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A Review on Li-Fi: The Next Generation Wi-Fi

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Abstract: ***The Li-Fi stands for Light Fidelity. The technology is very new and was proposed by the German physicist Harald Haas in 2011 TED (Technology, Entertainment, Design) Global Talk on Visible Light Communication (VLC). Light Fidelity (LiFi) is a Visible Light Communication (VLC) based technology that making a light as a media of communication replacing the cable wire communication. LiFi is evolved to overcome the rate speed in Wi-Fi, while using LiFi the rate speed can reach until 14 Gbps. This paper includes an introduction of the LiFi technology including the architecture, working, performance, and the challenges Li-Fi, its applications, features and comparison with existing technologies like Wi-Fi etc. Wi-Fi is of major use for general wireless coverage within building, whereas Li-Fi is ideal for high density wireless data coverage in confined area and especially useful for applications in areas where radio interference issues are of concern, so the two technologies can be considered complimentary.***

Keywords: LED, Li-Fi Technology, Wi-Fi Technology, Data Transmission, Visible Light, Li-Fi Applications

I. INTRODUCTION

Professor Harald Haas, Chair of Mobile Communications at the University of Edinburgh is considered to be the founder of the LiFi technology. He coined the term LiFi which stands for light fidelity when he promoted this technology in his 2011 TED Global talk and helped start a company to market it. According to this TED talk, light fidelity can be applied in traffic control systems using a car's headlights or in chemical manufacturing plants where radio frequency is too dangerous and could cause antenna sparks. LiFi will bring internet access in places that RFs cannot reach. The company Haas co-founded is called pureLiFi, formerly pureVLC is an equipment manufacturer firm set up to commercialize LiFi products for integration with existing LED- lighting systems. In September 2013, the company released the world's first commercially available LiFi technology. The Li-1st marked the introduction of a ground-breaking wireless communication technology and became the world's first LiFi technology available on the market. Li-Flame which was released in February 2015, claimed to be the first LiFi product that allowed for mobile wireless communications. A year later, pureLiFi and Lucibel, French lighting company, launched the world's first industrialized LiFi solution, having been deployed in multiple locations including Microsoft's Paris HQ. Chief Innovation Officer at Lucibel, Edouard Lebrun speaks to the benefits of this partnership. In October 2017, the LiFi-XC system was released. This device is a certified plug and play system that works with USB devices and is small enough to be integrated into your next laptop, tablet or smart appliance. And just this June, pureLiFi offered LiFi starter kits to academic researchers and opened a channel program for IT resellers to add LiFi to their portfolio.

A. What is Wi-Fi?

Currently, many people have grown fond of the concept of Wi-Fi and for good reason. Wi-Fi has invaded virtually all facets of human society from the domestic setting and business to basic government services such as ICT and transportation. Due to this heavy dependence on Wi-Fi, many are stuck on this concept as the best mode of wireless communication. For this reason, people seem to remain unfamiliar to a similar concept known as LiFi – even though the concept has been around for many years.

B. Disadvantages of Wi-Fi?

1) *Wi-Fi Connections tend to be Unsecure:* Its lack of security generally comes from its wide signal range, allowing the network to be accessed within a 20 to 50-meter radius. This allows others to access the network as long as they remain within range. Even when the connection is protected with a password, others may attempt to hack into the network, leaving all private data vulnerable. To counter this, most employ sophisticated techniques using high-end technologies to protect their data. However, such techniques also have their own weaknesses that can be exploited to gain access. They are also very expensive to implement.
2) *Signals Tend to be Unreliable:* That is because radio frequencies are still subject to various external interferences. These interferences can cause a variety of connection problems such as providing weak signals, poor reception, or even loss of connection. Add to that the fact that Wi-Fi connections are inherently slower than wired connections. Typically, wireless connections have speeds ranging from 1 to 54 Mbps whereas wired connections have speeds of 100 Mbps or higher.

