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NAME

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ABSTRACT

Li-Fi is a VLC, (visible light communication), technology developed by a team of scientists including Dr Gordan Povey, Prof. Harald Haas and Dr Mostafa Afgani at the University of Edinburgh. The term Li-Fi was coined by Prof. Haas when he amazed people by streaming high-definition video from a standard LED lamp, at TED Global in July 2011. Li-Fi is now part of the visible light communications (VLC) PAN IEEE 802.15.7 standard. “Li-Fi” is typically implemented using white LED light bulbs. These devices are normally used for illumination by applying a constant current through the LED. At present the most widely used non-cellular wireless technology is Wi-Fi (Wireless Fidelity). It is based on radio wireless local area networking of devices based on IEEE 802.11 standards operating at the frequency range of 2.4GHz (12cm) UHF (Ultra High Frequency) and 5.8GHz (5cm) SHF (Super High Frequency) is probably the most popular used non-cellular wireless technology. In case of Wi-Fi, we use routers and radio frequency waves to transmit data, whereas in Li-Fi we use LED bulbs and light signals to transmit and receive data. Li-Fi is preferred most due to its speed of transmission. It works 100 times faster than Wi-Fi and it uses visible light spectrum as transmission medium which gives wide range of bandwidth.

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CHAPTER 1

INTRODUCTION

In today's world communication between the devices are much common. Radio wave spectrum is very small part of spectrum available for communication. But with increase in advanced technology and number of users the network becomes overloaded which results in failure to provide high data rate. Visible light acts as rival to the present wireless radio frequency communication by achieving larger bandwidth and high data rate. Because with larger frequency spectrum it is possible to provide a larger portion of the bandwidth to each user to transfer information.

A switching LED can be improbably causing annoyance, but data can therefore be encoded in the light by varying the rate at the LEDs switch on and off to provide various strings of 1's and 0's. The use of fast pulses of light to transfer data without physical connection such method is called as Visible light communication (VLC). The LEDs can be switched ON and OFF very fast which is not noticeable by human eye thus the light source appear to be constantly on. When these signals transmitted to the receiver via the wireless channel, the photo diode will convert these optical signals to electrical signals and the original information will be recovered.

On the basis of visible light communication technology, the advanced technology called Li-fi provide dual function of visible light LED for illumination and data transmission. Li-fi is very latest version of Wi-Fi which uses visible light in place of radio waves. Hence, visible light data transmission rate has higher speed than another broadband. It overcomes the problem related with Wi-Fi, because Li-Fi has wider network area so traffic handling capacity improved and it is cheaper than Wi-Fi.

The VLC system is compared with other wireless communication system that are in current use like LAN and Wi-Fi. LAN is available in very short range and it is not mobile. And Wi-Fi has low traffic handling capacity as number of user increases Wi-Fi becomes unable to achieve user's need. Li-Fi offers significant capability to resolve this problem compared with Wi-Fi. It transmits data by switching LEDs on and off rapidly by changing light intensity which is not detected by human eye. The data transmission rate is about 10Gbps by using white bright LED. When an image sensor is used as a receiver, light sources are almost perfectly separated on a focal plane (a pixel array) because there are a massive number of pixels, and optical signals are separately output from each pixel.

This prevents signals from becoming mixed, thus allowing communication, even if many LED transmitters and superfluous lights (noise sources) such as sunlight and streetlights are present. The indoor visible light communication uses visible light spectrum to provide high-rate data transmission which at the same time used as energy efficient illumination. In this way, the idea of the dual function of communication and illumination offers opportunity for efficient cost reduction and carbon footprint reductions.

In simple terms, Li-Fi can be thought of as a light-based Wi-Fi. That is, it uses light instead of radio waves to transmit information. And instead of Wi-Fi modems, Li-Fi would use transceiver-fitted LED lamps that can light a room as well as transmit and receive information. Since simple light bulbs are used, there can technically be any number of access points. This technology uses a part of the electromagnetic spectrum that is still not greatly utilized – The Visible Spectrum. Light is in fact 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.

It is possible to encode data in the light by varying the rate at which the LEDs flicker on and off to give different strings of 1s and 0s. The LED intensity is modulated so rapidly that human eyes cannot notice, so the output appears constant. More sophisticated techniques could dramatically increase VLC data rates. Teams at the University of Oxford and the University of Edinburgh are focusing on parallel data transmission using arrays of LEDs, where each LED transmits a different data stream. Other groups are using mixtures of red, green and blue LEDs to alter the light's frequency, with each frequency encoding a different data channel. Li-Fi, as it has been dubbed, has already achieved blisteringly high speeds in the lab. Researchers at the Heinrich Hertz Institute in Berlin, Germany, have reached data rates of over 500 megabytes per second using a standard white-light LED.

Haas has set up a spin-off firm to sell a consumer VLC transmitter that is due for launch next year. It is capable of transmitting data at 100 MB/s – faster than most UK broadband connections. Light is inherently safe can be used in places where radio frequency communication is often deemed problematic, such as in aircraft cabins or hospitals. So visible light communication not only has the potential to solve the problem of lack of spectrum space, but can also enable novel application. The visible light spectrum is unused, it's not regulated, and can be used for communication at very high speeds. The consortium believes it is possible to achieve more than 10 Gbps.

CHAPTER 2

HISTORY

Li-Fi was created in 1997 and created by Harald Haas. The first idea of data transfer with lights was Prof. Harald Haas put it forward. Haas is professor of mobile communications at Edinburgh University and is widely recognized as the original founder of Li-Fi. He promoted this technology in his 2011 TED Global talk helped start a company to market it. He had the idea for years and has now created a working model of the Li-Fi system. Li-Fi has shown that it's 100 times faster than Wi-Fi. In October 2011, companies and industry groups formed the Li-Fi consortium, to promote high-speed optical wireless system and to overcome the limited amount of radio-based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. By August 2013, data rates of over 1.6 gbit/s were demonstrated over a single colour LED. in 2013, a press release said that Li-Fi, or VLC systems in general, do not require line-of-sight conditions. In October 2013, it was reported Chinese manufacturers were working on Li-Fi development kits.

How does Li-Fi works, it works by an Estonian start-up called Velmenni used a Li-Fi-enable light bulb to transmit data at speeds as fast as 1 gigabit per second, which is about 100 times faster than current Wi-Fi technology, meaning a high-definition film could be downloaded within seconds. Li-Fi refers to visible light communication (VLC) technology, which delivers high-speeds, bidirectional, networked mobile communication in manner similar to Wi-Fi. When a constant current is applied to an LED [light-emitting-diode] light bulb, a constant stream of photons is emitted from the bulb which is observed as visible light. If the current is varied slowly, the output intensity of the light dims up and down. Another major issue is that Li-Fi does not work outdoors, meaning that public Li-Fi will not be able to replace public Wi-Fi networks any time soon. Who discovered Li-Fi, who teaches at the University of Edinburgh in the UK, coined the term "Li-Fi" at his TED Global Talk where he introduced the idea of "Wireless data from every light". He is Chair of Mobile Communications at the University of Edinburgh and co-founder of pure Li-Fi. Haas demonstrated that he could transmit more data than a cellular tower by flickering light from a single LED, according to Science Alert. Haas has long been studying ways to communicate electronic data signals, designing modulation techniques that pack more data onto existing networks. His main research interests are in optical wireless communications, hybrid optical wireless and RF communications, spatial modulation, and interference coordination in wireless network. However, Li-Fi bulbs are outfitted with a chip that modulates the light imperceptibly.

