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Li-Fi Need of 21st Century

G. Kant[1*], V. Gogate[2*], V. Kotak[3]

[1]Dept. of Electronics, Shah and Anchor Kutchhi Engineering College, Mumbai, INDIA
[2]Dept. of Electronics, Shah and Anchor Kutchhi Engineering College, Mumbai, INDIA
[3]Dept. of Electronics, Shah and Anchor Kutchhi Engineering College, Mumbai, INDIA
Corresponding Author: gyatnalkar92@gmail.com

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Abstract- In today's digital world wireless internet and cellular mobile services are essential part of our life. It fully make use of wireless communication. According to standards of IEEE 802- 11n Wireless-Fidelity (Wi-Fi) gives the speed of 600 Mbps(theoretical),[sorce:www.Intel.com] but this is not enough to fulfill the need of desired users over the network. To overcome this major disadvantage of Wi-Fi, a new technology is developed by Germen physicist Harald Haas from the University of Edinburgh, UK known as Li-Fi which provides transmission of data via LED bulb whose intensity varies in a much faster speed that it could not be able to be detected by the naked eye. The efficiency, durability, and of light-emitting diodes (LEDs) have led to their use in a variety of applications. In a high speed wireless communication, Li-Fi can bring new dimensions in terms of data communication speed by utilizing visible light Communication technology. This report contains all about Li-Fi, importance of visible light spectrum, comparison of Li-Fi with other technologies, advantages and applications.

Keywords- Li- Fi (Light Fidelity), Wi Fi (Wireless Fidelity), VLC (Visible light communication), RF (Radio frequency), LED (Light emitting diode),ADC(analog to digital convertor)

I. INTRODUCTION

Li-Fi which is "Light Fidelity" is a boon to human beings by the modern science and it's a revolution in the field of Wireless communication.

The concept behind this technology is that the data can be transmitted with the help of light emitting diode (LED) bulbs and transmission rate can be control by using intensity of LED bulb. Light intensity is very fast so human eye cannot detect it. Prof. Harald Hass had leaded the visible light communication (VLC) research project at Edinburgh's Institute for Digital Communications from January 2010 and gives this project a name called D-light Project. Later on in 2011, Prof. Harald Haas promoted his research work at TED Global talk. The light emitting diode (LED) is used to send data in the visible light communication. LED acts as a source of illumination as well as can be used to transmit data[1-4].

The Research team of D-Light Project achieved a data rate of around 130 Megabits per second ,which is two time much faster as compare to wi-fi access point use for wireless communication. In 2012, at Las Vegas, Li-Fi technology is first time demonstrated for smartphone's at consumer electronics show to exchange data using light up to a distance of 10 meters. Li-Fi is the fast and cheap wireless communication system, which is the optical version of wi-fi. Light is easily available and spreads nearly everywhere, so communication can achieved with light easily. Data can be transfer through LED light. Overview of LiFi is as shown in fig.1.

Li-Fi is the name given to describe visible light communication technology applied to obtain high speed wireless communication .This name is derived from the similarity of wi-fi. wi-Fi works well for in-building broadband coverage, and Li-Fi is ideal for high density wireless data coverage inside a confined area or room and avoids radio interference issues. wi-Fi is working on a radio waves to provide wireless internet and network connections at high-speed. When an RF current is passes to an antenna that creates an electromagnetic field to propagate via space. [5].

Li-Fi uses optical wireless communication. Data is transmitted through a LED bulb. The variations are converted into digital signals. Data transmission is in Gbps. The data density is about 1000 times than wi-fi. This is due to less interference of light than RF waves.[6]

Wi-MAX and Wi-fi are both wireless broadband technologies, but they have difference in the technical execution. Wi-Fi was developed to be used for mobile computing devices, such as laptops, in LANs, but is now used for many services, like Internet and VoIP phone access, gaming, and basic connectivity of consumer electronics such as televisions and DVD players, or digital cameras. On the other hand Wi-MAX was developed as standard based technology enabling the delivery of last mile wireless broadband accesses as an alternative to cable and DSL. Wi-max 100 times faster than wifi, LiFi is 100 times faster than wi-max.[7]

Figure.1 .Overview of Li-Fi [10]

II. LITERATURE REVIEW

The literature related to the research topic has been reviewed in order to find out work carried out by various Researchers. R.Karthika1, S.Balakrishnan, in "Wireless Communication using Li-Fi Technology" [1] have designed a prototype LiFi system to transfer data as well as files. Their idea was to send data and file as serial data using UART serial communication from one PC to another PC using VLC. They used the visible light communication at the transmitting end and also for reception photodiodes at the receiving PC. PIC microcontroller for toggling of the LED at the transmitting end and again for binary conversion of received stream of data into a suitable file to be recognized by the PC software. Photo diode transistor is used to recover the data from visible light and inverting amplifier is used to get the data and processed by PIC controller connected to PC serial communication port as well as Android Phone using OTG cable. It can be used wherever LED light source is available.

