International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:11, No:7, 2017

Li-Fi Technology: Data Transmission through Visible Light

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***Abstract*—**People are always in search of Wi-Fi hotspots because Internet is a major demand nowadays. But like all other technologies, there is still room for improvement in the Wi-Fi technology with regards to the speed and quality of connectivity. In order to address these aspects, Harald Haas, a professor at the University of Edinburgh, proposed what we know as the Li-Fi (Light Fidelity). Li-Fi is a new technology in the field of wireless communication to provide connectivity within a network environment. It is a two-way mode of wireless communication using light. Basically, the data is transmitted through Light Emitting Diodes which can vary the intensity of light very fast, even faster than the blink of an eye. From the research and experiments conducted so far, it can be said that Li-Fi can increase the speed and reliability of the transfer of data. This paper pays particular attention on the assessment of the performance of this technology. In other words, it is a 5G technology which uses LED as the medium of data transfer. For coverage within the buildings, Wi-Fi is good but Li-Fi can be considered favorable in situations where large amounts of data are to be transferred in areas with electromagnetic interferences. It brings a lot of data related qualities such as efficiency, security as well as large throughputs to the table of wireless communication. All in all, it can be said that Li-Fi is going to be a future phenomenon where the presence of light will mean access to the Internet as well as speedy data transfer.

***Keywords*—**Communication, LED, Li-Fi, Wi-Fi.

I. Introduction

WE know that now a days in the world of technology, data transfer is the most common used activity. In the current setup, access to the Internet slows down considerably as the number of devices connected to the same Wi-Fi increases. And the reason for that is the fixed bandwidth, which restricts the data transfer rate. As we increase devices connected to the same Wi-Fi, the data transfer rate would decrease. Li-Fi is one solution to this problem because radio waves have a small spectrum available for data transfer [1].

Data rate faster than 10 megabits per second can be produced with Li-Fi, which is very fast as compared to broadband connections. LED lights are also becoming very popular being used in homes and offices for its bright efficacy improvement. Li-Fi proposes the use of increased bandwidth with better speeds using visible lights as compared to electromagnetic waves used in Wi-Fi. As an idea, we can say Li-Fi can offer bandwidth of 300 THz as compared to 300 GHz in RF communication [2]. It comprises of wavelengths and LED lights, which are also becoming very popular being used in homes and offices for its bright efficacy improvement.

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Li-Fi proposes the use of increased bandwidth with better speeds using visible lights as compared to electromagnetic waves used in Wi-Fi. It comprises of wavelengths and frequencies ranging from infrared down to UV spectrum. This technology uses white light spectrum and infrared and not limited to LED or laser technologies. So, it can be said that Li-Fi technology is a platform which can induce fast Internet connectivity to the entire range of technology. The increasing demand of Wi-Fi everywhere leads to low capacity, radio frequencies are getting higher, due to which, problems like RF interferences and complexities continue to grow [6], [8].

Photons of light are used in Li-Fi as data carriers which cannot be detected by the human eye. So, one of the benefits can include the replacement of other technologies in environments where more security is required and typical frameworks are not trusted easily. The system utilizing LEDs can be used for indoor lightning purposes as well as for transmitting data or information.

Fig. 1 Li-Fi Basic concept [8]

II. Overview of Li-Fi

In Li-Fi, optic fiber cables are used in such a way that instead of fiber, Light Emitting Diodes are used to transmit data after emission of light [4]. We can use the term fast and cheap wireless communication system. Just like other waves, the energy from the fluorescent bulb can illuminate whole area within an environment but due their limited range they are used for indoor environments. Also, thick walls will not allow light to pass through them. But the overall data rate is better as compared to Wi-Fi. During the transmission of data, the LED's current state i.e. on or off, will determine the binary state of ones and zeros; hence, the data will be transmitted this way. The microcontroller controls the data. The received data is forwarded to the computer to complete the transmission [5].