CHAPTER 3

OVERVIEW OF LI-FI

3.1 Overview

An advance way to transfer information could drastically change path that systems can communication with each other called Li-fi. Li-fi uses visible light to transfer data between two devices which do not have physical connection. This idea is inspired from VLC which uses visible light LED for transmitting data. An Infra- Red remote control works by switching an IR LED on and off with 38 kHz frequency. This light is detected by the sensor and microcontroller connected in TV converts it into commands. In place of IR Li-Fi uses visible light to transfer data between two devices. Visible light has wider range of electromagnetic spectrum which gives an advantage for increasing speed. By encoding, the colour LEDs like yellow and blue can use for high data rate because combination of both yellow and blue make white bright luminance. Li-fi can overcome the problems that users face in wireless communication which uses radio waves. Radio waves utilises electromagnetic wave spectrum which is very small part of communication available. Li-Fi offers unlicensed and freely available where light source is available, thus user can utilise wider range of bandwidth which increases traffic handling capacity of the system. Because the bandwidth is freely available data is transmitted with higher transmission rate. Visible light is safe to use, no electromagnetic spectrum is used in visible light communication does not cause any health hazards because visible light does not penetrate through wall while electromagnetic waves penetrates through walls. Thus, use of Wi-Fi is not allowed in hospital and aircrafts. The basic concept behind offering high data rate is direct Line of sight. Line of sight between transmitter and receiver should be provide properly. If any obstacle comes in between transmitter and receiver, line of sight get disturbed and corresponding communication will lost. But advantage of this is a hacker outside room cannot utilise data. With help of direct line of sight Li-fi can achieves greater than 1Gbps. This advancement technique can achieve theoretical speed around 10Gbps.

Li-Fi is made up with modified LED bulbs and power consumption through LEDs is less so overall system design is very simple. Thus, the VLC system is cheap, secure and simple. The data is transfer by switching the LED on and off very fast. On switching LED continuously on and off flickering is arise which can be detected by photodiodes but invisible for human eye. Different data can be transmitted with different strings of 0’s and 1’s by varying light intensities.

At the receiving side photodiodes convert optical signals into electrical receives the data in original form. For creating a message, switch LEDs number of times so a string of data with different sequence is obtained.

3.2 Properties of LED based data communication

Optical wireless communication through visible light has both advantages and disadvantages over current wireless technology such as Wi-Fi. The disadvantage includes correct line of sight to support high data rate transmission rate. If the line of sight is not proper in between transmitter end and receiver end data transmission rate will degrade. Another restraint, visible light communication system is essentially support short range applications. Any obstruction and interference can affect system performance. While researchers are working effort fully to improve performance of VLC system. VLC system has several advantages to become compliment to rival wireless technologies. Due to small amount of radio frequency spectrum, if the traffic is increased significantly on the network resulting complexity increases. Light itself has 10000 times wider bandwidth than radio waves [1]. Due to which the transfer of data is more effectively possible Radio waves are harmful for human beings as they penetrate the body and may cause mutation. So, it is safe. Since no signal penetration through walls, so nobody can hack it. Thus, it is secure to use.

3.3 Work of Li-Fi Light Sources

LI-FI is a new class of high intensity light source of solid design bringing clean lighting solutions to general and specially lighting. With energy efficiency, long useful lifetime, full spectrum and dimming, Li-Fi lighting application work better compared to conventional approaches. This technology brief describes the general construction of Li-Fi lighting systems and the technology building blocks behind their function. Light from the mobile device display communicates to the colour sensor on the consumer product, which converts the light into digital information. Light emitting diodes enable the consumer product to communicate synchronously with the mobile device. It uses visible light as a medium for the transmission of data. As a type of VLC system, it requires two components: a photodiode and a light source. The photodiode acts as a transceiver that receives light signals and transmits them back. The light source transmits data using emitted light as the medium. Within the light, the intensity of the colours red, green, and blue (RGB) is finely modulated to embed data into the LED light. This fine modulation of RGB can be better described as a form of code. Once the light is received by a photodiode, the light is demodulated. The information received is either relayed to a cloud server or transcribed by the receiver itself.

CHAPTER 4

LI-FI CONSTRUCTION

4.1 Components of Li-Fi

- Bulb
- RF power amplifier circuit (PA)
- Printed circuit board (PCB)
- Enclosure

4.2 Li-Fi block diagram

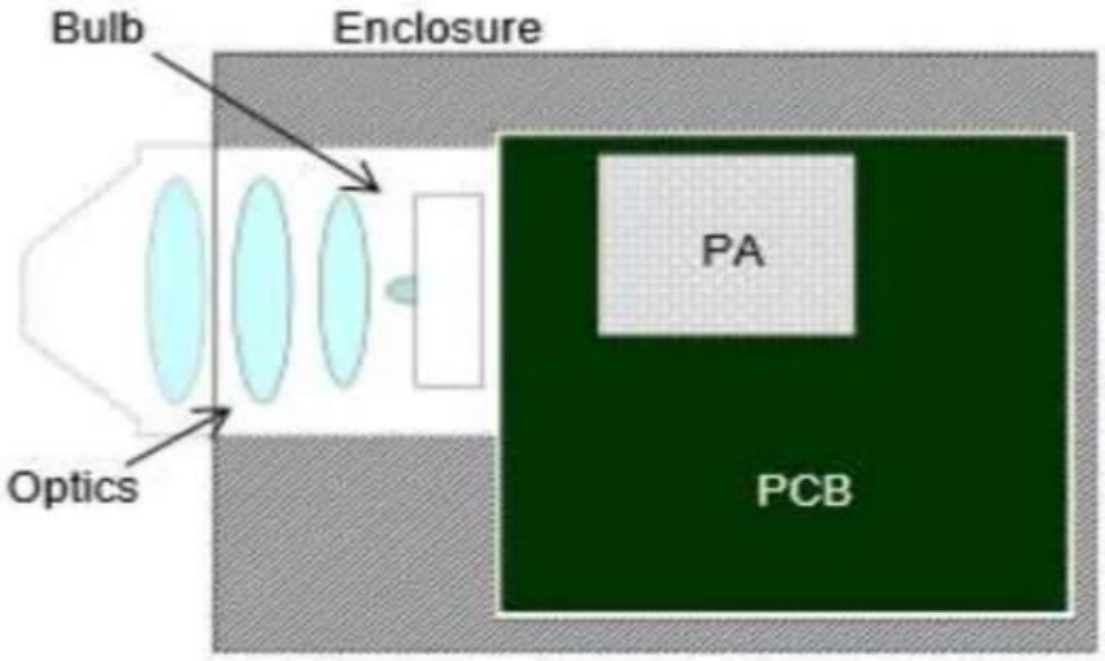

Figure 4.2 Block Diagram of Li-Fi

4.2.1 Printed Circuit Board

The PCB controls the electrical inputs and outputs of the lamp and houses the microcontroller used to manage different lamp functions. A printed circuit board can have multiple layers of copper which almost always are arranged in pairs. The number of layers and the interconnection designed between them (vias, PTHs) provide a general estimate of the board complexity. Using more layers allow for more routing options and better control of signal integrity, but are also time consuming and costly to manufacture. Likewise, selection of the vias for the board also allow fine tuning of the board size, escaping of signals off complex IC