Harald Haas, and Liang Yin in "What is LiFi?" Journal of light wave technology,[2] clarified the difference between visible light communication (VLC) and light-fidelity (LiFi). In particular, it shows how LiFi takes VLC further by using light emitting diodes (LEDs) to realize fully networked wireless systems. They also explain LiFi attocells concept used to enhance wireless capacity providing the necessary connectivity to realize the Internet-of-Things, and contributing to the key performance for the fifth generation of cellular systems (5G) and beyond. It covers all of the key research areas from LiFi. components to hybrid LiFi/ wireless fidelity (Wi-Fi) networks to illustrate that LiFi attocells are not a theoretical concept any more, but at the point of real-world deployment. VLC uses LEDs to transmit data wirelessly by using intensity modulation (IM). At the receiver the signal is detected by a photodiode (PD) and by using the principle of direct detection (DD). VLC has been conceived as a point-to-point data communication technique – essentially as a cable replacement. This has led to early VLC standardization activities as part of IEEE 802.15.7. This standard, however, is currently being revised to include LiFi. LiFi in contrast describes a complete wireless networking system. This includes bi-directional multiuser communication, i.e. point-to-multipoint and multipoint-to-point Communication. LiFi also involves multiple access points forming a wireless network of very small optical attocells without interference. This means that LiFi enables full user mobility, and therefore forms a new layer within the existing heterogeneous wireless networks. The fact that LEDs are natural beam formers enables local containment of LiFi signals.

Dobroslav Tsonev, Stefan Videv and Harald Haas, in "Light Fidelity (Li-Fi): Towards All-Optical Networking" [3] demonstrated that optical wireless communication (OWC) is a viable and matured solution to the RF spectrum crisis, the fundamental problem. In particular, for indoor communications where most mobile data traffic is consumed, light fidelity (Li-Fi) which is related to visible light communication (VLC) offers many key advantages, and effective solutions to the issues that have been posed in the last decade. They also discussed the technologies required to realize optical cellular communication systems referred as optical attocell networks. Optical attocells are the next step in the progression towards ever smaller cells.

Pooja Bhateley,Ratul Mohindra,S.Balaji,in **"**smart vehicular communication system using LI FI**"** [3] developed a smart vehicular communication system using Li Fi technology which provides protection against vehicular collisions on the roads. This project focuses on the safety on roads in which the headlights, which consists of LEDs acting as transmitter, communicate with photo sensors acting as receiver. White LEDs used in the head and tail lights can effectively be used for short range communication with the photo detectors.

The head lamps used in the cars are mostly high powered white LEDs. Speedometer reading is converted to the digital form using a microprocessor which is given as input to LEDs. The LEDs produce the digital sequence which travels in a wireless channel to the photodiode. The current generated by the silicon photo diode is decoded to a digital sequence using ADC and the number represented by the sequence carries the information which is used to alert the driver in the vehicle following the one which transmits its speed.[3]

Hardeep Singh and Geet Bawa [4] presented Visible Light Communication (VLC) system architecture suitable for outdoor applications. This proposed the usage of direct sequence spread spectrum to combat noise and interference. They demonstrated that it is feasible to achieve more than 40m communication range for low data rate applications even in the presence of optical noise levels. They used a VLC transceiver that converts visible light into an electrical signal and vice versa. Digital data is processed and converted by an encoder into an electrical signal that carries information. On the receiver side,

visible light pulses pass through an optical filter. The resulting signal is then filtered, amplified and converted into digital format using ADC.

III. WORKING PRINCIPLE

Prof. Harald Haas explained the working principle of Li-Fi in a very simple way. The decisive factor for Li-Fi technology is high brightness of light coming out of LED bulb. Generally implemented using white LED light bulbs at the downlink transmitter. These devices are used for illumination only by applying a constant current. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This property of optical current is used in Li-Fi setup.

