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Towards an understanding of Li-Fi: Next generation Visible Light Communication Technology

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Abstract: ***Li-Fi (Light Fidelity) is an optical version of Wi-Fi (Wireless Fidelity) technology. This technology is based upon the concept of visible light communication (instead of radio frequency waves). This technology introduced by German Physicist Harald Hass, the idea is to communicate through illumination i.e. use of LED light bulbs for data transmission.***

This paper gives an overview and working principle of the technology including its advantages, disadvantages and applications. Further the Li-Fi is compared to other existing communication technologies and the scope of Li-Fi in existing connectivity scenario is discussed.

Keywords: Visible light Communication (VLC), Optical Wireless Communication(OWC), Internet of Things (IoT), Light Fidelity (Li-Fi).

1. Introduction

With ever growing needs of telecommunication world, there is an increased thrust for higher bandwidth that facilitates faster and secure data transmission. Existing telecommunication industry relies on radio waves of electromagnetic spectrum for data transmission. Unfortunately, the radio wave spectrum has certain key limitations: Capacity, Efficiency, Availability and Security. With the advent of latest technologies for communication and the fact that it's reaching far and wide to every nook and cranny of the world, the electromagnetic spectrum of radio waves is running out.

A solution to this problem is Li-Fi (Light Fidelity) which is a concept based on data transmission via optical fiber and LED. Precisely stating it is nothing else but an optical version of Wi-Fi (Wireless Fidelity) technology that is based upon the concept of visible light facilitating digital communication rather than of radio frequency waves. This technology uses LED light bulbs for data transmission. A German physicist Harald Hass introduced the concept of Li-Fi. The data is transferred through a Light emitting diode (LED) by varying the intensity of light faster than a human eye can trace. Haas says his invention, which he calls DLIGHT, can produce data rates faster than 10 megabits per second, which is speedier than average broadband connection [1].

Li-Fi can be the technology for the future use where data for laptops, smart phones, and tablets will be transmitted through the light in a room. Security would not be an issue because if you can't see the light, you can't access the data. As a result, it can be used in high security military areas where RF communication is prone to eavesdropping [2]. In October 2011 a number of companies and industry groups formed the Li-Fi Consortium, to promote high-speed optical wireless systems and to overcome the limited amount of radio based wireless spectrum available by exploiting a completely different part of the electromagnetic spectrum. The consortium believes it is possible to achieve more than 10 Gbps, theoretically allowing a high-definition film to be downloaded in 30 seconds [1].

Visible Light Communication (VLC) is a substantial solution to the spectrum crunch problem. The fundamental property of light can be exploited to circumvent the problems associated with the RF waves which dominate the current communication domain [3]. Using this communication medium we use visible part of spectrum between 400nm to 700nm as optical carrier for data transmission. This visible spectrum is also ten thousand times broader than radio frequency spectrum. The intensity of light can be modulated at a very high speed for data transmission. Thousands of data streams can be modulated in parallel for high speed and efficiency.

2. Li-Fi Technology

The rapid and economical optical version of Wi-Fi is LI-Fi. It is based on Visible Light Communication (VLC).VLC is a data communication medium, which uses visible light between 400 THz (780 nm) and 800 THz (375 nm) as optical carrier for data

transmission and illumination. It uses fast pulses of light to transmit information wirelessly [2]. There are the 2 components of the Li-Fi which are given followings:

1. Transmission Source: a high brightness white LED.

2. Receiving Element: A fine response Silicon Diode.

LEDs can be switched on and off to generate digital strings of 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. The LEDs can be used as a sender or source, by modulating the LED light with the data signal. The LED output appears constant to the human eye by virtue of the fast flickering rate of the LED. Communication rate greater than 100 Mbps is possible by using high speed LEDs with the help of various multiplexing techniques. VLC data rate can be increased by parallel data transmission using an array of LEDs where each LED transmits a different data stream.

The Li-Fi emitter system consists of 4 primary subassemblies [4]:

a) Bulb
b) RF power amplifier circuit (PA)
c) Printed circuit board (PCB)
d) Enclosure

Deployment of basic Li-Fi structure is easy as it suits to existing infrastructure required for communication. For its implementation incandescent and fluorescent bulbs need to be replaced with LED's that are used as high speed transmitters. This combined with pre-programmed receivers (the silicon photodiode which receives light signals and converts them into streams of 1's and 0's) and wireless devices such as laptops, mobiles, tablets etc form the basic skeleton of the Li-Fi architecture.

