communication systems track different types of security issues. These issues limit its performance and can decrease the overall efficiency of the network. Some of the principal questions are given under the two LED related questions mentioned below.

LED Light Switching Mode:

Indoor Li-Fi-based communication systems are designed to provide communication for lighting, so the switching speed of LEDs plays a critical role. For a Li-Fi system, it is compulsive of a Light source presence in ON condition that initiates the main question: how data transmission will occur when the LEDs are in turned OFF mode. But even though the brightness of the LED transmitter stays low, data transmission can still be possible. Any desired data can be achieved using light intensity because of the organized way of dimming the LED. In a hybrid setup structure, radio frequency or infrared can work and still provide communication over the LED OFF mode but in Li-Fi-based communication it will not work. It will still be a challenge to find a possible solution of the way to communication. Also, any undesirable situation can occur when a light-emitting diode (LEDs) is in its OFF mode.

LED Junction Temperature:

Thermal temperature management is a critical design that is issued to maintain high-power LEDs. Spectral efficiency can be affected by high junction temperature. Due to variation in drive current, the high junction temperature of LEDs can increase which can cause self-heating and ambient temperature. Degradation can happen because of this high function temperature. This power of single respect to time can reduce the signal-noise ratio (SNR) and degrade the lifespan of LEDs. If hundreds of LEDs arrays are connected in a lighting system, the effect could cause serious problems on a larger scale. By providing an advanced feature of power-saving the Li-Fi system can act smart most of the time. According to the number of users and their necessity the brightness level can be controlled by the lighting system to save power using sensors [5].

3. Conclusions

We have done research on how the Li-Fi technology can turn into a substitute for Wi-Fi.

At present day, Li-Fi lacks the infrastructure that Wi-Fi has, which makes replacement unideal. Rather, Li-Fi can be seen as complementary to Wi-Fi and used to improve current technology. In this article, we gave a general introduction to Li-Fi technology that gives the reader an average idea about how Li-Fi works. Then we included the related work where we describe the frame of Li-Fi technology, and the advantages and the disadvantages of the protocol. In the next part, we illustrated the architectural structure of Li-Fi. We broke the working protocol and the structure into parts with a picture so that the reader could understand the actual way Li-Fi works. Then we presented the hybrid indoor System based on Li-Fi and Wi-Fi which gave a glance at how Li-Fi can be an intelligent light technology and a source of reliable internet.

Our research indicated that Li-Fi technology can be a successful substitute for Wi-Fi. Mainly, we can save a huge amount of energy usage by using Li-Fi technology. By using the natural light source, we can reduce the cost of data management services and get other technical Benefits. Though Li-Fi technology will have security concerns, it is possible to improve the service over time. If we could utilize it properly, we will have new possibilities for managing the data connection better. In the near future, we can create many alternatives and reduce the overwhelming situation of managing data by using Li-Fi technology. Nowadays the demand for technology is booming and keeping these demands up will be less challenging if we properly utilize the Li-Fi technology.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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