Li-Fi: The emerging Future Technology

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ABSTRACT
LiFi or Light- Fidelity is a technology that uses light as the transmission medium usually known as visible light communication (VLC). This paper proposes a survey on Li-Fi Technology. The Li-fi technology was invented by Professor Harald Hass of University of Edinburgh. It is supposedly capable of 1 Gbps speed that's much faster than the average Wi-Fi speed that most of us have today. With such high throughput, it would be possible to download content such as movies in a fraction of the time it takes now. Li-Fi refers to 5G Visible Light Communication systems using light-emitting diodes as a medium to high-speed communication in a similar manner as Wi-Fi.[13] In this paper, the comparison is made between Wi-Fi and Li-Fi technology. The invention of Prof. Hass the D-light is nothing but to produce data rates higher than 10 megabits per second, this rate faster than the average broadband connection.

Keywords
Li-Fi, Wi-Fi, VLC, LED

1. INTRODUCTION
LiFi is a two-way communication technology that sends data using light, via LED bulbs which flicker on and off at a frequency not even noticeable to our eyes. The term was first coined by German physicist Harald Haas at a TED talk back in 2011, where he discussed the idea of using light bulbs as routers. He took this idea and, together with a group from the University of Edinburgh, founded pure LiFi a year later. The idea behind Li-Fi is to use a form of visible light communication instead of radio waves like conventional Wi-Fi routers, enabling much faster data transfer speeds. VLC technology delivers high-speed, bi-directional mobile communications similar to Wi-Fi, but in a much more secure way.

In fact, Li-Fi technology is able to increase bandwidth by 100 times and recently managed to achieve 1Gbps real-world results during testing, while boasting a theoretical top speed of 224Gbps. The technology isn't affected by the number of devices using the signal either, a massive bonus when compared to traditional Wi-Fi technology. Standard LED light bulbs use a constant current, which emits a constant stream of photons perceived by us as visible light. Li-Fi is different because the current it uses varies, meaning that the output intensity of the light fluctuates.

LEDs are semiconductors so the current and output can be modulated at high speeds, which is picked up via a photodetector device. The optical output is then converted back into an electrical current, which is processed and sent to your device as data. The varying light intensity isinvisible to the naked eye, making it about as noticeable as Wi-Fi signals. LI-FI is implemented using white LED light bulbs which are used for illumination by applying a constant current. However, by fast variations of the current, the light output can be made to vary at extremely high speeds. If the LED is on, it transmits a digital 1 otherwise it transmits a digital 0. The LEDs can be switched on and off quickly to transmit the data that can't be detected by a human eye [7]. There are also some enhancements that could be made, like using an array of LEDs for parallel transmission, or using amalgamation of basic three colour's i.e., red, green and blue LEDs as different frequency with each having a different data channel[11] To further get a grasp of LI-FI consider an IR remote. It sends a single data stream with 10-20 kbps speed. Now if we replace the IR LED with a large LED array then that can be capable of sending thousands of such streams at a very fast rate[2]. The figure-1 shows the environment with the LI-FI technology where light bulbs are used as a data communication medium to PC, Laptop, Tablet and PDA as it all have photo detector connected to it as receiver.[8]

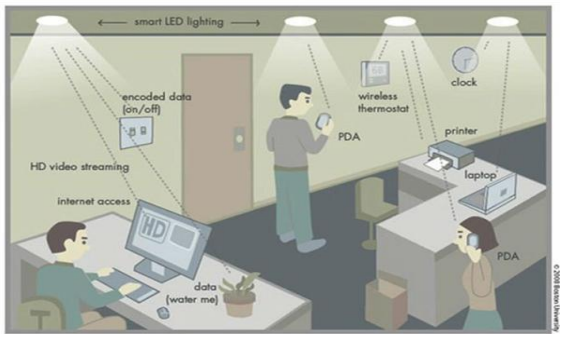

Fig 1: Environment with Li- Fi technology

2. WORKING PRINCIPLE OF LI-FI
Li-Fi and Wi-Fi are quite similar as both transmit data electromagnetically. However, Wi-Fi uses radio waves while Li-Fi runs on visible light. As we now know, Li-Fi is a Visible Light Communications (VLC) system. This means that it accommodates a photo-detector to receive light signals and a signal processing element to convert the data into 'stream-able' content. An LED light bulb is a semi-conductor light source meaning that the constant current of electricity supplied to an LED light bulb can be dipped and dimmed, up and down at extremely high speeds, without being visible to the human eye. For example, data is fed into an LED light bulb (with signal processing technology),it then sends data (embedded in its beam) at rapid speeds to the photo-detector (photodiode). The tiny changes in the rapid dimming of LED bulbs is then converted by the 'receiver' into electrical signal. The signal is then converted back into a binary data stream that we would recognize as web, video and audio applications that run on internet enables devices.