Likewise, selection of the vias for the board also allow fine tuning of the board size, escaping of signals off complex ICs, routing, and long-term reliability, but are tightly coupled with production complexity. One of the simplest boards to produce is the two-layer board. It has copper on both sides that are referred to as external layers; multi-layer boards sandwich additional internal layers of copper and insulation. After two-layer PCBs, the next step up is the four-layer. The four-layer board adds significantly more routing options in the internal layers as compared to the two-layer board, and often some portion of the internal layers is used as ground plane or power plane, to achieve better signal integrity, higher signalling frequencies, lower EMI, and better power supply decoupling.

A basic PCB consists of a flat sheet of insulating material and a layer of copper foil, laminated to the substrate. Chemical etching divides the copper into separate conducting lines called tracks or circuit traces, pads for connections, vias to pass connections between layers of copper, and features such as solid conductive areas for electromagnetic shielding or other purposes. The tracks function as wires fixed in place, and are insulated from each other by air and the board substrate material. The surface of a PCB may have a coating that protects the copper from corrosion and reduces the chances of solder shorts between traces or undesired electrical contact with stray bare wires. For its function in helping to prevent solder shorts, the coating is called solder resist or solder mask.

4.2.2 Radio Frequency

An RF signal is generated by the solid-state PA and is guided into an electric field about the bulb. The high concentration of energy in the electric field vaporizes the contents of the bulb to a plasma state at the bulb's centre. This controlled plasma generates an intense source of light. All of these components are contained in an aluminium enclosure.

Many modern RF amplifiers operate in different modes, called classes, to help achieve different design goals. Some classes are class A, class AB, class B, class C, which are considered the linear amplifier classes. In these classes the active device is used as a controlled current source. The bias at the input determines the class of the amplifier.

A common trade-off in power amplifier design is the trade-off between efficiency and linearity. The previously named classes become more efficient, but less linear, in the order they are listed. Operating the active device as a switch results in higher efficiency, theoretically up to 100%, but lower linearity. Among the switch-mode classes are class D, class F and class E. The class D amplifier is not often used in RF applications.

Modern RF power amplifiers use solid-state devices, predominantly MOSFETs (metal–oxide–semiconductor field-effect transistors). The earliest MOSFET-based RF amplifiers date back to the mid-1960s. Bipolar junction transistors were also commonly used in the past, up until they were replaced by power MOSFETs, particularly LDMOS transistors, as the standard technology for RF power amplifiers by the 1990s, due to the superior RF performance of LDMOS transistors.

MOSFET transistors and other modern solid-state devices have replaced vacuum tubes in most electronic devices, but tubes are still used in some high-power transmitters (see Valve RF amplifier). Although mechanically robust, transistors are electrically fragile – they are easily damaged by excess voltage or current. Tubes are mechanically fragile but electrically robust – they can handle remarkably high electrical overloads without appreciable damage.

The basic applications of the RF power amplifier include driving to another high-power source, driving a transmitting antenna and exciting microwave cavity resonators. Among these applications, driving transmitter antennas is most well-known. The transmitter–receivers are used not only for voice and data communication but also for weather sensing (in the form of a radar).

4.2.3 Transmitters

The following components are used at the transmitting side:

Coloured LED's: An array of Red, Green and blue LEDs is used at the transmitter end as visible light sources. They are connected as loads in the transistor circuitry. They are high power and emit a focused beam. Each colour is used to carry a different data stream.

MOSFETs: A high speed N-type power MOSFET IRF 520 is used to modulate the LEDs using OOK (On off keying). The serial output from the computer is converted into TTL compatible form and is then applied to the gate of the transistor. Thus, it switches the load (LEDs) on and off in accordance with the input data 4.3.1.3 RS232 line driver. Since the output of computer is RS232 compatible, a 16 pin RS232 line driver IC MAX 232 is used to make the computer output TTL level compatible to drive the transistor circuit carrying through LED load.

USB to RS232 converter cable: In laptops, serial port is not available. Since data is to be transmitted serially between the two computers, a USB to RS232 converter cable is used to interface the serial output from MAX 232 IC to the laptop using the built-in USB port.

This cable contains an embedded controller to conform the RS232 compatible data into USB protocol compatible form.

Voltage Regulator: A voltage regulator is used to supply constant voltage (5V) to MAX232 IC. A 3 pin 7805 IC is used to serve the purpose. Every kind of light source can theoretically be used as transmitting device for VLC. However, some are better suited than others. For instance, incandescent lights quickly break down when switched on and off frequently. These are thus not recommended as VLC transmitters. More promising alternatives are fluorescent lights and LED's. VLC transmitters are usually also for providing illumination of the rooms in which they are used.

This makes fluorescent lights a particularly popular choice, because they can flicker quickly enough to transmit a meaningful amount of data and are already widely used for illumination purposes. However, with an ever-rising market share of LED's and further technological improvements such as higher brightness and spectral clarity. LEDs are expected to replace fluorescent lights as illumination sources and VLC transmitters.

The simplest form of LEDs is those which consist of a bluish to ultraviolet LED surrounded by phosphorus which is then transmitted by the actual LED and emits white light. This leads to data rates up to 40 Mbit/s.

RGB LEDs do not rely on phosphorus any more to generate white light. They come with three distinct LEDs (a red, a blue and a green one) which, when lighting up at the same time, emit light that humans perceive as white. Because there is no delay by stimulating phosphorus rust, Data rates of up to 100 Mbit/s can be achieved using RGB LEDs.

In recent years the development of resonant cavity LEDs (RCLEDs) has advanced considerably. These are similar to RGB LEDs in that they are comprised of three distinct LEDs. But in addition, they are fitted with Bragg mirrors which enhance the spectral clarity to such a degree that emitted light can be modulated at very high frequencies. In early 2010, Siemens has shown that transmission at a rate of 500 Mbit/s is possible with this approach.