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C. What is Li-Fi?

On the other side of the spectrum, there lies LiFi. LiFi, which means Light Fidelity, is an emerging piece of technology that makes use of Visible Light Communication (VLC) technology instead of radio waves to transmit data. In LiFi, solid-state lighting (SSL) such as LED bulbs are used in the transmission of data and provide access to the internet or a wireless network. This is done by modulating the light given off by the light source (the transmitter) and is received by a photodiode (the receiver). The signals received from the transmitter are then translated into usable data forms that are readily consumed by the end user. Connections provided by LiFi are typically confined within the space where they are provided due to the nature of visible light.

D. The Visible Light Spectrum

In contrast to using radio waves, LiFi makes use of visible light. This allows LiFi to have access to a greater range of available frequencies as the visible light spectrum is 10,000 times larger than the entire radio spectrum. The visible light spectrum covers frequencies from 430,000 to 770,000 GHz and colors from near ultraviolet to near infrared. Information may be obtained within vicinity of visible light by means of electronic gadgets with photodiode. This means that light bulbs can bring not only light but wireless connection at same time anywhere where LEDs are used. Wi-Fi plays an efficient role in wireless data coverage within buildings, while using Li-Fi we will provide excellent density data coverage in particular location without any radio interference issues. Li-Fi provides better latency, performance, accessibility, and security than Wi-Fi, and under laboratory conditions has even reached extreme speeds greater than 1 Gbps.

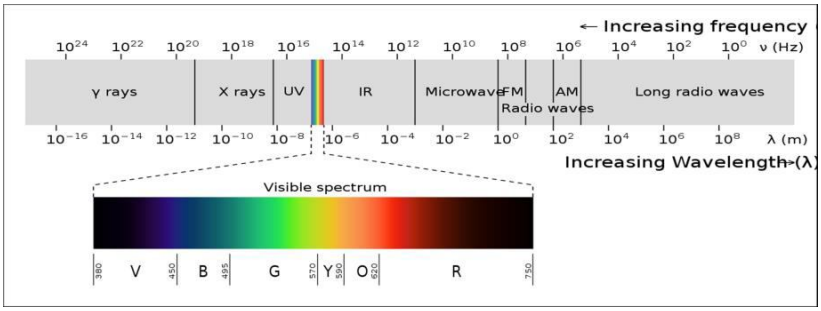

Fig. 1 Visible Light Spectrum

II. MOTIVATION

In the era of overcrowded (data communication) world, Li-Fi is a new way of wireless communication that uses LED lights to transmit data wirelessly. Transmission of data is one of the most important day to day activities in the fast-growing world. The current wireless networks that connect us to the Internet are very slow when multiple devices are connected. Also, with the increase in the number of devices which access the Internet, the availability of fixed bandwidth makes it much more difficult to enjoy high data transfer rates and to connect a secure network. Radio waves are just a small part of the electromagnetic spectrum available for data transfer. Li-Fi has got a much broader spectrum for transmission compared to conventional methods of wireless communications that rely on radio waves. The basic ideology behind this technology is that the data can be transferred through LED light by varying light intensities faster than the human eyes can perceive. This technology uses a part of the electromagnetic spectrum that is still not greatly utilized- The Visible Spectrum, instead of Gigahertz radio waves for data transfer.

III.LITERATURE SURVEY

A. Debanjana Ghosh, Soumyajit Chatterjee, Vasudha Kothari, Aakash Kumar, Mahesh Nair, Ella Lokesh, et.al, An application of Li-Fi based Wireless Communication System using Visible Light Communication, International Conference on Opto-Electronics and Applied Optics (Optronix), 2019

This paper has attempted to clarify the concept and applications of Li-Fi technology. The current Wi-Fi network use Radio Frequency waves, but the usage of the available RF spectrum is limited. Therefore, a new technology, Li-Fi has come into picture. Li-Fi is a recently developed technology. This paper has explained how array of LEDs are used to transmit data in the visible light spectrum. This technology has advantages like security, increased accessible spectrum, low latency efficiency and much higher speed as compared to Wi- Fi. This research paper has successfully demonstrated design of a Li-Fi transceiver using Arduino which is able to transmit and receive data in binary format. The software coding is done in Arduino- Uno platform. Successful transmission and reception of data(alphanumeric) has been done.