The working of Li-Fi is very easy as Wi-Fi. There is a light emitter on one corner, for example, an LED, and a photo detector (light sensor) on the other corner. The photo detector

registers a binary one when the LED is on; and a binary zero if the LED is off.[6][10] A data rate of greater than 100 Mbps is possible by using high speed LEDs with appropriate multiplexing techniques. So it has very fast data rates.[9]. The figure-2 shows the working principle of a LI-FI.

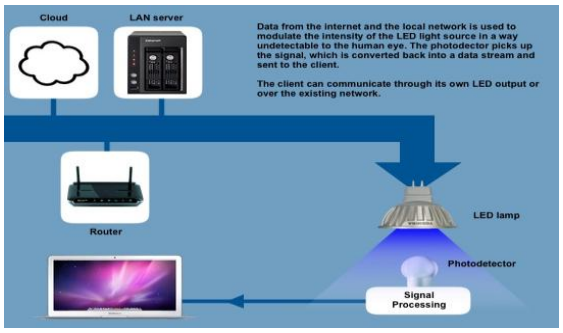

Fig 2: Working Principle of Li-Fi

The data can be encoded in the light by varying the flickering rate at which the LEDs flicker on and off to generate different strings of 1s and 0s.The LED intensity is modulated so rapidly that human eye cannot notice, so the light of the LED appears constant to humans Light-emitting diodes can be switched on and off faster than the human eye can detect, causing the light source to appear to be on continuously, even though it is in fact 'flickering'. The on-off activity of the bulb which seems to be invisible enables data transmission using binary codes: switching on an 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. This method of using rapid pulses of light to transmit information wirelessly is technically referred to as Visible Light Communication (VLC), though it is popularly called as Li-Fi because it can compete with its radio-based rival WiFi.

3. TECHNICAL ASPECT & MODULATION

This section deals with physical layer, modulation formats and frequency spectrum that is related with Li-Fi communication. The IEEE 802.15.7 standard defines the physical layer (PHY) and media access control (MAC) layer. Li-Fi communication is modelled after protocols established by the IEEE 802 workgroup. It 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 dividedinto 3 types: PHY I, II, III and employ a combination of different modulation schemes[15]. The modulation formats recognized for PHY I and PHY II are the coding on-off keying (OOK) and variable pulse position modulation (VPPM). The Manchester coding used for the PHY I and PHY II layers include 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 the light extinction in case of an extended line of logic 0. Optical Orthogonal Frequency Division Multiplexing (O-OFDM) modulation methods which have been optimized for data rates, multiple-access and energy efficiency which can be used for Li-Fi communication. The new high-speed optical wireless models used in both indoors and outdoors. The Li-Fi provides resources for OEM [Original Equipment Manufacturer] and ODM [Original Design Manufacturers] developers to create exciting new products. With the emergence of high-speed cable connections like Thunderbolt and USB 3.0, the stage is set for a wireless equivalent.

4. COMPARISON BETWEEN LI-FI AND WI-FI

LI-FI as discussed, is a term used to describe visible light communication technology applied to high speed wireless communication. It acquired this name due to the similarity to WI-FI, only using light instead of radio. WI-FI is great for general wireless coverage within buildings and LI-FI is ideal for high density wireless data coverage in confined area and for relieving radio interference issues, so the two technologies can be considered complimentary. [4] Table 1 gives a comparison between Li-Fi and Wi-Fi using different parameters.

Table 1. Comparison between Li-Fi and Gi-Fi

Parameter	Li-Fi	WIFi
IEEE Standard	802.15.7	802.11b
Development year	2011	1999
Range of Spectrum	10000 times than Wi-fi	Radio spectrum range
Network topology	Point to point	Point to Multipoint
Data density	High	Low
Speed	1-3.5Gbps	54-250Mbps
Security	High	Low
Cost	Less	High
Communication	Based on Visible light Communication	Based on Radio frequency Communication
Licenses	Not required	Required
Data transfer medium	Used light as carrier	Use Radio Spectrum
Range	10meters	20-100meters
Frequency band	100 timesof Tera Hz	2.4GHz
Routing device	LED	Access point
Environmental Impact	Low	Medium
Usage location	Anywhere where LED lights are available like roads, home, offices etc.	Within the WLAN Range and infrastructure used
Carrier	Information carried over optical intensities	Information carried over electric field

5. ADVANTAGES OF USING LI-FI

Li-Fi technology is a ground-breaking light-based communication technology, which makes use of light waves instead of radio technology to deliver data.