It should be noted that VLC will probably not be used for massive data transmission. High data rates as the ones referred to above, were reached under meticulous set ups which cannot be expected to be reproduced in real life scenarios. One can expect to see data rates of about 5 kbit/s in average applications, such as location estimation. The distance in which VLC can be expected to be reasonably used ranges up to about 6 meters.

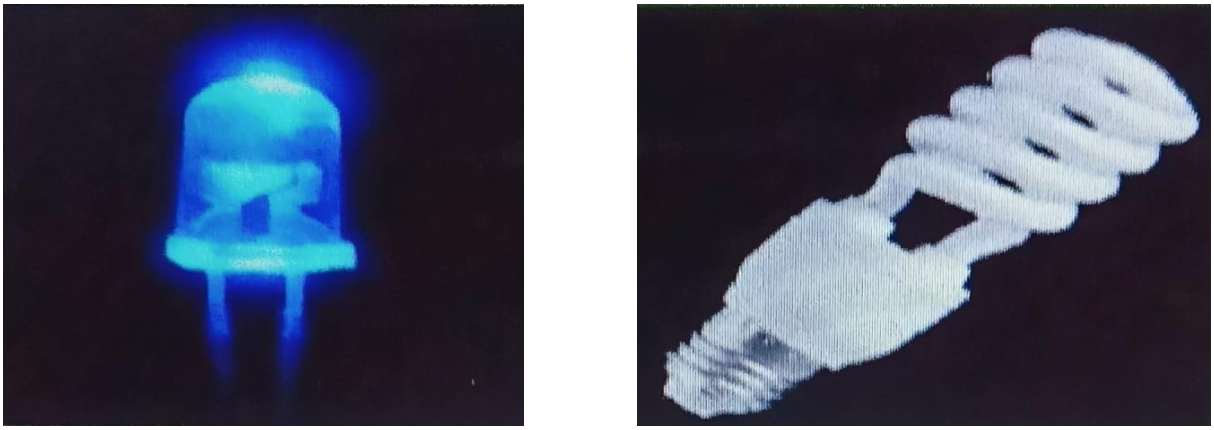

Figure 4.3 Solid state LED and fluorescent bulb used as transmitter

4.2.4 Receivers

The following components are used at the receiving side:

Optical Receiver: A 6 pin fibre optic receiving module TORX 173 is used as the light sensing device. On receiving light pulses, it gives a high output whereas the output goes low in the absence of light.

Optical Filters: Red, green and blue light filters are used at the receiver to de multiplex the multiple data streams. These are sharp narrowband filters. A red-light filter allows the frequency band corresponding to red colour to pass through it and blocks all other wavelengths. Thus, when a red-light filter is placed in front of the optical receiver, only the data stream carried by the red beam falls at the receiver while the other streams are blocked. Similarly, blue or green light filters can be used to allow the desired data stream to reach the receiver.

Voltage Regulator: A voltage regulator is used to supply constant voltage (5V) to TORX 173.A 3 pin7805 IC is used to serve the purpose.

RS232 line driver: Since the output of TORX 173 is TTL level compatible, a 16 pin RS232 line driver MAX 232 is used to make the output RS232 compatible so that the receiving module can be interfaced to the computer.

USB to RS232 converter cable: In laptops, serial port is not available. Since data is to be transmitted serially between the two computers, a USB to RS232 converter cable is used to interface the serial output from MAX 232 IC to the laptop using the built-in USB port. This cable contains an embedded controller to conform the RS232 compatible data into USB and

protocol compatible form. The most common choice of receivers are photodiodes which turn light into electrical pulses. The signal retrieved in this way can then be demodulated into actual data. In more complex VLC-based scenarios, such as Image Sensor Communication even CMOS or CCD sensors are used (which are usually built into digital cameras).

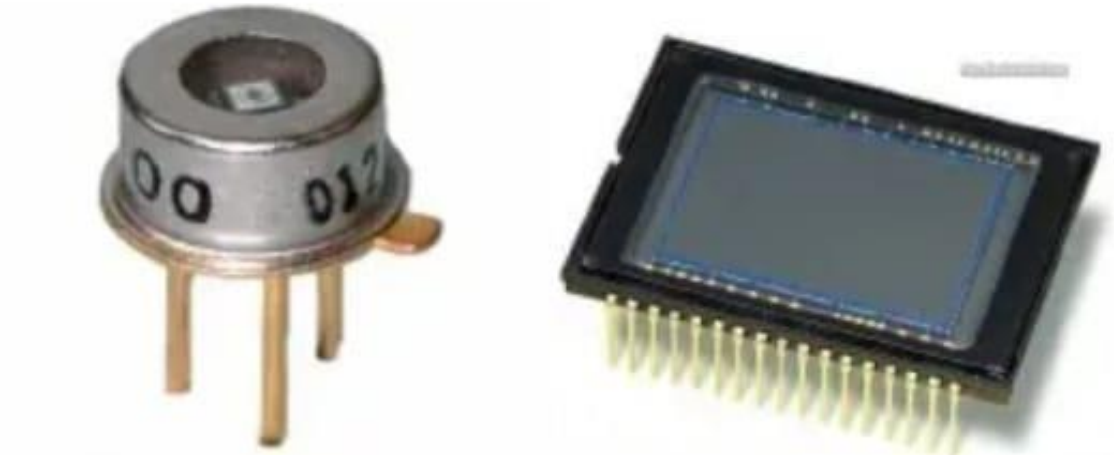

Figure 4.4 Receiver such as Avalanche Photodiode and Image sensor

4.3 Function of the Bulb

At the heart of Li-Fi is the bulb sub-assembly where a sealed bulb is embedded in a dielectric material. This design is more reliable than conventional light sources that insert degradable electrodes into the bulb. The dielectric material serves two purposes:

- First as a waveguide for the RF energy transmitted by the PA and second as an electric field concentrator that focuses energy in the bulb.
- The energy from the electric field rapidly heats the material in the bulb to a plasma state that emits light of high intensity and full spectrum.

The design and construction of the Li-Fi light source enable efficiency, long stable life, full stable life, full spectrum intensity that is digitally controlled and easy to use. The LED's can be switched on and off quickly, which gives nice opportunities for transmitting data. Hence, all that required is some LEDs and a controller that code data into those LEDs. Thus, every light source will work as a hub for data transmission. The light from the LED lamps transforms intensity lots of times a second, quicker than the eye can view.