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B. *Dileep Reddy Bolla, Shivashankar, R Praneetha, B S Rashmi, et.al, Li-Fi Technology Based Audio And Text Transmission, 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), 2019*

Proposed research provided a demonstration of Light fidelity technology which can be used as an alternative for Wi-Fi as it uses visible light communication. It has high durability, high data transmission rate with its additional quality of long- life expectancy which is an appreciative quality of the Light Emitting Diodes (LEDs) which are being used here as the source of light. In the proposed paper, an innovative concept Light Fidelity (Li-FI) is used to transmit the data to demonstrate the use the case study of Light Fidelity technology. Here, two types of data transmission i.e. Audio and text is carried out using Li - Fi. Proposed work has demonstrated how this above concept can be implied for indoor Location Based Services for the visually challenged people.

C. *Paul Tota, Mircea-F Vaida et.al, Light Fidelity (Li-Fi) Communications Applied to Telepresence Robotics, 21th International Carpathian Control Conference (ICCC), 2020*

This paper has demonstrated how LiFi can be used in telepresence robotics for remote control of the robot and for real-time data exchange. In the Li-Fi system, the data can be transmitted via Visible Light Communication (VLC) system with speeds up to 100 times faster then Wi-Fi This can be an advantage for robots that have direct visual field for a short period of time. This paper has tested the possibility of using the Li-Fi technology on telepresence robots with different mechanical mobility possibilities. An experimental prototype was developed to test the functionality of Li-Fi communications and compare it with Wi-Fi and Bluetooth, for the telepresence robots used in education and medicine.

Rosilah Hassan; Mamoon Salam Flayyih; Ahmed Mahdi; Arbaiah Inn,et.al, Visibile Light Communication Technology For Data Transmission Using Li-Fi, 2nd International Conference on Computer and Information Sciences (ICCIS), 2020

This paper has successfully investigated the performance of data communication using VLC. This research is based on an implementation for different types of data transmission through Li-Fi. The methodology that has been adopted for this study consists on a simulation topology by NS-3 which has been built to study the performance TCP and UDP protocols in Li-Fi environment for VLC communication. Various types of data have been transmitted through an appropriate designed model. The simulation results have shown the differences between the two common algorithms.

D. *Igor L. Kaftannikov, Anastasia V. Kozlova, et.al Prototype of a Li-Fi Communication System for Data Exchange Between Mobile Devices, Global Smart Industry Conference (GloSIC), 2020*

This paper has shown the design and development of a Li-Fi (light fidelity) simplex communication system for data exchange between Android mobile devices. Li-Fi is an up-to-date technology in the modern world, since it uses visible light for data exchange, allowing for high- speed communication. This paper has included the brief review of Li-Fi technology, a review of the literature used, and a study of technological methods for implementing such systems, based on scientific sources. This system has demonstrated the algorithms for data exchange, packet formation, and encryption-decryption. This paper has presented the developed mobile application and the transceiver device, the development results, as well as experiments with the developed prototype.

IV. EXPERIMENTS

A. *Experimental Setup*

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 on-off activity enables data transmission using binary codes. If the LED is on, a digital '1' is transmitted and if the LED is off, a digital '0' is transmitted. Also, these LEDs can be switched 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 position of extremely fast wireless communication over short distances.