III. Design and Working of Li-Fi

If we analyze the design of Li-Fi, we will find that it consists of Light Emitting Diodes which act as the primary transmitter. The main components in the construction of Li-Fi system are as follows:

A. White LED bulb as transmitter

B. Silicon photodiode as receiver

An LED bulb with good brightness level transmits the data and the photodiode, with considerably higher sensitivity towards light, works as the data receiver. There are few factors to be taken care of while designing a Li-Fi system i.e. it is advised to use fluorescent light emitting diodes with a good presence of light [12].

The Li-Fi Emitter based system contains four parts:

A. Bulb

B. RF Power Amplifier circuit

C. Printed circuit board

D. Enclosure

To regulate the various light functions, a microcontroller is used which is controlled by PCB designed circuit. An RF power amplifier circuit (PA) is used to generate the radio frequency signal which is guided to the electric field about the light bulb. The content of the bulb gets transformed to a plasma state at the bulb center due to high concentration of energy in the electric field. This controlled plasma makes an uncommon wellspring of light. In Fig. 2, we can see that all parts are contained in an aluminum enclosure.

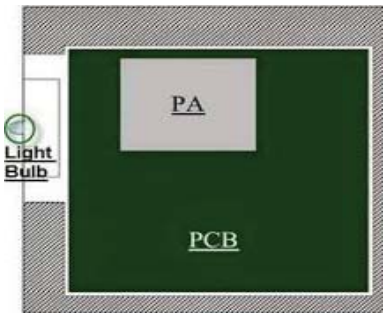

Fig. 2 Enclosure [12]

The sub-assembly of the bulb is main element of the Li-Fi Emitter system. This assembly contains a dielectric medium in which a settled bulb is embedded. This design is better than inserted degradable electrodes into the bulb, as in a conventional light source. Two needs are fulfilled by dielectric material. The power amplifier generates the radio frequency signal which is directed into an electric field around the bulb. Due to the high absorption in the electric field, a plasma state is generated in the center of bulb which results in intense source of light. Fig. 3 shows the sub-assembly of the bulb.

This approach has numerous advantages such as outstanding color quality, increased illumination, and high luminous efficiency of the emitter which has a range of 150 lumens/watts. The structure is mechanically intense without standard degradation and frustration instruments related with tungsten terminals and glass to metal seals, achieving profitable light presence of 30,000+ hours. Likewise, the stand-out mix of high temperature plasma and precisely controlled solid-state equipment achieves a fiscally conveyed gathering of lights versatile in groups from 3,000 to more than 100,000 lumens.

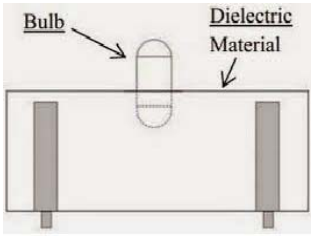

Fig. 3 Bulb Sub-Assembly [12]

To generate digital strings of 0s and 1s, LEDs are turned on and off. Data transmission is done by altering the signaling or blinking of the light emitting diode i.e. by changing the frequency different data can be generated. The data or information is modulated by LED light, and the output appears to be constant because of the fast blinking rate of the light source [13]. Using multiplexing and some other methods, speed up to over 100 Mbps is easily acquirable. Parallel transmission is implemented using many LEDs to increase the amount of data, with every LED transmitting a different data stream.

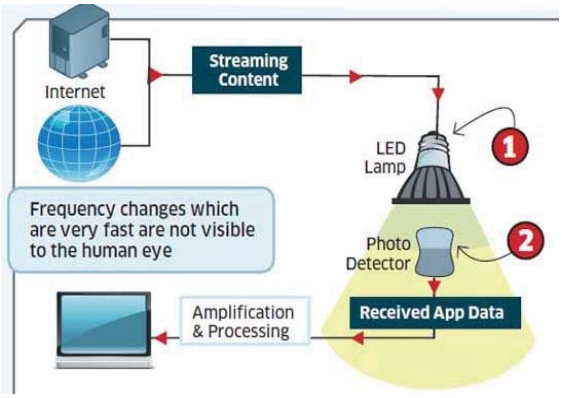

Fig. 4 Overall Design of Li-Fi [4]

In Fig. 4, a Lamp driver is connected to the internet. The LED Lamp and switch is also connected to the Lamp driver through optical fiber. On this end, when the LED is ON, the data is converted into light. On the receiving end, the photodiode then processes the light emitted. This device is also connected to an electronic device like a PC. After receiving the signal, a photo detector converts it again into digital form. This way the data or information is retrieved using a simple circuitry [14].