CHAPTER 5

WORKING OF LI-FI

5.1 Architecture of Li-Fi

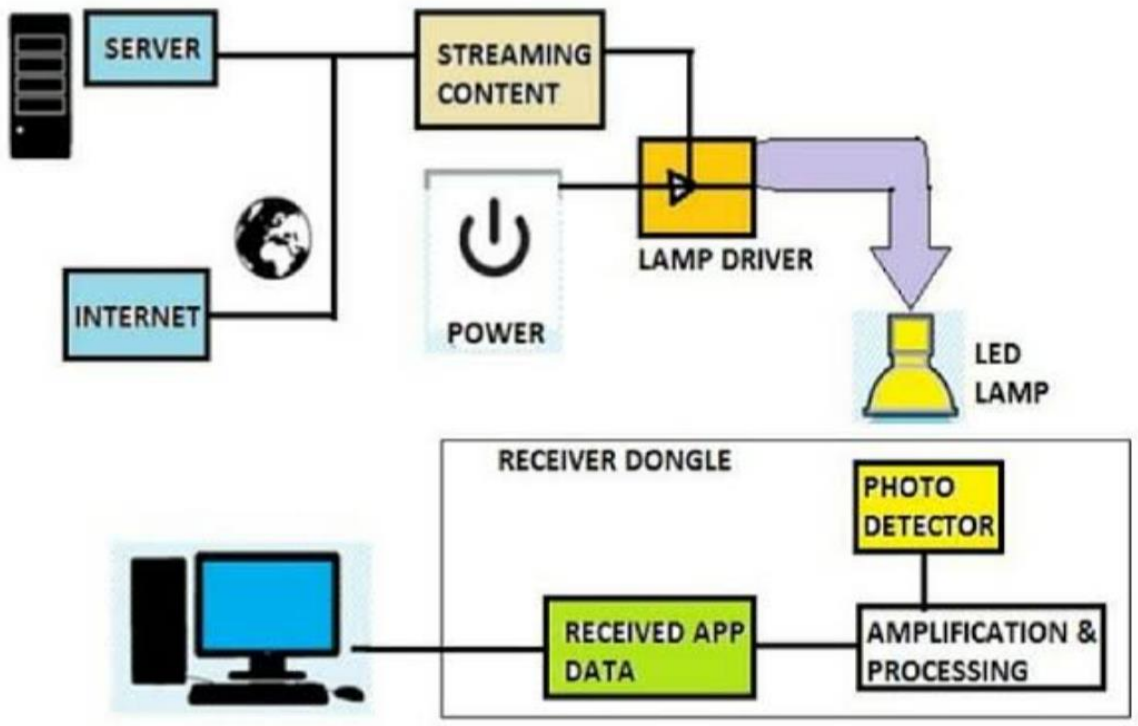

Figure 5.1 Architecture of Li-Fi

This brilliant idea was first showcased by Harald Haas from University of Edinburgh, UK, in his TED Global talk on VLC. He explained," Very simple, if the LED is on, you transmit a digital 1, if it's off you transmit a 0. The LEDs can be switched on and off very quickly, which gives nice opportunities for transmitting data." So, what you require at all are some LEDs and a controller that code data into those LEDs. We have to just vary the rate at which the LEDs flicker depending upon the data we want to encode. Further enhancements can be made in this method, like using an array of 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. Such advancements promise atheoretical speed of 10 Gbps can download a full high-definition film in just 30 seconds. Simply awesome! But blazingly fast data rates and depleting bandwidths worldwide are not the only reasons that give this technology an upper hand. Since Li-Fi uses just the light, it can be used safely in aircrafts and hospitals that are prone to interference from radio waves.

This can even work underwater where Wi-Fi fails completely, thereby throwing open endless opportunities for military operations. Imagine only needing to hover under a street lamp to get public internet access, or downloading a movie from the lamp on your desk. There's a new technology on the block which could, quite literally as well as metaphorically, 'throw light on' how to meet the ever-increasing demand for high-speed wireless connectivity. Radio waves are replaced by light waves in a new method of data transmission which is being called Li -Fi. Light-emitting diodes can be switched on and off faster than the human eye can detect, causing the light source to appear to be on continuously. A flickering light can be incredibly annoying, but has turned out to have its upside, being precisely what makes it possible to use light for wireless data transmission.

5.2 Working of the Li-Fi system

The logic behind the working of light fidelity technology is that, if the LED is on, a digital string ‘1’ is transmitted and when the LED is off then a digital string ‘0’ is transmitted. For example, there is a LED at one end and photodetector at another end, whenever the LED is on, a binary ‘1’ and when the LED is off, a binary ‘0’ is registered by the photodetector. Thus, a message is built up by many flashes of LED. Li-Fi provides 10,000 times wider bandwidth than Wi-Fi and the light sources of Li-Fi are already installed. So, it doesn’t need any well-equipped equipment. A high rate of transmission of information up to 10Gbps can be succeeded and low implementing cost. It also provides high security because the light cannot travel or enter the walls and due to this the factor of misuse cannot happen. Li-Fi can be used in underwater remotely operated vehicles, as a means of communication during disasters, in power plants, in traffic management where it could communicate with the lights of vehicles. The radiations of radio waves are genuinely harmful to people’s health and the reduction of its usage might give good health and live longer.

- Data coming from the internet or web browser will first go to the modem or streaming content to provide necessary modulation.
- Here, modulated data will go to the LED lamp with a help of LED driver or lamp driver and will be transmitted from there to the optical receiver that consists of photo detector, amplification processing and received data.
- Optical receiver created with photo diodes will receive sent signals and send it to devices such as computers, phone or tab with signal regulator.
- pureLi-Fi company is currently working on this technology.

CHAPTER 6

LI-FI VS WI-FI

6.1 Comparison between Li-Fi and Wi-Fi

Li-Fi is a term used to describe VLC technology applied to high-speed wireless communication. It acquired this name due to the similarity to Wi-Fi, only using light instead of radio Wi-Fi is great for general wireless coverage within buildings, and Li-Fi is ideal for high density wireless data coverage in confined area and for relieving radio interference issues, so the two technologies can be considered complimentary.

Table 6.1 Comparison between Li-Fi and Wi-Fi

SI. No.	Parameter	Li-Fi	Wi-Fi
1.	Speed	>1 GB/s	Around 150mb/s
2.	Medium of data transfer	Uses light	Uses radio spectrum
3.	Spectrum range	Visible light has 10000 times more	Having less spectrum range than VLC
4.	Cost	Cheaper	Expensive
5.	Network Topology	Point-to-Point	Point-to-Point
6.	Operating Frequency	Hundreds of Tera Hz	2.4 GHz
7.	Security	High Secure	Medium secure
8.	Power consumption	Low	Medium
9.	Standard	IEEE 802.15	IEEE 802.11
10.	Bandwidth	High due to broad spectrum	Low

6.2 Issues with Wi-Fi using radio waves

Capacity: We transmit wireless data is by using electromagnetic waves in particular, radio waves. Radio waves are scarce, expensive and we only have a certain range of it. Due to this limitation, one can't forever hope to cope with the demand of wireless data transmissions and the number of bytes and data which are transmitted every month.

Efficiency: There are 1.4 million cellular radio masts deployed worldwide. Most of the energy consumed, is not used to transmit the radio waves, but is used to cool the base stations. The efficiency of such a base station is only at about five percent.