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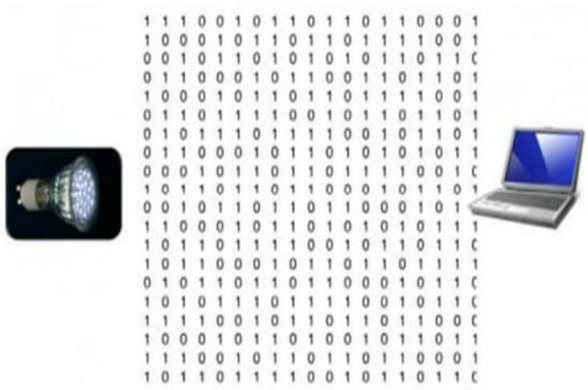

Fig. 2 Li-Fi Transmission

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 into the light (technically referred to as Visible Light Communication) by varying the flickering rate at which the LEDs flicker 'on' and 'off' to generate 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 rapidly that human eye cannot notice, 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 flicker 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 to the data network (Internet through the modem) and the receiver (photo detector/light sensor) on the receiving end receives the data as light signal and decodes the information, which is then displayed on the device connected to the receiver. The receiver (photo detector) registers a binary '1' when the transmitter (LED) is ON and a binary '0' when the transmitter (LED) is OFF. Thus, flashing the LED numerous times or using an array of LEDs (perhaps of a few different colors) will eventually provide data rates in the range of hundreds of Mbps. The Li-Fi working is explained in a block diagram.

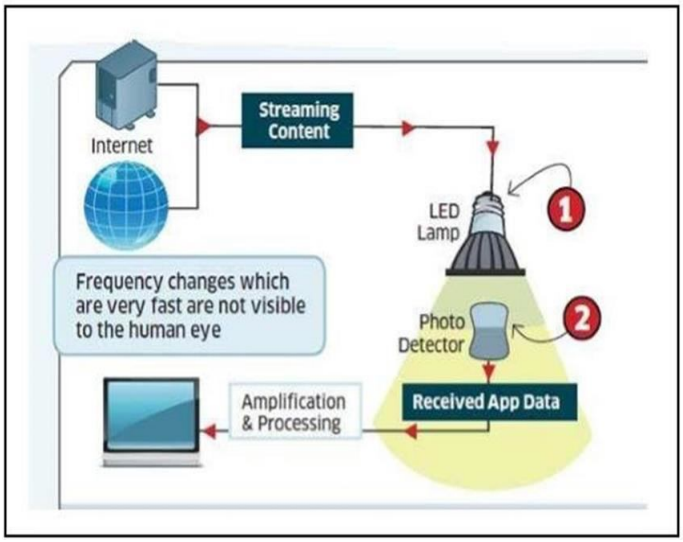

Fig. 3 Block Diagram of Li-Fi Sub System

Hence all that is required, is some or an array of LEDs and a controller that controls/encodes data into those LEDs. All one has to do is to vary the rate at which the LEDs flicker depending upon the data input to LEDs. Further data rate enhancements can be made in this method, by using array of the LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light's frequency, with each frequency encoding a different data channel. Figure 4.2 shows working/deployment of a Li-Fi system connecting the devices in a room.

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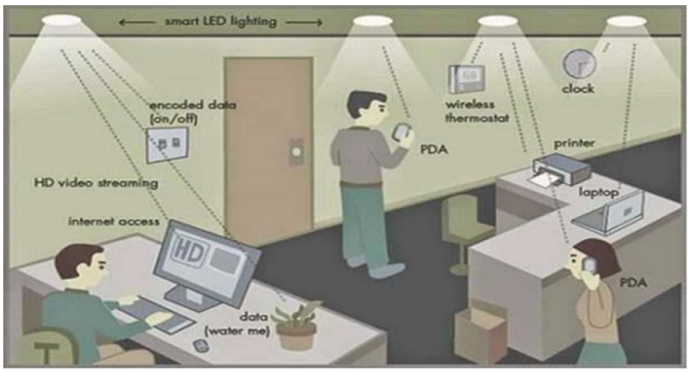

Fig. 4 Li-Fi System Connecting Devices in a Room

B. Result Analysis

When compared to Wi-Fi, Li-Fi has better through put and less delay in transmission of data.

