A Review Paper on Li-Fi Technology

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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 fiber out of fiber optics and sending data through LED light bulb.**

Keywords:- LI-FI, WI-FI, Visible Light Communication, Radio Spectrum.

INTRODUCTION

In today's world of overcrowded (data communication), Li-Fi is a new and efficient way of wireless communication. Li-Fi uses LED lights to transmit data. The Transmission of data is done wirelessly. The current wireless networks that connect us to the Internet becomes very slow when many devices are connected. Also with the increase in the number of devices, which uses 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 of data compared to conventional methods of wireless communications that are done on radio waves. The basic idea behind this technology is that the data can be transferred through LED light by varying light intensities faster than the human eyes can't detect. This technology uses a part of the electromagnetic spectrum that is still not generally utilized- The Visible Spectrum, instead of Gigahertz radio waves for transferring of data.

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 introducing 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.

ARCHITECTURE OF LI-FI

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.

Turning the LEDs on and off can make them generate digital strings with different combination of 1s and 0s. To generate a new data stream, data can be encoded in the light by varying the flickering rate of the LED. In this way, the LEDs work as a transmitter by modulating the light with the data signal. The LED output appears constant to the human because they are made to flicker at a phenomenal speed (millions of times per second) and it's impossible for human eye to detect this frequency. Communication rate more than

100 Mbps can be achieved by using high speed LEDs with the help of various multiplexing techniques. 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 consists of four primary subassemblies:

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

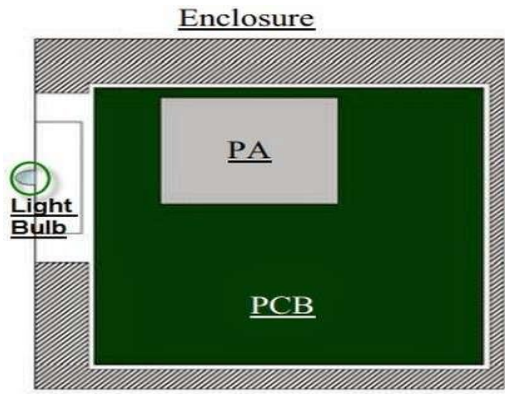


Fig 2: Block Diagram of Li-Fi sub assemblies.
(Source:http://www.ijcta.com/documents/volumes/vol5issue1/ijcta2014050121.pdf)

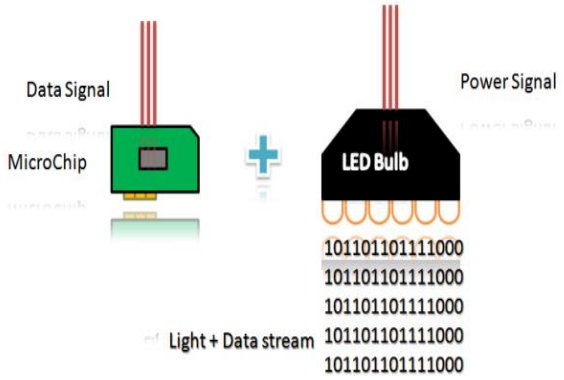
The Printed circuit board (PCB) controls the electrical inputs and outputs of the lamp and houses the microcontroller used to manage different lamp functions. A Radio Frequency (RF) signal is generated by the Power Amplifier and is directed into the electric field of the bulb. As a result of the high 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 aluminum enclosure as shown in Fig. 2 above.

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 rate at which the LEDs turns 'on' and 'off' to achieve different strings of 1s and 0s. The on off activity of the LED transmitter which seems to be invisible (The LED intensity is modulated so fast that human eye cannot notice it, so the light of the LED appears constant to humans), enables data transmission in light form in accordance with the incoming binary codes: switching ON a LED is a logical '1', switching it OFF is a logical '0'. By varying the rate at which the LEDs turns on and off, information can be encoded in the light to different combinations of 1s and 0s.In a typical setup, the transmitter (LED) is connected 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).

Working of Li-Fi

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



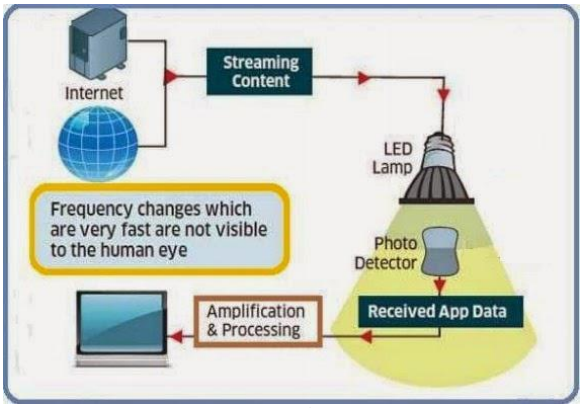


Fig 6: Block diagram of Li-Fi Sub System.

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

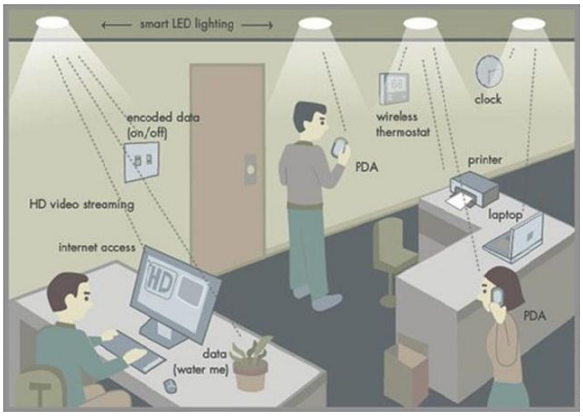


Fig 7: Li-Fi system connecting devices in a room (Source:http://ijariie.com/AdminUploadPdf/Review_Paper_on_Li_Fi__Light_Fidelity__ijariie2056.pdf)

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

Advantages of Li-Fi

a) Efficiency: Energy consumption can be minimized 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 and high bandwidth and also 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 almost everywhere – in homes, offices, shops, malls and also in 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.

Limitations of Li-Fi

- 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 pass 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.

Applications of Li-Fi

There are numerous applications of Li-Fi technology:-

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 through every light source such as 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 chain 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, highpowered lamp — then they would be much freer to explore. They could also use their headlamps to communicate with each other, processing data individually 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 field 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) 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.

g) 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) Equivalent 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 easily used in the places where Bluetooth, infrared, Wi-Fi, etc. are banned.

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

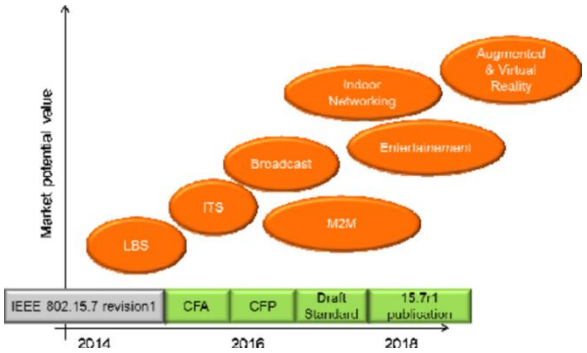


Fig 8: Li-Fi Roadmap

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

At Present, LBS (location Based Service) or Broadcast 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.

CONCLUSION

Although there's still a long way 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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