Study Paper

on

LiFi (Light Fidelity)

&

its Applications

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Abstract

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). Li-Fi is a wireless optical networking technology that uses light emitting diodes (LEDs) for transmission of data. The term Li-Fi refers to visible light communication (VLC) technology that uses light as medium to deliver high-speed communication in a manner similar to Wi-Fi and complies with the IEEE standard IEEE 802.15.7. The IEEE 802.15.7 is a high-speed, bidirectional and fully networked wireless communication technology based standard similar to Wi-Fi's IEEE 802.11.

This paper focuses on 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.

Li-Fi provides better bandwidth, efficiency, connectivity and security than Wi-Fi and has already achieved high speeds larger than 1 Gbps under the laboratory conditions. By leveraging the low-cost nature of LEDs and lighting units, there are lots of opportunities to exploit this medium. Li-Fi is the transfer of data through light by taking fibre out of fibre optics and sending data through LED light bulb (shown in Fig 1).

Fig 1: LED light Li-Fi Bulb

(Source: http://www.ijcta.com/documents/volumes/vol5issue1/ijcta2014050121.pdf)

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1. Introduction

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.

The idea of Li-Fi was introduced for the first time by a German physicist Harald Hass in the TED (Technology, Entertainment, Design) Global talk on Visible Light Communication (VLC) in July 2011, by referring to it as “data through illumination”. He used a table lamp with an LED bulb to transmit a video of a blooming flower that was then projected onto a screen. In simple terms, Li-Fi can be thought of as a light-based Wi-Fi i.e. instead of radio waves it uses light to transmit data. In place of Wi-Fi modems, Li-Fi would use transceivers fitted with LED lamps that could light a room as well as transmit and receive information. By adding new and unutilized bandwidth of visible light to the currently available radio waves for data transfer, Li-Fi can play a major role in relieving the heavy loads which the current wireless system is facing. Thus it may offer additional frequency band of the order of 400 THz compared to that available in RF communication which is about 300 GHz. Also, as the Li-Fi uses the visible spectrum, it will help alleviate concerns that the electromagnetic waves coming with Wi-Fi could adversely affect our health.

By Communication through visible light, Li-Fi technology has the possibility to change how we access the Internet, stream videos, receive emails and much more. Security would not be an issue as data can’t be accessed in the absence of light. As a result, it can be used in high security military areas where RF communication is prone to eavesdropping.

2. Architecture of Li-Fi system

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:

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

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:

- Bulb
- RF Power Amplifier Circuit (PA)
- Printed Circuit Board (PCB)
- Enclosure

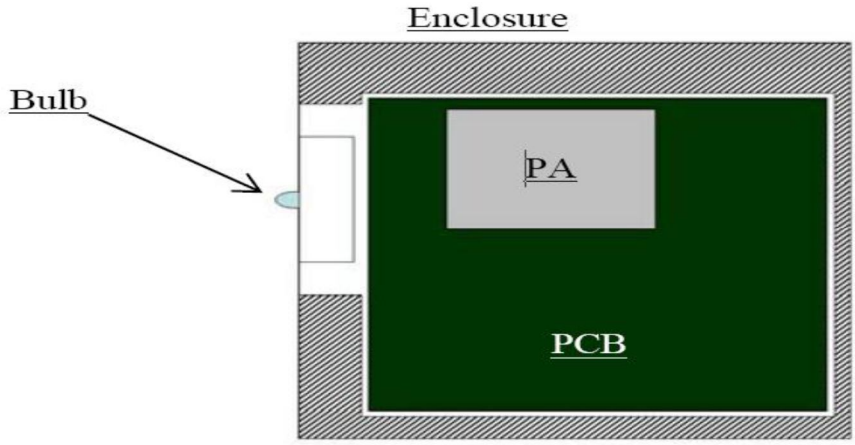

Fig 2: Block Diagram of Li-Fi sub-assemblies.

(Source: http://www.ijcta.com/documents/volumes/vol5issue1/ijcta2014050121.pdf)

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 of these subassemblies are contained in an aluminium enclosure as shown in Fig. 2 above.

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 3 shows the sub-assembly of the bulb.