The workings of the system are very simple. When the light emitting diode is on, one is stored on the other end, while if off, a zero is stored. When the LED flicks many times (this can be achieved by using array of LEDs of different color) a

message builds up and data rate in the range of hundreds can be achieved because of the fast flickering of LED.

If increased data rate is required, other colored light emitting diodes can be incorporated to enhance the range of light frequency.

IV. Modulation Techniques for VLC and Li-Fi

Intensity modulation is the basic principle used in the modulation technique for VLC and Li-Fi that shows that the information can be varied while altering the light intensity [7]. It even enhances the modulation used in radio frequency modulation techniques. M-level quadrature amplitude modulation is implemented to gain extensive transmission of data. Li-Fi, which uses the lightning system for indoors, requires high average optical power to provide sufficient illumination. Hadamard coded modulation (HCM) is developed by researchers for low error probabilities in VLC systems requiring high power. The efficiency of HCM may increase while reducing the DC aspect of the emitted data signal. Hence, it provides the signal which is considered best suited to systems requiring lightning, as now the signals are with low peak amplitudes in contrast with HCM signals, but the HCM signals are exposed to non-linear distortion. To make the signal resistive to Inter symbol interference (ISI), Interleaving can be applied [19].

V. Visible Light Communication

Visible light waves are less harmless to human beings as compared other waves. In earlier era radio waves were adopted for communication but due to lack of security features and cost, the utilization of radio waves were not encouraged, similarly low powered infrared waves were used for communication. Furthermore, due the adverse effect of UV light and gamma ray, they were strongly discouraged for communication. Due to the harmless nature of visible light, it can be used with a maximum bandwidth. Visible light communication uses visible light ranging from 400 THz to 800 THz for data transmission.

VI. Li-Fi Head to Head Comparison

Li-Fi, as is mentioned above, is a wireless communication using light transmission. It essentially works the same as Wi-Fi, but over a different transmission medium. In a simple sentence, Wi-Fi is considered better for outdoors and normal coverage, while Li-Fi is limited to closed spaces in order to avoid any losses due to other electrical devices.

TABLE I
Comparison of Data Transfer Rates of Different Wireless Technologies

Technologies	Speed
Bluetooth	3 Mbps
Infrared Data Association	4 Mbps
Wi-Fi	150 Mbps
Li-Fi	>1 Gbps

Table I shows a comparison between the different technologies Bluetooth, Infrared Data Association, Wi-Fi and Li-fi with respect to their speeds.

TABLE II
Comparison of Different Technologies Performance

Technologies	Connections	Reach	Security	Cost	Bandwidth Expansion
Wi-Fi	Electromagnetic Field	Very Good	Good	High	Limited
Hardwired	Wires	Good	Very Good	High	Limited
Li-Fi	Light	Very Good	Very Good	Low	Exceptional

Table II shows a comparison of different technologies Wi-Fi, Hardwired and Li-Fi with respect to their performances on the basis of connections, Reach, Security, Cost and Bandwidth Expansions [15].

VII. Limitations of Wi-Fi

Problems like efficiency, capacity, security, and availability are present in Wi-Fi. The transmission of data is considered expensive and not reliable using Wi-Fi because of limited bandwidths. It is presumed that with the pace technology growing, existing technologies do not cater to the needs associated with sensitive data. With regard to efficiency, there are millions of base stations which use a lot of energy, much of which should be used for transmitting data or information is instead used in cooling down base stations. The availability of radio waves is also a big issue as the use of mobile phones is not allowed in many places. Another security aspect can be that Wi-Fi can go pass through walls, and thus, if you do not want the signals to transmit to neighboring locations, this is not the best option [17].