1) Compared to all the medium of transmission of data Li-Fi has more transmission rate per second.

2) Li-Fi has a wide range of market and might take over other mode of data transfer by 2030.

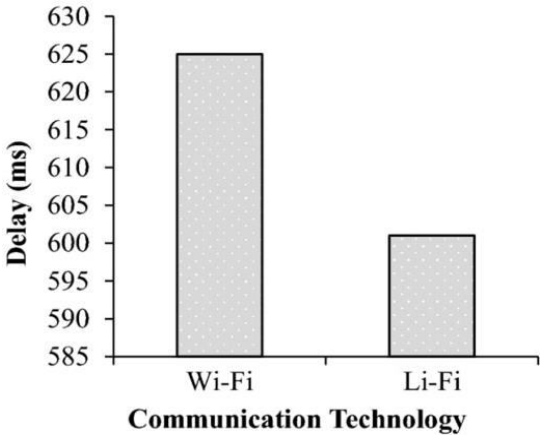

Fig. 5 Delay Comparison

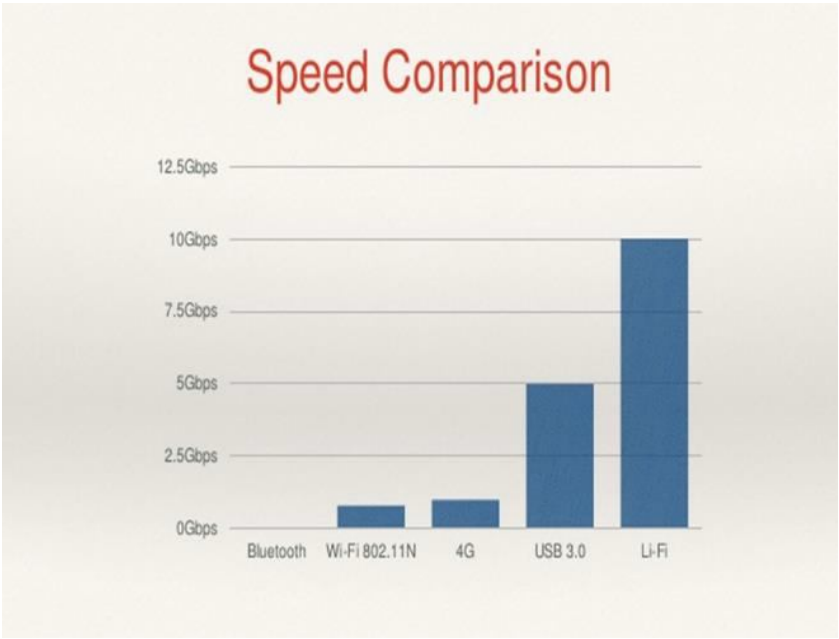

Fig. 6 Speed Comparison

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V. SYSTEM ARCHITECTURE

Deep Li-Fi which can be the future of data communication appears to be a fast and 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:

1) A high brightness white LED which acts as transmission source.
2) A silicon photodiode with good response to visible light as the receiving element.

Switching 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 sender 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. And this VLC data rate can be further increased to as high as 10 Gbps via parallel data transmission using an array of LED lights with each LED transmitting a different data stream.