The operational procedure is very simple-, if the LED is on, we transmit a digital 1, and if it's off we transmit a 0. The decisive factor to transmit the data is quickly switching on and off of LED. Hence all that is required is LEDs and a controller that code data into those LEDs. So LED's flicker rate can be varied depending upon the data we want to encode.fig.2 Further improvement can be made, 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 enhancement can increase a theoretical speed of 10 Gbps – meaning one can download a full high-definition film in just 30 seconds.

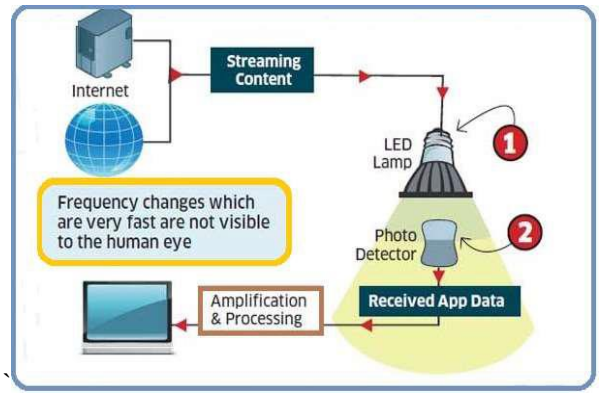

Figure. 2 Working Principle [5]

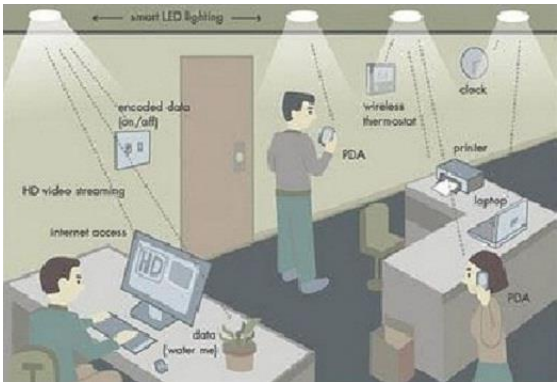

Figure 3. Indoor communication [7]

IV. LI-FI COMPONENTS

The main components of Li-Fi system are as follows:

LI-FI SOURCE – LED

The LEDs act as light source, that is, 'transmitter', which transmits O's or l's. LEDs are used in Li-Fi as a data source more conveniently and efficiently to generate data streams. As compare to the IR LED which generate a single data stream with 10-20 kbps speed, these LED's generates a thousands of data streams spreading all over the room where the light can reach with a very fast rate [5]. The potential of these LED's can be increased by using Luminaire Design Optimization techniques.

Recently the R & D centre of pure VLC has achieved 3.5 Gbps of data rate from a single color micro LED operating at 5mW with a 1m distance and 1.1Gbps of data rate at 10m at 5mW[5] as shown in fig.4. So using three colors RGB LED's the data rates of more than 10Gbps Communication rate greater than 100 Mbps is possible. VLC data rate can be increased by parallel data transmission using an array of LEDs.

Data rate versus size of the LED

Data rate is inversely proportional to size of LED

The variations in data rate (R) with the size of LEDs are important in the Li-Fi technology. Different data rates can be achieved with different sizes of LEDs. The size of normal LED bulb can be reduced to micro-LED which handles millions of alterations in light intensity. A micro LED light bulb to transmit 3.5 Gbps and the data rate of more than 10 Gbps is possible. The tiny micro LED bulbs allow the stream of light to be beamed in parallel and transmitting huge amount of data in terms of Gbps. The microchip LED bulb can generate data rates up to150 Mbps with single bulb which provide fast internet connectivity and services. Here it can be concluded that data rate (R) is inversely proportional to the size of LED . The LEDs are of different sizes e.g. 5mm,3mm, 1.8mm, 1mm, and 1nm LED.

Data rate versus number of LED

Data rate is directly proportional to number of LED

The data rate can be increased with the increasing number of LEDs. The number of LEDs depend on available space inside the lamp. The number of LEDs can be adjusted so that it can achieve the maximum bit rate (bps).