Availability: Availability of radio waves or RW signals causes another concern. We have to switch off our mobile devices in aero planes. It is not advisable to use mobiles at places like petrochemical plants and petrol pumps.

Security: The radio waves penetrate through walls. They can be intercepted, and somebody can make use of one 's network.

6.3 Visible light communication

Many people 's first exposure to optical wireless technology was VLC. This emerging technology offers optical wireless communications by using visible light. Today, it is seen as an alternative to different RF-based communication services in wireless personal-area networks. An additional opportunity is arising by using current state-of-the-art LED lighting solutions for illumination and communication at the same time and with the same module. This can be done due to the ability to modulate LEDs at speeds far faster than the human eye can detect while still providing artificial lighting.

Thus, while LEDs will be used for illumination, their secondary duty could be to piggyback data communication onto lighting systems. This will be particularly relevant in indoor smart lighting systems, where the light is always on. 'In contrast to infrared, the so-called what you see is what you send feature can be used to improve the usability of transmitting data at shorter point-to-point distances between different portable or fixed devices. There, illumination can be used for beam guiding, discovery or generating an alarm for misalignment. The premise behind VLC is that because lighting is nearly everywhere, communications can ride along for nearly free. Think of a TV remote in every LED light bulb and you 'll soon realise the possibilities of this technology.

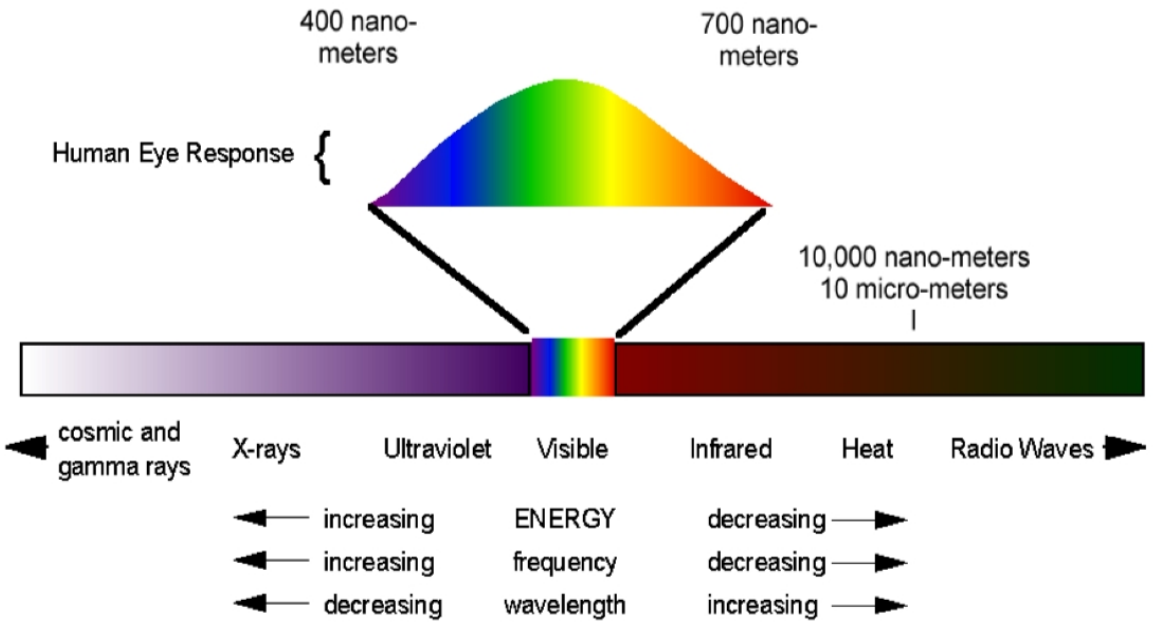

Figure 6.3 Electromagnetic spectrum

One of the biggest attractions of VLC is the energy saving of LED technology. Nineteen per cent of the worldwide electricity is used for lighting. Thirty billion light bulbs are in use worldwide. Assuming that all the light bulbs are exchanged with LEDs, one billion barrels of oil could be saved every year, which again translates into energy production of 250 nuclear power plants. Driven by the progress of LED technology, visible light communication is gaining attention in research and development.

The VLC Consortium (VLCC) in Japan was one of the first to introduce this technology. After establishing a VLC interest group within the IEEE 802.15 wireless personal-area networks working group, the IEEE 802.15.7 task group was established by the industry, research institutes and universities in 2008. The final standard was approved in 2011. It specifies VLC comprising mobile-to-mobile (M2M), fixed-to-mobile (F2M) and infrastructure-to-mobile (I2M) communications. There, the focus is on low-speed, medium-range communications for intelligent traffic systems and on high-speed, short range M2M and F2M communications to exchange, for example, multimedia data. Data rates are supported from some 100 kbps up to 100Mbps using different modulation schemes. Other standardization groups are working on standardized optical wireless communication (OWC) solutions using visible and infrared light. The most important groups are IrDA with its new 10 Giga-IR working group, ISO and ICSA.

CHAPTER 7

APPLICATIONS

Li-Fi technology is still in its infancy stage. But it has potential to serve multiple applications in various sectors. Some of those where Li-Fi finds its applications are discussed. The design and construction of the Li-Fi light source enable efficiency, long stable life, full spectrum intensity that is digitally controlled and easy to use.

7.1 Hospitals

Figure 7.1 Li-Fi in Operation Theatre

For a long time, medical technology has lagged behind the rest of the wireless world. Operating rooms do not allow Wi-Fi over radiation concerns, and there is also that whole lack of dedicated spectrum. While Wi-Fi is in place in many hospitals, interference from cell phones and computers can block signals from monitoring equipment. Li-Fi solves both problems - lights are not only allowed in operating rooms, but tend to be the most glaring fixtures in the room. Since the Li-Fi technology provides very fast data transmission, it will be possible to monitor the condition of patients in real time instantaneously. It eliminates all health problems that Wi-Fi can cause such as headaches, cancer and more.

There are advantages for using VLC in hospitals and in healthcare. Mobile phones and Wi-Fi are undesirable in certain parts of hospitals, especially around MRI scanners and in operating theatres.