The Li-Fi transmitter system comprises of four primary subassemblies:

a) Bulb
b) RF Power Amplifier Circuit (PA)
c) Printed Circuit Board (PCB)
d) Enclosure

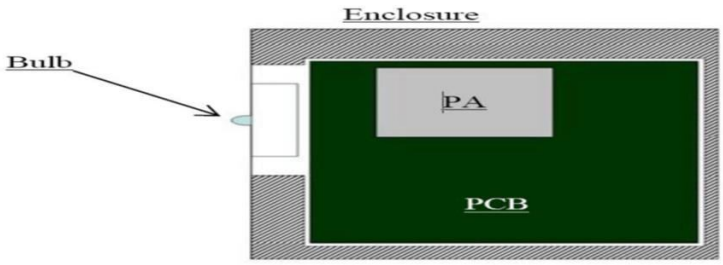

Fig. 7 Block Diagram of Li-Fi sub-assemblies

The Printed circuit board (PCB) controls the electrical inputs and outputs of the lamp and houses the microcontroller used to manage different lamp functions. A 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, the contents of the bulb will get vaporized into a plasma state at the bulb's centre. And this controlled plasma in turn will produce an intense source of light. All these subassemblies are contained in an aluminium enclosure as shown in Fig. 1 above.

A. Li-Fi Bulb sub-assembly

The bulb sub-assembly is the main part of the Li-Fi emitter. It consists of a sealed bulb embedded in a dielectric material which serves two purposes: one, it acts as a waveguide for the RF energy transmitted by the PA (Power Amplifier) and two, it acts as an electric field concentrator that focuses the energy into the bulb. The collected energy from the electric field rapidly heats the material in the bulb to a plasma state that emits light of high intensity of Visible light spectrum. Figure 2 shows the sub-assembly of the bulb.

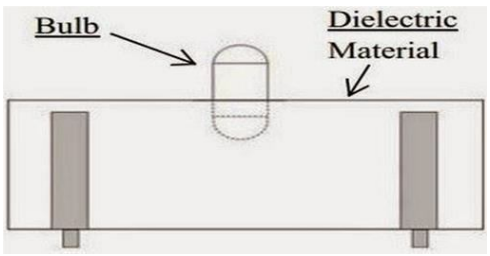

Fig. 8 Bulb Sub Assembly

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There are various inherent advantages of this approach which includes high brightness, excellent colour quality and high luminous efficacy of the emitter – in the range of 150 lumens per watt or greater. The structure is mechanically robust without typical degradation and failure mechanisms associated with tungsten electrodes and glass to metal seals, resulting in useful lamp life of 30,000+ hours. In addition, the unique combination of high temperature plasma and digitally controlled solid state electronics results in an economically produced family of lamps scalable in packages from 3,000 to over 100,000 lumens.

Important factors that should be considered while designing Li-Fi are as follows:

1) Presence of Light
2) Line of Sight (Los)
3) For better performance use fluorescent light & LED

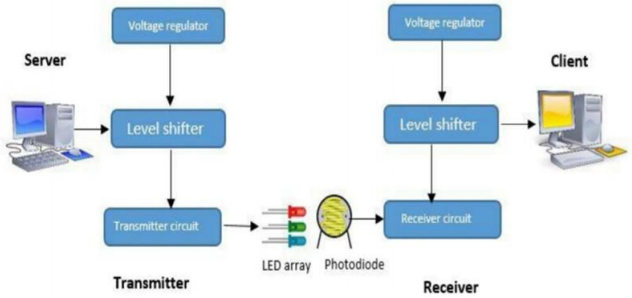

Fig. 9 Construction of Li-Fi System

VI. APPLICATIONS

There are numerous applications of Li-Fi technology, from public Internet access through existing lighting (LED) to auto-piloted cars that communicate through their headlights (LED based). Applications of Li-Fi can extend in areas where the Wi-Fi technology lacks its presence like aircrafts and hospitals (operation theatres), power plants and various other areas, where electromagnetic (Radio) interference is of great concern for safety and security of equipment and people. Since Li-Fi uses just the light, it can be used safely in such locations or areas. In future with the Li-Fi enhancement all the streetlamps can be transformed to Li-Fi connecting points to transfer data. As a result of it, it will be possible to access internet at any public place and street.

1) *In Aircrafts:* The passengers travelling in aircrafts get access to low speed Internet that too at a very high price. 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.