VIII. Advantages of Li-Fi

In Li-Fi, light emitting diodes can generate lights from most parts of the light spectrum with sufficient speeds to enable large data download as quickly as possible. The limitations Wi-Fi are overcome by Li-Fi due to its high bandwidth as compared to other electromagnetic waves. Moreover, most of the equipment needed for this technology is already present [3]. The LED being energy economical and efficient provides cheap data transfers. Existing light bulbs can be replaced by them and we have the platform of data transfer [16], [18]. Unlike radio waves, light cannot travel through dense mediums, and thus, the medium is somewhat more secure for internal communication. With any light, one can use the Internet as the connection depends upon light, and also, there will be no need for routers or other Wi-Fi related equipment.

IX. Disadvantages of Li-Fi

Li-Fi will work in direct line of sight, as artificial light source's reach is limited and cannot transmit data through thicker interferences such as walls. Li-Fi enabled devices may lose connectivity while outside the source of Internet, as light intensity drops with the increase in distance. Despite being a powerful system, there are a few operation disadvantages such

as to use Internet the lights must be kept ON all the time, including the day, which results in wasting a lot of power. Even low light will make the Internet slow. As such, one might not be able to enjoy gaming or watching movies in a dark room.

X. Application of Li-Fi

Li-Fi is helpful for securing communication, as well data. There are different uses for Li-Fi technology. Li-Fi secures the communication in a large area, such as a meeting where a lot of users are accessing the Wi-Fi, which results in a slowdown in the speed of Wi-Fi. Li-Fi technology provides 1000 times more speed then Wi-Fi in this case. Moreover, light does not travel through walls so there is less chance of data loss [10], [11]. These environments have a greater area of artificial lighting, so as the lightening area is greater it provides high speed and greater accessibility. Sometimes the distance between radio stations are 200-250 meter. Rather to dispose the radio stations, street lamp is used. These lamps are not only light up at night but also gives the high-speed communication data

It is a 5G technology in which LEDs are used as a medium for wireless communication [7], [9].

In commercial aircraft, Li-Fi gives a facility of high data rate to passengers, which is available throughout the journey. Wifi is good for over-all wireless coverage while Li-fi is perfect for high density coverage region in a confined area such as museum or galleries where visitors use their mobile phone to explore more details related to artifacts or art work.

Li-Fi can also be used for product advertisement. Wi-Fi is not used in underwater communications; however, with the help of Li-Fi it is also possible to communicate underwater [13]. Li-Fi technology can be adopted in the environment where the use of mobile phone is hazardous. It is helpful in-home automation to control appliances such air conditions and fans, lights, washing machine etc. This is also useful the medical field, by allowing patient records to be saved and easily accessed in times of emergency.

XI. Conclusion

In this paper, a survey on Li-Fi has been discussed. In the future, data for electronic devices can be transmitted through light via Li-Fi technology. In 2014 Mexican company (Sisoft), achieved data rate up to 10 GB/s across a light spectrum emitted by LED bulb which means that one HD movie will take approximately half minute to download. Also, micron sized LEDs are being developed which can flicker around 1000 times faster than large LEDs. They not only offer faster data rate, but also take less space to allow more communication. Micron diodes can transmit millions of packets of data streams as compared to the large diodes. Prone to interference, visible light waves are a far better option than radio waves. The technology is not only free to use, but offers highly secure and safe access. This technology and concept is attracting a lot of attention because of its harmless nature and greater bandwidth capacity. One of the main reasons making this technology very attractive is that it offers a solution to clogged airwaves that result from an increasing population in the field of wireless communication, which hinders the passage of data at good speeds and with strong signals.

Li-Fi can be termed as the solution to low radio bandwidths. Li-Fi can be the replacement of fifth generation networks and can be used as the primary source of data transfer in all the existing as well as the upcoming technological equipment. Therefore, it suffices to say that Li-Fi can be used in multiple areas of technology and its applications can alter the way we access the Internet.

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