7.2 On ocean beds

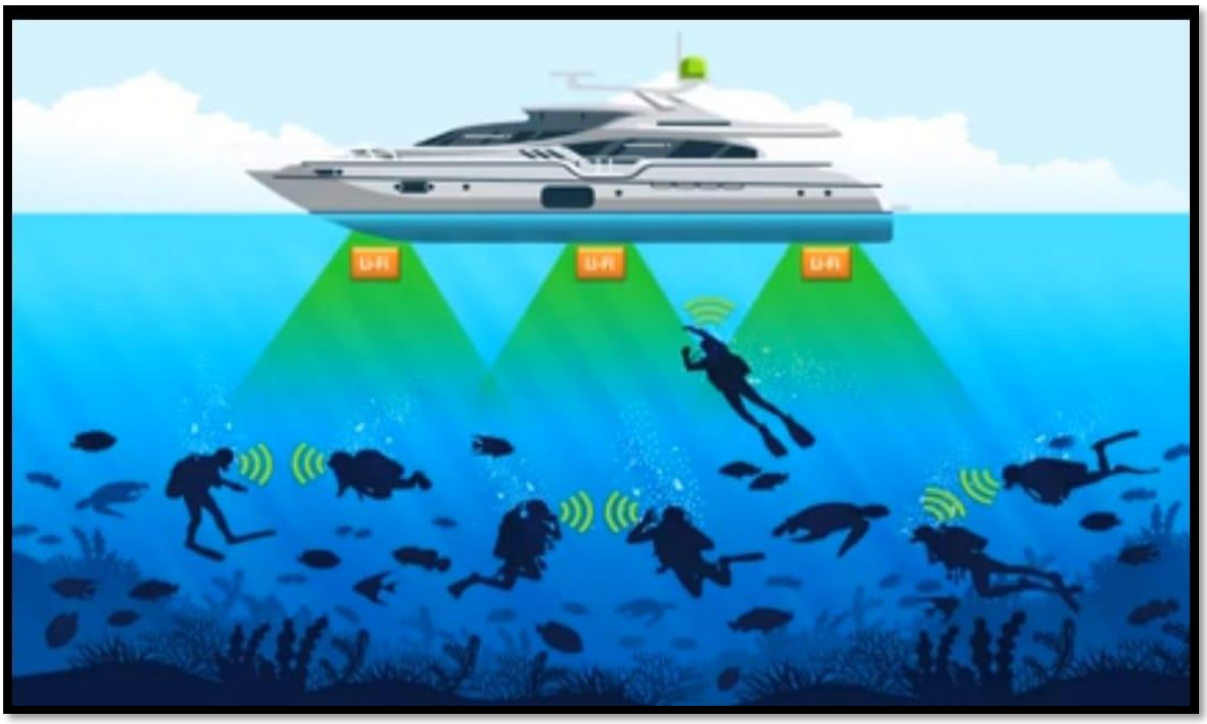

Figure 7.2 Under water communication

Underwater remotely operated vehicles (ROVs) are those favourite toys of treasure seekers that operate from large cables that supply their power and allow them to receive signals from their pilots above. ROVs work great, except when the tether isn't long enough to explore an area, or when it gets stuck on something. If their wires were cut and 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 referring findings periodically back to the surface, all the while obtaining their next batch of orders.

7.3 Traffic lights and Vehicles

Vehicles and traffic lights can communicate with each other through their front-end real lights and with other system. Accidents can be avoided using this technology which can alert drivers when other vehicles are too close.

Figure 7.3 LEDs of automobiles providing Li-Fi

7.4 Airlines

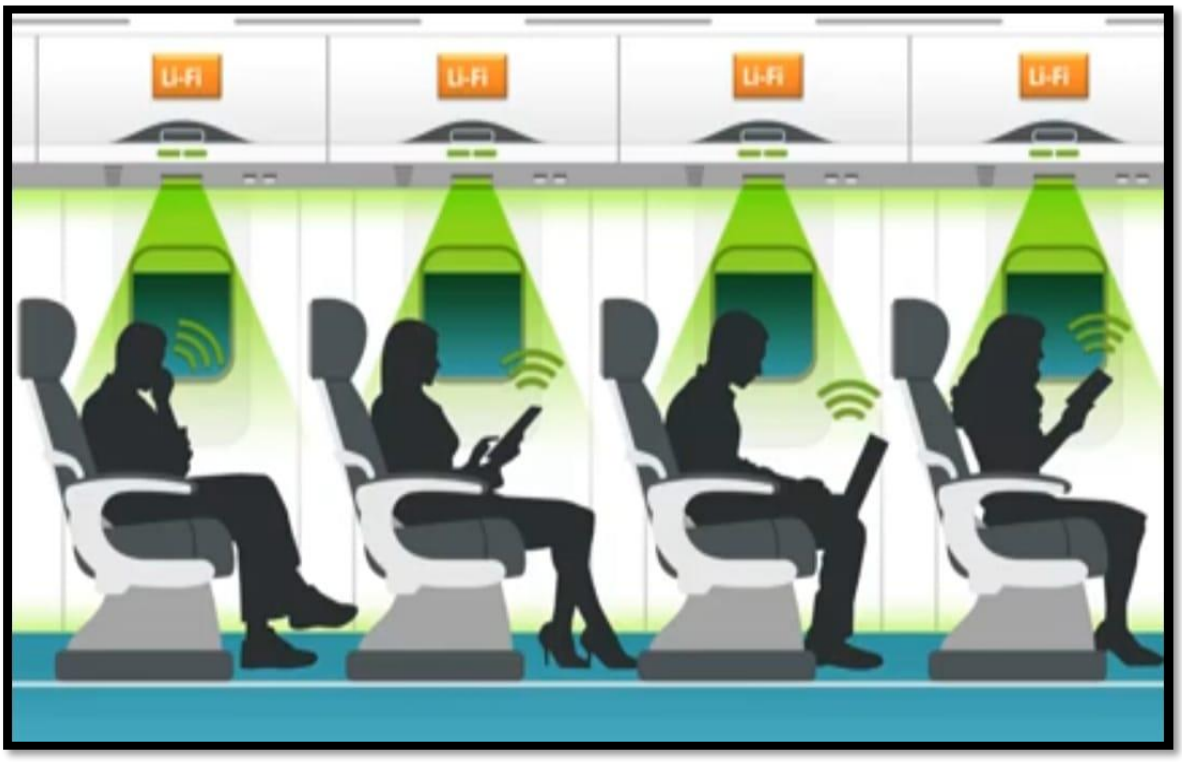

Figure 7.4 Li-Fi in Aeroplane

Nothing says captive audience like having to pay for the service of dialup speed Wi-Fi on the plane. The best heard so far is that passengers will soon be offered a 'high-speed like' connection on some airlines. United is planning on speeds as high as 9.8 Mbps per plane. Li-Fi could easily introduce that sort of speed to each seat's reading light. With advancement in Li-Fi technology, more higher speeds can be achieved. It can be used to provide passengers with internet access while in the air.

7.5 Street Lamps

Figure 7.5 Street lights as Li-Fi hubs

Even LED street lights can become a way of using the outdoor li-fi network making it possible to stay connected while walking around the city. If L-Fi technology can be adapted to our street lights then streets can provide us with free and fast internet.

Any lightings device is performed as a hotspot it means that the light device like car lights, ceiling lights, street lamps etc. area able to spread internet connectivity using visual light communication. Which helps us to low-cost architecture for hotspot. (Hotspot is a limited region in which some amount of device can access the internet connectivity). These are some of the areas where Li-Fi technology can be used. Therefore, in the coming years, we may see new devices that support Li-Fi technology in our lives.