Fig. 10 Application of Li-Fi in Aircrafts

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2) *Application of Li-Fi in the field of Health Technologies:* Operation theatres (OTs) do not allow Wi-Fi due to radiation concerns. Usage of Wi-Fi at hospitals interferes/blocks the signals for monitoring equipment. So, it may have hazardous effect to the patient's health, due to improper working of medical apparatus. To overcome this and to make OT tech savvy Li-Fi can be used to access internet and also to control medical equipment.

Fig. 11 Application of Li-Fi in Medical Field

3) *Traffic Application:* In traffic signals Li-Fi can be used to communicate with passing vehicles (through the LED lights of the cars etc) which can help in managing the traffic in a better manner resulting into smooth flow of traffic and reduction in accident numbers. Also, LED car lights can alert drivers when other vehicles are too close.

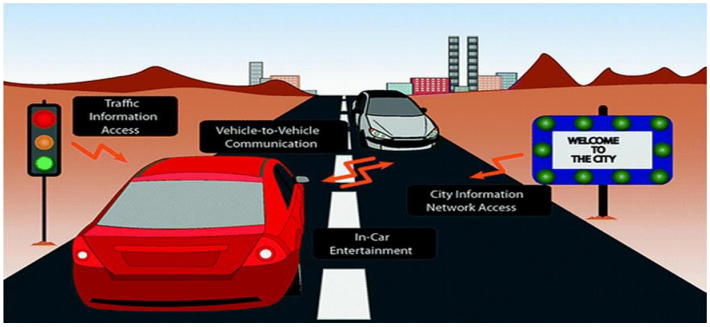

Fig. 12 Application of Li-Fi in Traffic Management

4) *Under Water Communication:* Underwater ROVs (Remotely Operated Vehicles) operate from large cables that supply their power and allow them to receive signals from their pilots above. But the tether used in ROVs is not long enough to allow them to explore larger areas. If their wires were replaced with light — say from a submerged, high-powered lamp — then they would be much freer to explore. They could also use their headlamps to communicate with each other, processing data autonomously and sending their findings periodically back to the surface. Li-Fi can even work underwater where Wi-Fi fails completely, thereby throwing open endless opportunities for military underwater operations.

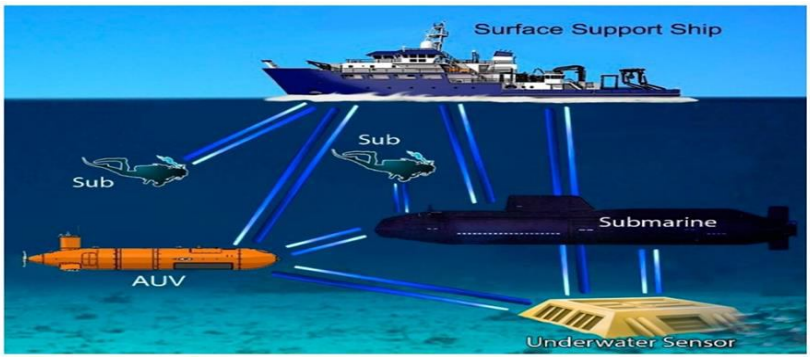

Fig. 13 Application of Li-Fi in Under Water Communication

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VII. CONCLUSIONS

Although there's still a long way to go to make this technology a commercial success, it promises a great potential in the field of wireless internet. A significant number of researchers 15 and companies are currently working on this concept, which promises to solve the problem of lack of radio spectrum, space and low internet connection speed. By deployment of this technology, we can migrate to greener, cleaner, safer communication networks. The very concept of Li-Fi promises to solve issues such as, shortage of radio-frequency bandwidth and eliminates the disadvantages of Radio communication technologies. Li-Fi is the upcoming and growing technology acting as catalyst for various other developing and new inventions/technologies. Therefore, there is certainty of development of future applications of the Li-Fi which can be extended to different platforms and various walks of human life.