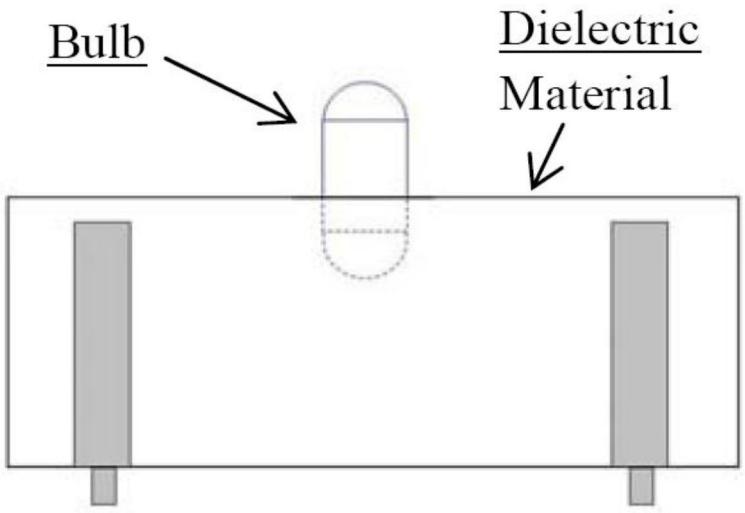

Fig 3: Bulb Sub Assembly

(Source:http://www.ijcta.com/documents/volumes/vol5issue1/ijcta2014050121.pdf)

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

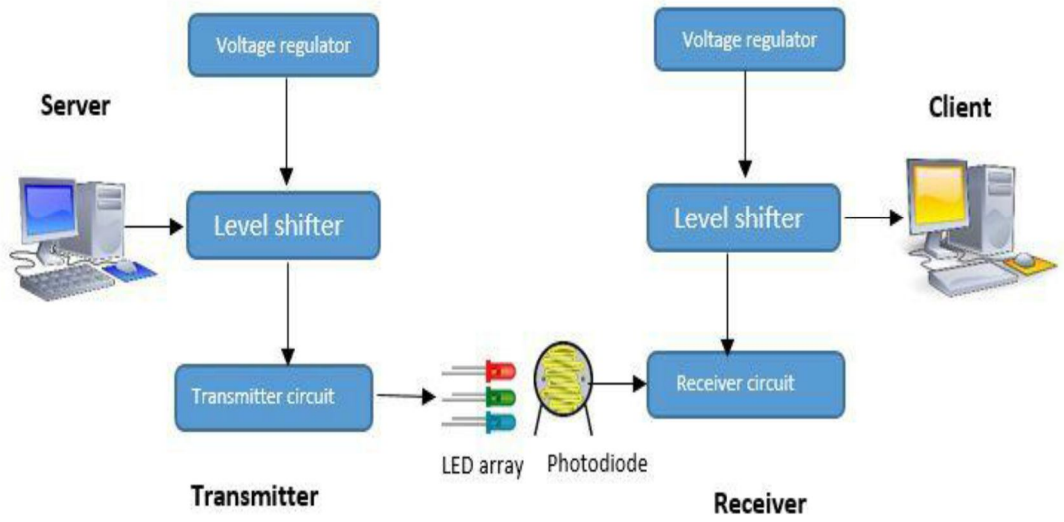

Fig 4: Construction of Li-Fi System

(Source:http://ijariie.com/AdminUploadPdf/Review_Paper_on_Li_Fi__Light_Fidelity__ijariie2056.pdf)

3. Working of Li-Fi

3.1 Basic Concept:

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.