V. LI-FI RECEIVER – PHOTODIODE

The photodiode is used as a Li-Fi receiver to sense the data stream. The Avalanche photodiodes are used to make better receivers. At Haas's recent talk on "My Li-Fi Revolution" at Tam Dalyell prize lecture he showed the first receiver chip for Li-Fi with integrated Avalanche photodiodes on CMOS created by his team at the Li-Fi R&D centre. The 7.8 –square–mm IC houses 49 photodiodes. At the IEEE Photonics Conference in

October, Li-Fi consortium showed off the progress of combining both emitters and photodiodes to detect light using available red, green and blue LED's in this way, the system can send and receive data at aggregate rates of 110 Mbps .[12]

Amplifier- The signal received through photo detector is very weak and it is in the mV range, so it needs to be amplified. Hence voltage amplifier circuit is used to amplify the detected.

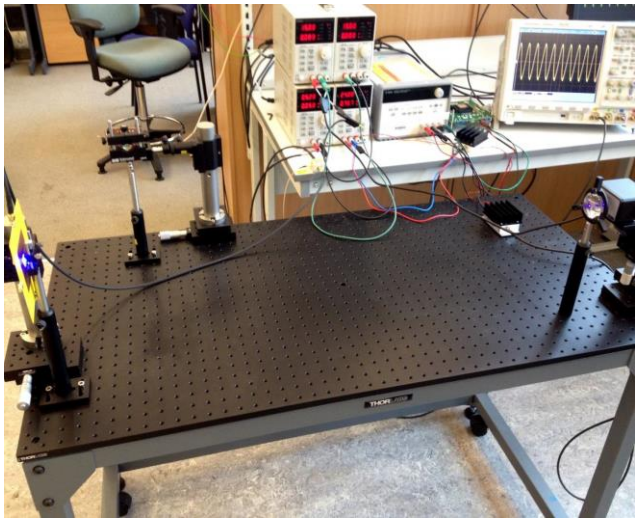

Figure 4. Demonstrations for 1.1Gbps at 10 m at 5mW[12]

VI. RF SPECTRUM CRISIS

Li-Fi which is based on visible light communication is a need of 21st century. Why?
Reason is due to globalization need of data communication increases every year but the capacity to accommodate more users is limited and Radio Frequency Spectrum is already congested. So in this present scenario Radio spectrum with limitation of Capacity, Efficiency, Cost, Availability and Security cannot be ignore. We know that its radio spectrum bandwidth is limited. When we use radio waves for communication millions of base station consume huge amount of energy in transmitting radio waves and to cool the base station as a result less efficiency is achieved. Radio waves signal have limited availability, within range of base station and at some areas like in aero plane and under water we can't use it.

Electromagnetic Spectrum
So if we consider Electromagnetic Spectrum, Visible light spectrum is the one which can be use because it is ten thousand times broader than the spectrum of radio frequency, and have unlimited capacity so when we talk about visible light communication, Light fidelity is the one which can provide us faster alternative of radio wave communication with advantages of more capacity, Efficiency, Cost, Availability and Security.

Li-Fi comprises a wide range of frequencies and wavelengths, from the infrared through visible and down to the ultraviolet spectrum as shown in figure 5.[5]

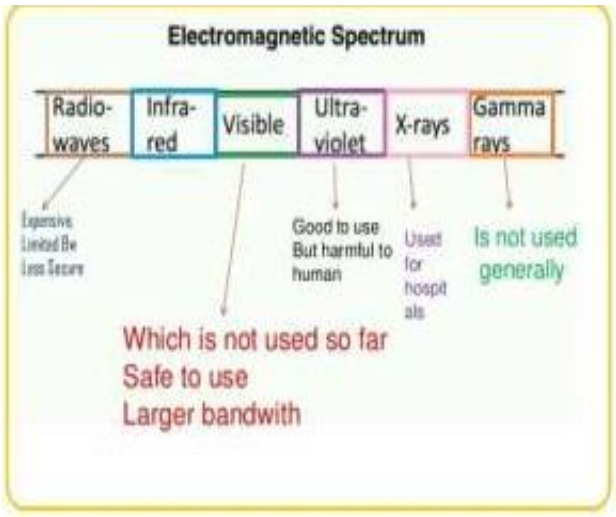

Figure 5. Electromagnetic Spectrum [5]