CHAPTER 8

PROS AND CONS OF LI-FI

8.1 Advantages

8.1.1 Quicker Data transmission than Wi-Fi

An essential selling purpose of Li-Fi innovation is that it has a quicker information transmission rate than Wi-Fi. Noticeable light range has a transmission capacity that is multiple times bigger than whole radio recurrence and microwave range. Analysts at the University of Oxford have asserted that they effectively tried a trial Li-Fi application with a bi-directional speed of 224 gigabits for each second. Observe that most Wi-Fi networks send information at around 20 megabits for each second and move rates are subject to distance and obstructions. This bit of leeway is the motivation behind why defenders have bets on Li-Fi as an answer for settling that issues including the transmission capacity impediments of Wi-Fi and the developing measure of information created and devoured by clients.

8.1.2 Simple and Inexpensive to Deploy

Recall that the current operational ideas and trial utilizations of Li-Fi innovation focus on the utilization of LED lights. This implies that a Li-Fi organization can be incorporated effectively with existing LED lighting frameworks. Basically, any place there is a light source, there can be admittance to the Internet. It is additionally worth referencing that LED lights are reasonable to deliver and their market cost is moderately moderate. Investigators foresee that Li-Fi organization would be multiple times less expensive than Wi-Fi. They are likewise more energy productive than radiant lights and fluorescent lights. Albeit a Li-Fi-empowered LED light should stay went on to continue sending information, it tends to be diminished to underneath human perceivability and save energy cost while as yet emanating enough light to function as an organization switch.

8.1.3 Security due to the limitations of light

Another remarkable advantage or preferred position of Li-Fi is that it is safer than Wi-Fi. Remote correspondence innovations dependent on radio recurrence and microwaves are more helpless against snooping, signal capturing or unapproved interference, beast power assaults, and spontaneous organization associations. Recollect that light waves can’t enter through dividers and entryways. They additionally have a more limited reach. Equivalent is valid for infrared light and bright radiation.

The signs transmitted by a Li-Fi item and information it communicates stay limited to a shut territory, for example, a room or lobby. Admittance to organization is restricted. This implies that Li-Fi innovation offers an additional layer of security than Wi-Fi.

8.1.4 Safe from Electromagnetic Interferences

Moreover, Li-Fi additionally has a bit of leeway of being insusceptible from electromagnetic impedances that influence radio-based remote correspondence advancements. The innovation is likewise helpful in territories that are electromagnetic delicate, for example, airplane lodges, clinics, and atomic force plants, among others since it doesn't cause electromagnetic obstructions. Note that some clinical instruments utilized in clinics, just as the radar and correspondence frameworks in an airplane are delicate to radio recurrence.

8.1.5 Sweeping future Applications

The advancement of additional availability is another bit of leeway of Li-Fi innovation. The way that it offers quicker information move rates implies that it can propel the mainstream sending of the Internet of Things or IoT which require huge information and compelling and effective network. A portion of the particular predictable utilizations of Li-Fi incorporate home and building mechanization. Specialists have likewise conceptualized traffic applications, for example, utilization of road and traffic signals to give data about current street circumstances, and headlights and backdrop illuminations of vehicles to impart and mechanize security measures.

8.2 Disadvantages

8.2.1 Restricted range and Connectivity

The impediments of the noticeable light furnish Li-Fi with a security advantage over Wi-Fi. Be that as it may, these constraints likewise make burdens. Actual boundaries, for example, dividers and entryways limit operational extent of a Li-Fi-empowered LED light. Recall that information communicated by a Li-Fi item stays bound to a nearby dispersed on grounds that light can't infiltrate misty articles and has a more limited reach. In foundations, for example, house or building, empowered LED lights should be deliberately positioned in rooms, corridors, and different segments to extend extent of the Li-Fi network. A solitary Wi-Fi switch has more extensive and longer reach than a Li-Fi switch. These impediments of Li-Fi likewise make it not ideal for use in open Wi-Fi networks.

8.2.2 Inaccessibility of Compatible Technologies

It will take a long time for Li-Fi to turn out to be more reasonable than Wi-Fi. Current gadgets, for example, PCs, cell phones, and tablet PCs actually use equipment for Wi-Fi organizing. These gadgets would not promptly work with a Li-Fi network since they don't have the essential equipment details. Li-Fi isn't promptly in reverse viable. It is additionally worth referencing that the quicker information move pace of this innovation stays irrelevant or unimportant until Internet speed from specialist organizations improves. In territories or nations that are infamous for having more slow Internet speeds than their partners, conveying a Li-Fi organization would be inane. Thus, it will take coordination from different businesses and areas to advance mass selection of this innovation.

8.2.3 Light Interference and Light Pollution

Different burdens of Li-Fi are powerlessness to light obstruction and advancement of light contamination. Observe that despite fact that this innovation is invulnerable to electromagnetic impedances, different wellsprings of light may meddle with sign. Daylight can meddle with light signals created by a Li-Fi-empowered LED light. The relating recipient may struggle handling these signs. Web interference is conceivable. Besides, on grounds that empowered LED lights should stay on, they can offer further to light contamination, particularly whenever set at higher splendor to make up for conceivable impedance with other light sources.

8.2.4 Conceivable Cost Implications

Sending Li-Fi is hypothetically reasonable due to the little expense related with creation of LED lights. In any case, establishment cost can be more costly than Wi-Fi sending due to innovation is generally new and the interest stays low and concentrated experts are as yet not many. The way that a solitary home requirement a few Li-Fi switches to grow extent of the organization and accessibility of Internet availability could likewise mean extra buy and establishment costs. Observe that a solitary Wi-Fi switch is sufficient for a normal measured house.

CHAPTER 9

CONCLUSION

With this technology, we can save up to 100 times energy by performing data communication and lighting tasks on a single device. In the future Li-Fi technology seems to be a technology that will complement all existing technologies rather than replacing other wireless technologies. Because Li-Fi provides short range communication in other words we can use Wi-Fi and other telephone communications in places where we need wide coverage and Li-Fi technology in places where we want short range but safe and fast communication. In the future, it may lead to the realization of the Internet of Things (IOT) by enabling more than 100 devices to connect to the Internet with a single distributor device with Li-Fi technology. Starting from here, it will no take long for Li-Fi to enter homes, the system can easily be connected to any device with an LED light this can make the era of the IOT much faster.

The possibilities of Li-Fi are numerous and can be explored further. If his technology can be put into practical use, every bulb can be used something like a Wi-Fi hotspot to transmit wireless data and we will proceed toward the cleaner, greener, safer and brighter future. The concept of Li-Fi is currently attracting a great deal of interest, not least because it may offer a genuine and very efficient alternative to radio-based wireless. As a growing number of people and their many devices access wireless internet, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. This may solve issues such as the shortage of radio-frequency bandwidth and also allow internet where traditional radio-based wireless isn’t allowed such as aircraft or hospitals. One of the shortcomings however is that it only works in direct line of sight.

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