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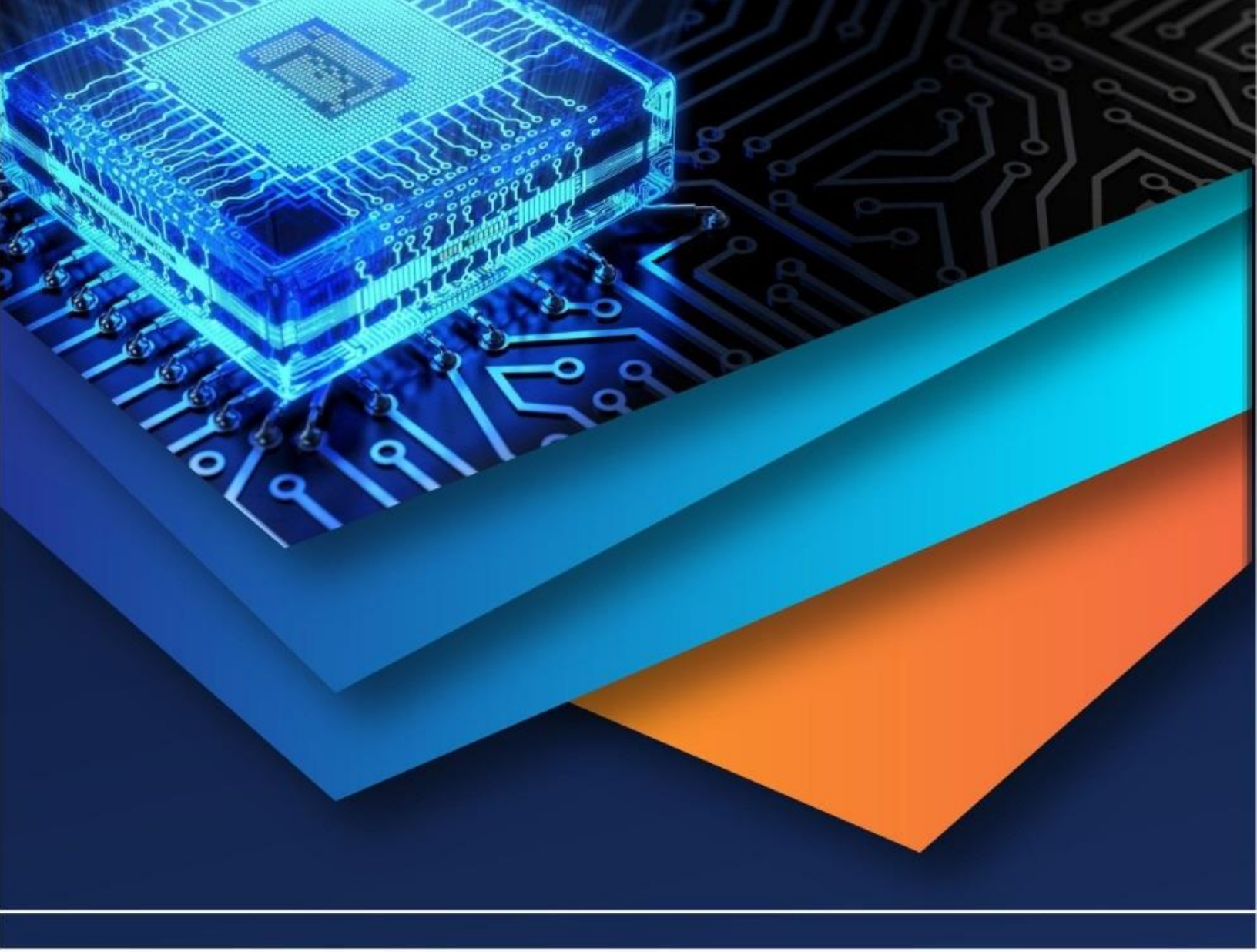

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