Visible Spectrum
It is a part of electromagnetic spectrum that the human eye can see. Its wavelength ranges from 390-700nm.This spectrum is continuous and has seven colors. Fig 6. shows the spectrum of visible light. On either sides of the spectrum exists Ultraviolet and Infrared spectrum. Transmission of data takes place in this visible region.[8]

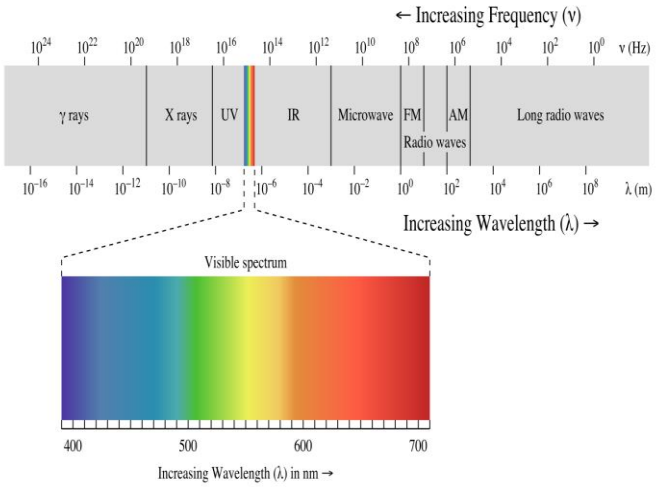

Figure 6. Visible Spectrum

VII. APPLICATIONS AND CHALLENGES WITH LI-FI

1. Airways:
In travelling by airways communication media, is the major issue,because the airways communications are performed by the radio waves. We can overcome this drawback by using LI-FI technology. figure 7.

Figure 7. LI FI in Airways [7]

2. Green information technology:
LI-FI never gives any side effects on any living thing like radio waves and other communication waves which effects on the birds, human bodies, etc.
Free From Frequency Bandwidth Problem: LI-FI is a visible light communication medium, so it does not require any kind of spectrum license i.e. we don't need to pay any amount for communication and license.

3. Smarter Power Plants:
Power plants need fast and data systems with interconnected to monitor things like grid integrity, core temperature. Wi-Fi could not work properly in these areas as these are more sensitive to radio frequency like as in petrochemical plants. LI-FI could work properly in these sensitive areas and it also safe to use
.
4. Communication Security:
Light can't penetrate to the wall so in visible light communication, security is higher than any other communication technology as shown in below figure 8.

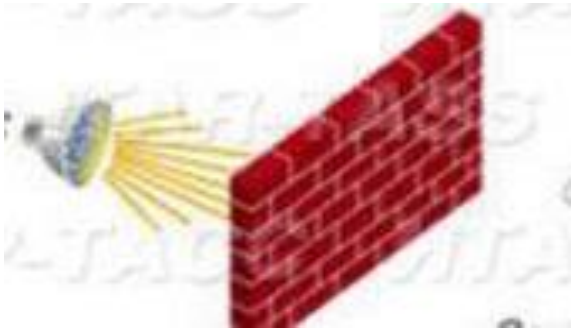

Figure 8. Secure Communications [7]

5. Lightings Points Used as Hotspot
Any lighting devices like car lights, ceiling lights, street lamps, etc. are performed as a hotspot. It means that the any light able to spread internet using visual light communication which helps us to low cost architecture for a hotspot. The hotspot is a limited region in which some amount of device can access the internet connectivity.
Traffic lights also can communicate to the car and with each other as cars have LED-based headlights, LED-based back lights, and cars can communicate with each other and prevent accidents in by exchanging information.

6. Indoor Communication
The Li-Fi system allows an indoor navigation where the LED lights sources are used like shopping malls, cinema theatres, government offices, work offices or any indoor locations. One of the examples of Indoor Communication system using VLC is shown in figure . In this example figure 9, one user who is using his Personal computer can send his important data toward printer, to his laptop and toward his friend smart phone by using Li-Fi.[5].