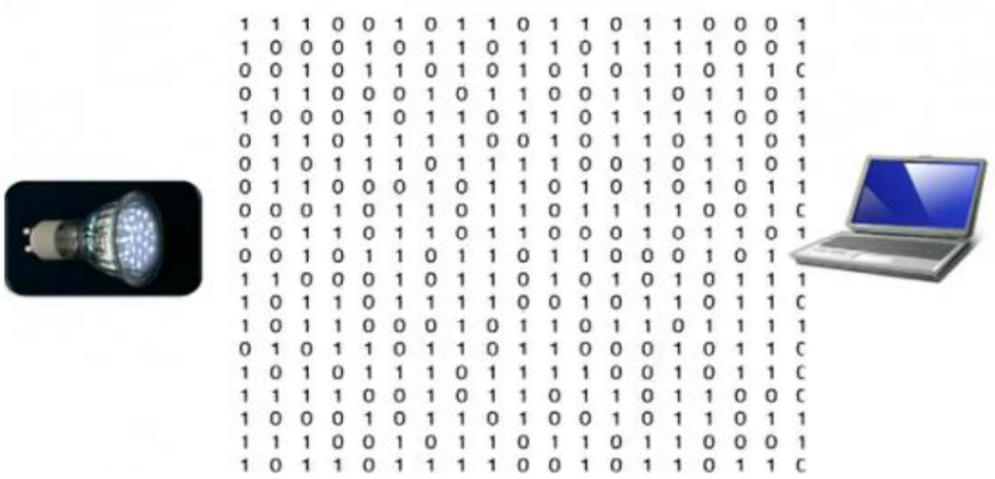

Fig 5: Li-Fi Transmission

(Source: http://www.internationaljournalssrg.org/IJECE/2015/Volume2-Issue3/IJECE-V2I3P107.pdf)

3.2 How it Works:

The working of Li-Fi is very simple. There is a light emitter on one end i.e. an LED transmitter, and a photo detector (light sensor) on the other. The data input to the LED transmitter is encoded in to the light (technically referred to as Visible Light Communication) by varying the 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 colours) will eventually provide data rates in the range of hundreds of Mbps. The Li-Fi working is explained in a block diagram (Fig.6).

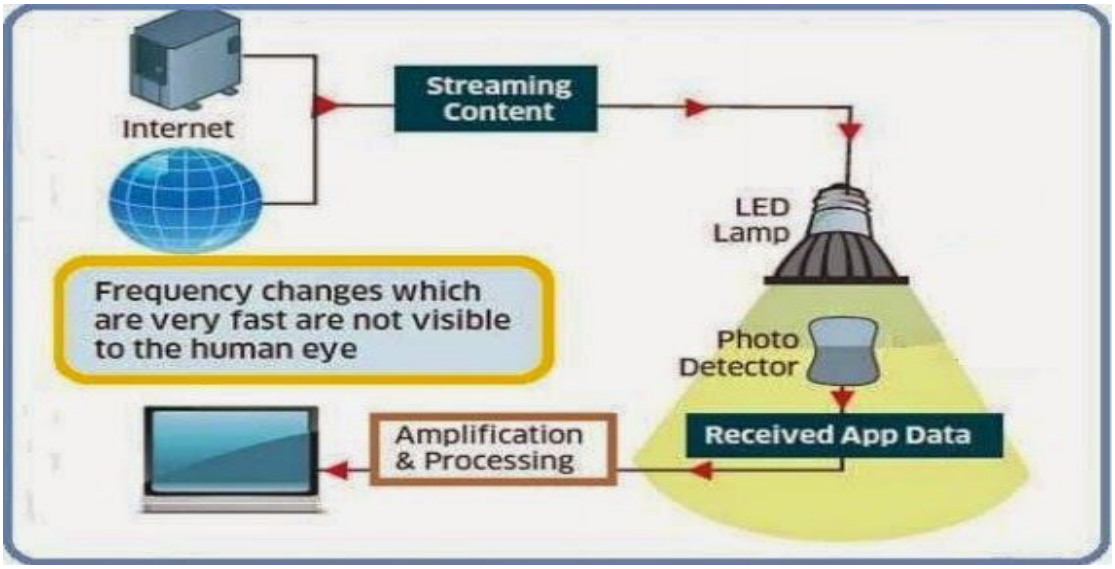

Fig 6: Block diagram of Li-Fi Sub System

(Source: http://www.warse.org/pdfs/2014/icetetssp25.pdf)

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 7 shows working/deployment of a Li-Fi system connecting the devices in a room.