- Availability: light is presence everywhere, for proper transmission of data, just need to replace with LED
- Lower electricity cost [2]

- Security: light waves do not penetrate through the walls, so there is no question for misuse it. It is highly secure.[7]
- Li-Fi not required license, it has free band[2] Li-Fi technology cheap in cost. Capacity: light has 10000 times wider bandwidth than radio waves, so it has got large capacity and equipment are easily available.
- Speed is high as compared to other existing technology
- Efficiency: Li-Fi is more efficient because it consumes less energy, but compare with cellular phones for the base stations required large energy
- It is used in VLC band which safe for human health.

6. APPLICATIONS OF LI-FI TECHNOLOGY

6.1 Education systems

Li-Fi is the latest technology that can provide fastest speed internet access. So, it can replace Wi-Fi at educational institutions and at companies so that all the people can make use of LiFi with the same speed intended in a particular area.

6.2 Use in Medical sector

Operation theatres (OTs) do not allow Wi-Fi due to radiation concerns. Usage of Wi-Fi at hospitals interferes with the mobile and pc which blocks the signals for monitoring equipments. So, it may be hazardous to the patient's health. To overcome this and to make OT tech savvy Li-Fi can be used to accessing internet and to control medical equipments. This can even be beneficial for robotic surgeries and other automated procedures.

Fig 3. Li Fi in Operation theatres

6.3 Airlines and Aviation

Whenever we travel through airways we face the problem in communication media, because the whole airways communications are performed on the basis of radio waves. To overcome this drawback LI-FI is best for use. Li-Fi can easily provide high speed internet via every light source such as overhead reading bulb, etc. present inside the airplane.[3]

Fig 4. LiFi usage inside the airplanes

6.5. Smarter Power Plants

Power plants need fast and data systems to monitor things like grid integrity, demand and (in nuclear plants) core temperature and 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 saves money.[3]Li-Fi offers a safe alternative to electromagnetic interference due to radio waves in environments such as petrochemical plants and mines

Fig 5. Smart Power Plants using LiFi

6.6 Traffic management

In traffic signals Li-Fi can be used which will communicate with the LED lights of the cars which can help in managing the traffic in a better manner and the accident numbers can be decreased [1]. Also, LED car lights can alert drivers when other vehicles are too close.

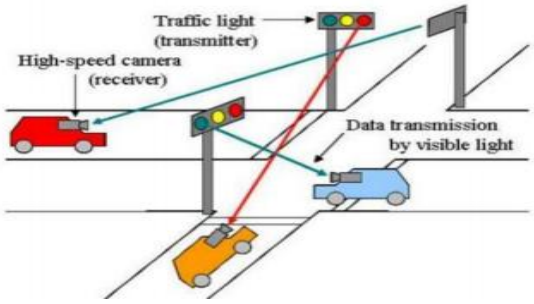

Fig 6. Road to vehicle visible light communication

6.7 Underwater Communication

Due to strong signal absorption in water, RF use is impractical. Acoustic waves have extremely low bandwidth and disturb marine life. Li-Fi provides a solution for short range communications.[1][5]

7. CHALLENGES OF LI-FI TECHNOLOGY

Apart from many advantages over Wi-Fi, Li-Fi technology is facing some problems such as Li-Fi requires line of sight. Another demerit of this technology is that the artificial light

cannot penetrate into walls and other opaque materials which radio waves can do and is easily blocked by somebody simply walking in front of LED source. If the apparatus is set up indoors, one would not be able to shift the receiver.

8. CONCLUSION AND FUTURE SCOPE

Li-Fi has great potential in the field of wireless data transmission. It is a promising alternative to conventional methods of wireless communications that use radio waves as data carrier. Many enhancements can be made to the existing technology. For example, encoding and decoding can be implemented directly in the transmitter and receiver part of the circuit. This technology, can become one of the major technologies in the near future. If this technology can be used efficiently, we might soon have something of the kind of WI-FI hotspots wherever a light bulb is available. It will be cleaner and greener and the future of mankind will be safe. The future of LI-FI is GI-FI. GI-FI or gigabit wireless refers to wireless communication at a data rate of more than one billion bits (gigabit) per second. It will allow wireless transfer of audio and video data at up to 5 gigabits per second, ten times the current maximum wireless transfer rate, at one-tenth the cost. Researchers chose the 57–64 GHz unlicensed frequency band since the millimeter-wave range of the spectrum allowed high component on-chip integration as well as the integration of very small high gain arrays. The available 7 GHz of spectrum results in very high data rates, up to 5 gigabits per second to users within an indoor environment, usually within a range of 10 meters [12]. Some press reports called this "Gi-Fi"[13][14].

This would reduce error in transmission. Also, by using fast-switching LEDs, data transmission rates can be further enhanced. The driving speed of the circuit can be improved by using fast-switching transistors.

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