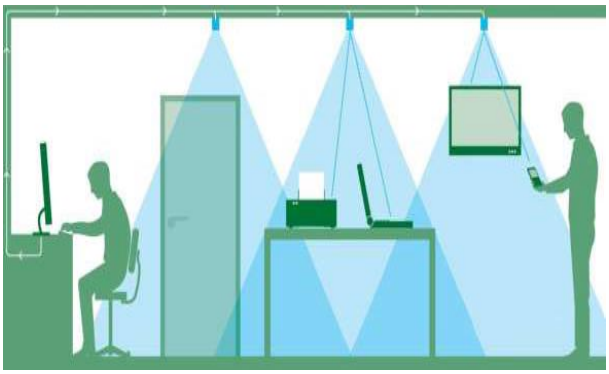

Figure 9. Indoor Communications [5]

7. In Hospitals:
The Li-Fi transmitters can be installed in hospitals also where the RF wave does not. They can be used in different machines to communicate with each other for fast data interpretation

8.In Petrochemical Industries:
These industries do not allow RF because various radioactive chemicals are used for processing. The Li-Fi system can be used here as it uses a VLC.

9.Useful for internet of things :
Li-Fi node is built with communication and networking features of optical wireless physical layer and TCP/IP layers to interconnect the things at anytime, anywhere.

10. Undersea water:
Underwater there are large cables that supply power and allow receiving signals from others but if their wires were cut and replaced with light high-luminance lamp then they would be much freer to explore. They could use their lamps to communicate with each other [1] as shown in figure 10.

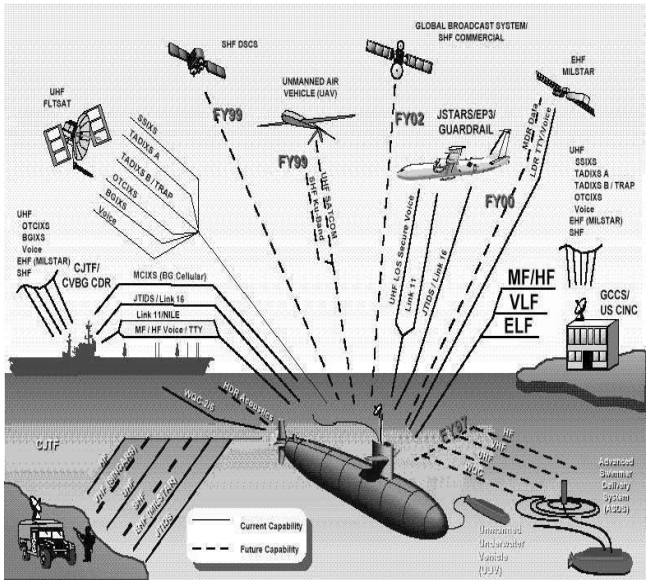

Figure 10. Underwater Communication [7]

11. Vehical communication

Any lighting devices like car lights, ceiling lights, street lamps, etc. are performed as a hotspot. It means that the any light able to spread internet using visual light communication which helps us to low cost architecture for a hotspot.

Traffic lights also can communicate to the car and with each other as cars have LED-based headlights, and back lights, and cars can communicate with each other and prevent accidents in by exchanging information as shown in fig. 11. [7]

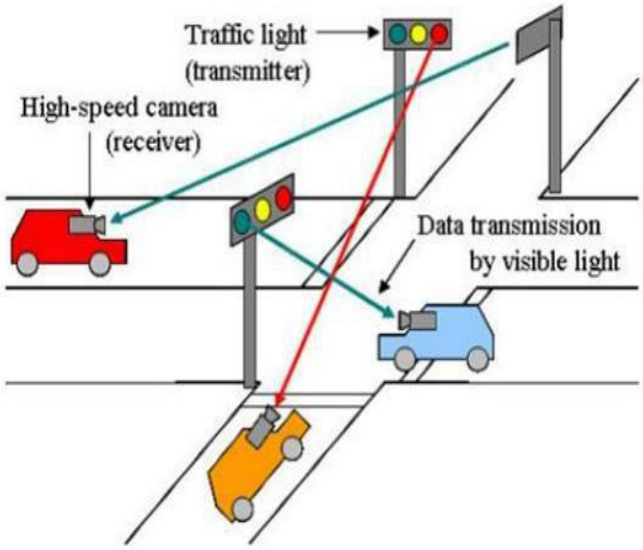

Figure 11. Vehicle communication [7]

CHALLENGES:

Apart from many advantages over Wi-Fi, Li-Fi technology is facing some problems such as Li-Fi requires line of sight. Receiving device would not be shift in indoors. Other disadvantage is visible light can't penetrate through brick walls as radio waves and is easily blocked by somebody simply walking in front of LED source. From the above discussion it is seen that Li-Fi will not be able to replace completely the Wi-Fi, they both are complimentary to each other. User can only receive the data with Li-Fi VI. From the above discussion it is seen that Li-Fi will not be able to replace completely the Wi-Fi, they both are complimentary to each other. User can only receive the data with Li-Fi technology but if the user needs to send back the data then it should switch to Wi-Fi. As Li-Fi uses only LED to transmit the data, if we can manage to inbuilt a LED bulb in our Wi-Fi routers or externally connect a LED bulb to our existing Wi-Fi routers then we can surely use both the technologies. If a device can be made which works on both Li-Fi and Wi-Fi, then the problem of range can be sorted out to some extent. Another method is to equip the newly manufactured Wi-Fi routers with the LED bulb that works according to this technology inbuilt in it i.e. the power light, LAN light etc. Suppose a person is sitting in a room under a LED bulb can use the full 60 GHz spectrum with the greater speed and if that person want to move to other room there is no need of any other LED bulb in other room also, as the range of Li-Fi diminishes, the user gets switched to Wi-Fi automatically.

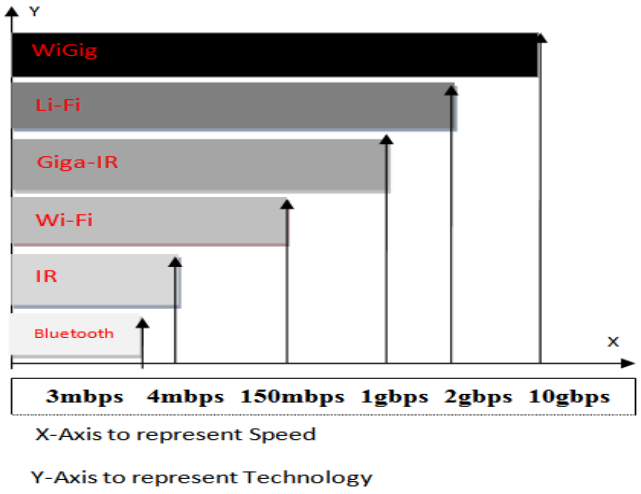

Figure 12. Technology v/s speed [10]

VI. COMPARISION

Comparison of LI-FI with Other Technologies is as shown below and graphical analysis with speed is as shown in fig.12.

Table 1. Comparison of LI-FI and WI-FI [11

Features	Light Fidelity	Wireless Fidelity
IEEE standard	802.15.7	802.11b
System components	Lamp driver, LED bulb and photo detector	Routers and subscriber device stations (laptops, PDAs, desktops
Topology	Point to point	Multipoint
Data transmission	Bits	Radio waves
Features	Light Fidelity	Wireless Fidelity
Frequency	1000 times to wifi	Radio spectrum range
Frequency band	100times to TeraHz	2.4GHz, 4.9GHz and 5GHz
Data transfer speed	2.4GHz, 4.9GHz and 5GHz	WLAN-11n offers 150Mbps,
Coverage area	10 meters	20 - 100 meters (WLAN 802.11b/11g), varies based on type of transmission power and antenna
Operation	Data transmission by light of LED bulbs	Data transmission by radio waves with Wi-Fi router
Interference	No interference issues with RF waves	Interfere with neighbor AP Routers
Ecological Impact	Low	High
Privacy	More secure data transfer	RF cannot be prevented by brick walls and hence less security data transmission
Data density	High	Low
Latency	Microsecond	Milliseconds
Cost	Low	High
Market maturity	Low	High

VII. CONCLUSION

To use LI-FI technology into practical use, every bulb used to transmit a data and will lead toward the cleaner, greener, safer and brighter future. LI-FI can solve issues such as the shortage of radio-frequency bandwidth and is worth at creating new communication channels with the use of existing equipment.

Li-Fi can provide us more efficient and genuine substitute of RF based wireless network. Li-Fi Technology has a great future because it's a hope for next generation wireless network because this technology has the ability to turn every street bulb in to a wireless hotspot and there are many possibilities to implement it in many areas where RF based system cannot be used.

As use of internet is increasing very rapidly capacity of frequency spectrum to accommodate further users in future is limited and also it would be difficult for service providers to provide user more reliable and high speed communication so this short come can only be solve in future by using Li-Fi technology.

Li-Fi communication user always need line of sight connectivity with its light source therefore some advance research work is required to overcome this limitation to implement this technology in practice.

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