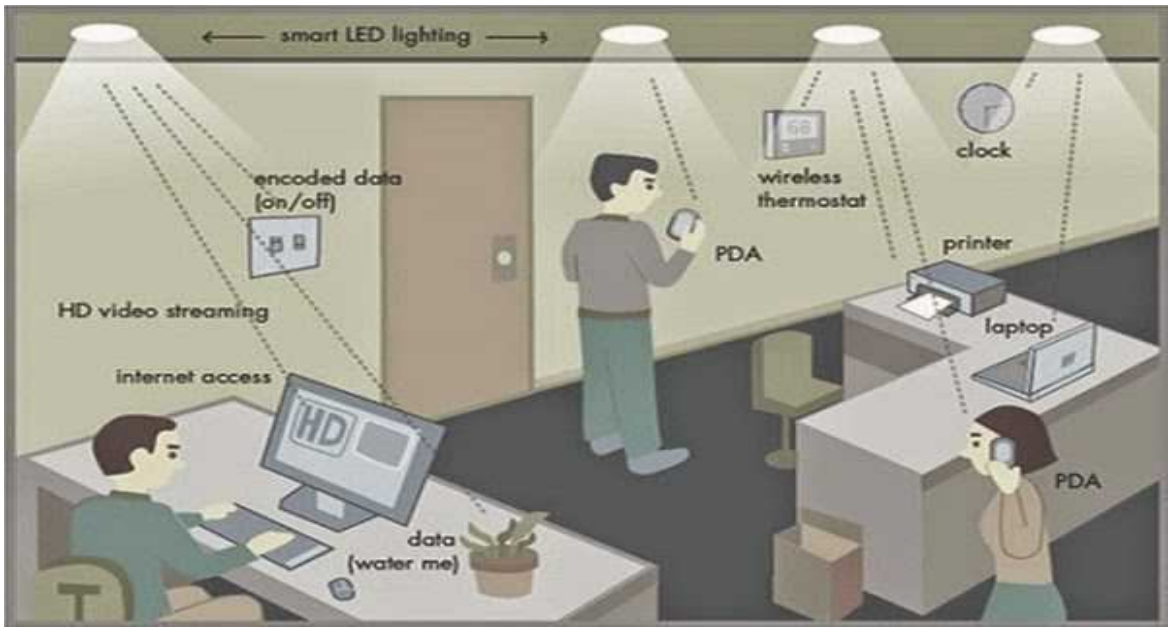

Fig 7: Li-Fi system connecting devices in a room

(Source:http://ijariie.com/AdminUploadPdf/Review_Paper_on_Li_Fi__Light_Fidelity__ijariie2056.pdf)

3.3 Why Visible Light Communication:

The frequency spectrum that is available to us in the atmosphere consists of many wave regions like X-rays, gamma rays, u-v region, infrared region, visible light rays, radio waves, etc. Any one of the above waves can be used in the upcoming communication technologies but why the Visible Light part is chosen? The reason behind this is the easy availability and lesser harmful effects that occur due to these rays of light. VLC uses the visible light between 400 THz (780 nm) and 800 THz (375 nm) as medium which are less dangerous for high-power applications and also humans can easily perceive it and protect themselves from the harmful effects whereas the other wave regions have following disadvantages:-

- Radio waves are expensive (due to spectrum charges) and less secure (due to interference and possible interception etc.)
- Gamma rays are harmful because it could be dangerous dealing with it, by the human beings due to their proven adverse effects on human health.
- X-rays have health issues, similar to the Gamma Rays.
- Ultraviolet light can be considered for communication technology purposes at place without people, otherwise they can also be dangerous for the human body when exposed continuously.
- Infrared, due to high safety regulation, can only be used with low power.

Hence the Visible light portion (from red to blue) of the electromagnetic spectrum does not cause any harm to the people as visible rays are safe to use, provide larger bandwidth and also have a promising future in the communication field.

4. Comparison Between Li-Fi and, Wi-Fi and other Radio Communication technologies

Both Wi-Fi and Li-Fi can provide wireless Internet access to users, and both the technologies transmit data over electromagnetic spectrum. Li-Fi is a visible light communication technology useful to obtain high speed wireless communication. The difference is: Wi-Fi technology uses radio waves for transmission, whereas Li-Fi utilizes light waves. Wi-Fi works well for general wireless coverage within building/campus/compound, and Li-Fi is ideal for high density wireless data coverage inside a confined area or room and is free from interference issues unlike the Wi-Fi.

Table I shows a comparison of transfer speed of various wireless technologies. Table II shows a comparison of Li-Fi with Wi-Fi.

Table 1: Comparison of speed of various wireless technologies

Technology	*Speed*
Li-Fi	~1 Gbps
Wi-Fi – IEEE 802.11n	~150 Mbps
IrDA	~4 Mbps
Bluetooth	~3 Mbps
NFC	~424 Kbps

Table 2: Comparison of Wi-Fi and Li-Fi

Parameter	*Li-Fi*	*Wi-Fi*
Spectrum Used	Visible Light	RF
Standard	IEEE 802.15.7	IEEE 802.11
Range	Based on Light Intensity (< 10m)	Based on Radio propagation & interference (< 300 m)
*Data Transfer Rate**	Very high (~1 Gbps)	Low (100 Mbps-1 Gbps)
Power consumption	Low	High
Cost	Low	High
Bandwidth	Unlimited	Limited

* https://www.ijsr.net/archive/v4i12/NOV151778.pdf

4.1 Shortcomings of Radio Waves Transmission vis-à-vis Li-Fi Transmission:

The following are the basic issues with radio waves:

a) *Capacity:* Wireless data is transmitted through radio waves which are limited and expensive. It has a limited bandwidth, vis-à-vis Li-Fi. With the rapidly growing world and development of technologies like 3G, 4G and so on we are running out of radio spectrum.

b) *Energy Efficiency:* There are a large number of cellular radio base stations that consume massive amount of energy. Most of the energy is used for cooling down the base station instead of transmission. Therefore, efficiency of such Radio base stations is very low.

c) *Availability:* Availability of radio waves is a big concern. Further, Radio waves are not advisable to be used in aeroplanes and at places where radio interference may cause undesirable/catastrophic result.

d) *Security:* Radio waves can penetrate through walls. They can be intercepted. If someone has knowledge and bad intentions, they may misuse it. This causes a major security concern for Wi-Fi.

4.2 Advantages of Li-Fi:

Li-Fi, which uses visible light to transmit signals wirelessly, is an emerging technology poised to compete with Wi-Fi. Also, Li-Fi removes the limitations that have been put on the user by the Radio wave transmission such as Wi-Fi as explained above vide 4.1. Advantages of Li-Fi technology include:

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

4.3 Limitations of Li-Fi:

Some of the major limitations of Li-Fi are:

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

5. Standardization

The Visible Light Communication interest group, certified by the IEEE, with its standard approved in 2011 by IEEE as IEEE 802.15.7 is the most active one. The standard of VLC (IEEE 802.15.7) specifies VLC consisting of mobile-to-mobile (M2M), fixed-to-mobile (F2M) and infrastructure-to-mobile (I2M) communications. The main purpose of VLC standard is to focus on medium-range communications for intelligent traffic systems at low-speed and on short-range mobile to mobile and fixed to mobile communications at high speeds to exchange data. Data rates are supported up to 1 Gbps using various modulation schemes. IEEE 802.15.7 defines physical layer (PHY) & media access control (MAC) layer for VLC/Li-Fi. The MAC layer supports 3 multi-access technologies: peer-to-peer, star configuration and broadcast mode. It also handles physical layer management issues such as addressing, collision avoidance and data acknowledgement protocols. The physical layer is divided into 3 types: PHY I, II, III and employ a combination of different modulation schemes.

- The PHY I was established for outdoor application and works from 11.67 kbps to 267.6 kbps.
- The PHY II layer permits reaching data rates from 1.25 Mbit/s to 96 Mbit/s.
- The PHY III is used for many emissions sources with a particular modulation method called colour shift keying (CSK). PHY III can deliver rates from 12 Mbit/s to 96 Mbit/s.

The modulation formats recognized for PHY I and PHY II are on-off keying (OOK) and variable pulse position modulation (VPPM). The Manchester coding used for the PHY I and PHY II layers includes the clock inside the transmitted data by representing a logic 0 with an OOK symbol "01" and a logic 1 with an OOK symbol "10", all with a DC component. The DC component avoids light extinction in case of an extended run of logic 0's.

There are also two Japanese standards for VLC networking (JEITA CP-1221 and CP-1222).

6. Applications of Li-Fi

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 equipments 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 street lamps 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.

Some of the future applications of Li-Fi could be as follows:

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

b) *Medical Applications:* Operation theatres (OTs) do not allow Wi-Fi due to radiation concerns. Usage of Wi-Fi at hospitals interferes/blocks the signals for monitoring equipments. 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 equipments. This will be beneficial for conducting robotic surgeries and other automated procedures.

c) *Cheaper Internet 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. present inside the airplane.

d) *Underwater applications:* 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.

e) *Disaster management:* Li-Fi can be used as a powerful means of communication in times of disaster such as earthquake or hurricanes. The average people may not know the protocols during such disasters. Subway stations and tunnels, common dead zones for most emergency communications, pose no obstruction for Li-Fi.

f) *Applications in sensitive areas:* Power plants need fast, inter-connected data systems so that demand, grid integrity and core temperature (in case of nuclear power plants) can be monitored. The Radio communication interference is considered to be bad for such sensitive areas surrounding these power plants. Li-Fi can offer safe, abundant connectivity for all areas of these sensitive locations. Also, the pressure on a power plant

‘s own reserves (power consumption for Radio communications deployments) will be lessened.

g) *Traffic management:* 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.

h) *Mobile Connectivity:* Mobiles, laptops, tablets, and other smart phones can easily connect with each other. The short-range network of Li-Fi can yield exceptionally high data rates and higher security.

i) *Replacement for other technologies:* Li-Fi doesn‘t work using radio waves. So, it can be easily used in the places where Bluetooth, infrared, Wi-Fi, etc. are banned.

6.1 Use Cases:

6.1.1 The pureLiFi, which is a UK based company, claims to be one of the leading companies in LiFi technology, having the following VLC products as on date:

Li-Flame Ceiling Unit to connect to an LED light fixture and Li-Flame Desktop Unit which connects to a device via USB, both aiming to provide light and connectivity in one device. LiFi-X, claims to be evolution of the world’s first LiFi system, the Li-Flame. The system offers a fully networked LiFi solution which supports multiple access, roaming, complete mobility and ease of use – providing a level of user experience that is comparable and more secure than existing wireless technologies i.e. Wi-Fi. The LiFi-X delivers high data densities and eliminates unwanted external network intrusion. In addition, the merger of illumination with wireless communications claims to provide a measurable reduction in both infrastructure complexity and energy consumption. LiFi-X apparently delivers: -

- Full duplex communication with a 40Mbps downlink and 40Mbps uplink;
- Full mobility (portable, USB-powered station)
- Multiple users per LiFi Access Point, supported through multiple access
- Secure wireless communications constrained by walls, eliminating the risk of signal leakage to external eavesdroppers
- Safe wireless communication in environments where radio frequencies are not suitable
- Flexible deployments
- Extensive range of wireless communication applications including and beyond existing Wi-Fi
- A cost-effective delivery of light and data via a single infrastructure

LiFi-X consists of two main parts namely,

a) LiFi-X Access Point (AP)

- Support for Power over Ethernet (PoE) or Power Line Communications (PLC)
- Simple installation
- Connect to a wide range of LED light fixture to form an atto-cell
- Multiple access
- Handover control enables seamless switching between APs

b) LiFi-X Station (STA)

- USB 2.0 powered
- Supports handover, allowing users to move while maintaining their wireless session.

6.1.2 **OLEDCOMM**, a French company, designs and manufactures Li-Fi router solutions for LED based lighting systems. The OLEDCOMM claims to be a world leader in the field offering the following products /services based on its Li-Fi LED drivers:

a) GEOLiFi- Indoor Location Based Services:

GEOLiFi, a high efficiency dimmable LED driver combined to an Indoor Positioning System (IPS) and works as a Li-Fi broadcast system. With GEOLiFi, the LED lightings in a building can be converted into a true Indoor Positioning System or IPS. An IPS is a system to locate objects or people inside a building. Based on the indoor map, it allows to create Location Based Services like: mobile marketing via digital place-based media that communicates with consumers on the move, Shoppers can locate objects with ease, and also call for service when needed, person purchasing a printer can be guided to ink cartridges available at a discounted rate, physical tracking of a customer inside a store yields useful information on behaviour, Storage, stock-keeping and retrieval of stock keeping units become easier.

b) LiFiNET - Unlimited bandwidth for connecting people and IoT:

LiFiNET is a solution which is a combination of a high efficiency dimmable LED driver with a bidirectional Li-Fi communication for people and IoT. It allows a highly secure and private bidirectional communication for the Internet of Things (IoT). This system is designed to take care of major obstacles with regards to unleashing the potential of the Internet of Things namely - high energy consumption and leak of connectivity.

The company also claims to have developed the first Light Fidelity enabled car using Li-Fi technology for car to car communication in the year 2007 and had equipped the first public space in the world (a Museum in Europe) with Li-Fi technology in the year 2012.

Li-Fi is also reportedly being tested in Dubai, by UAE-based telecommunications provider, du and Zero1. Du claims to have successfully provided internet, audio and video streaming over a Li-Fi connection

7. Future Scope:

As light is everywhere and free to use, there is a great scope for the use and evolution of LiFi technology. If this technology becomes mature, each Li-Fi bulb can be used to transmit wireless data. As the Li-Fi technology becomes popular, it will lead to a cleaner, greener, safer communications and have a bright future and environment. The concept of Li-Fi is deriving many people as it is free (require no license) and faster means of data transfer. If it evolves faster, people will use this technology more and more.

Li-Fi Roadmap:

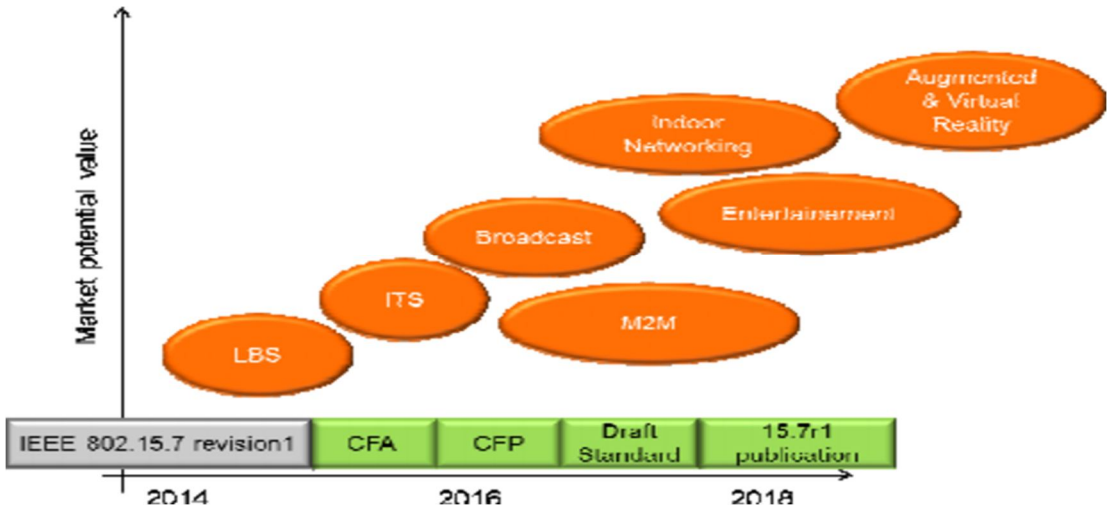

Fig 8: Li-Fi Roadmap

(Source:https://www.researchgate.net/publication/284173584_Light_Fidelity_LiFi_The_new_wireless_communication_system)

Currently, LBS (location Based Service) or Broadcast solution are commercially available. The next step could be a Li-Fi WLAN for B2B market with high added value on specific business cases and could grow towards mass market. In the long term, the Li-Fi could become an alternative solution to radio for wireless high data rate room connectivity and new adapted service, such as augmented or virtual reality.

8. Conclusion

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

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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Abbreviations:

Li-Fi:	Light Fidelity
TED:	Technology, Entertainment & Design

VLC:	Visible Light Communication
LED:	Light Emitting Diodes
PA:	Power Amplifier
PCB:	Printed Circuit Board
RF:	Radio Frequency
M2M VLC:	Mobile-to-Mobile Visual Light Communication
PHY:	Physical Layer
MAC:	Media Access Control
CSK:	Colour Shift Keying
OOK:	On-Off Keying
Gbps:	Gigabit per Second
IrDA:	Infrared Data Association
NFC:	Near Field Communication

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