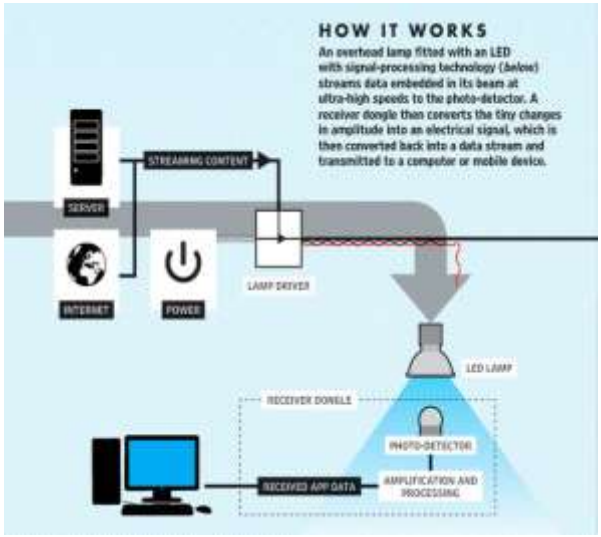

Figure 1: Working of a Li-Fi [11]

Important factors to be considered while setting up a Li-Fi system:

- Source of light (For efficiency, LEDs and Fluorescent lights are preferable).
- Line of Sight (Los)
- Integration (of the streaming content) with the Network – so as to have minimal data loss.

In Li-Fi, the LED BULBS at the downlink transmitter are used to generate combinations of 1's and 0's by switching on and off the device faster than the human eye can trace. This task is carried out using a controller that has the data already fed into it. It, thus, encodes the data in the form of light by flickering or changing the intensity of the LED bulbs (wherever switching them on and off is not feasible) according to the input of a variable string of 1's and 0's. Parallel data transmission can be done by using array of multiple LED's or by using red, green, blue LED's to alter light frequency with the frequency of different data channel. High data rates can be achieved by using high speed LED's and appropriate multiplexing techniques. Such add on(s) promise a theoretical speed of up to 10GBPS [5] [6] [7].

3. Benefits of Li-Fi

- If A free band of the electromagnetic spectrum (the Visible Light Spectrum) is used, and hence does not need any license, making it economical for the industry.
- It is faster, safer and cheaper than other forms of wireless internet, so could eliminate the need for costly mobile-phone radio masts and towers in the near future.
- Can be used in electromagnetic sensitive areas such as airplanes, hospitals, petrochemical industrial plants, nuclear power plants, underwater networking with divers and submersibles able to gain connectivity.
- Instant start time. Users need to just switch on the lights, and it starts working.
- Theoretical data transmission rate as of now is around 10Gbps, resulting in less time and energy consumption than the other conventional media.
- Trouble free integration into existing light engine platform. Negligible additional infrastructure is required.
- Dynamic dark: Brightness modulation by lamp results in enhanced video contrast thus enhancing the quality of the data transmitted.
- Life on earth has evolved through exposure to visible light. There are no known safety or health concerns for this technology [8].

4. Limitations of Li-Fi

Equalize As no technology can be a full-proof solution to existing problems on the same lines, Li-Fi suffers from its own set of limitations as discussed below:

- The main problem is any hindrance or obstacle between the line of sight of the transmitting LED and the receiver. This will lead to immediate signal cut out. If the light signal is blocked, or when the users need to use device to send information then Li-Fi is not the optimal solution.
- Reliability and network exposure are the major issues to be considered by the companies while providing VLC services. Since the coverage area is prone to other sources of light as well, so, any interference from external light sources like sun light, normal bulbs; and opaque materials in the path of transmission can lead to interruption in the smooth communication.
- High installation cost of the VLC systems is again a consideration to implement Li-Fi based communication system. Since laying of optical fiber and availability of LED and electricity in all areas is a major challenge posed.

5. Applications of Li-Fi

Medical

Medical technology's lagging behind the rest of the wireless world is one of the major concern since long. Operating rooms do not allow Wi-Fi over radiation concerns, and there is also that whole lack of dedicated spectrum. While Wi-Fi is in place in many hospitals, interference from cell phones and computers can block signals from monitoring equipment. Li-Fi solves both problems: lights are not only allowed in operating rooms, but also they are the most essential fixtures in the room.

Connectivity on the fly

Wi-Fi on airplane is more or less a forbidden thought. Nothing says captive audience like having to pay for the "service" of dial-up speed Wi-Fi on the plane. The best rumor so far is that passengers will "soon" be offered a "high-speed like" connection on some airlines. United is planning on speeds as high as **9.8 Mbps** per plane[1], which is far less then what we access and at much more higher cost. Li-Fi could easily introduce that sort of speed to each seat's reading light.

Smarter Power Plants

Wi-Fi and many other radiation types are bad for sensitive areas like those having power plants in surrounding. Further power plants may need fast, inter-connected data systems to monitor things like demand, grid integrity and (in nuclear plants) core temperature. The savings from proper monitoring at a single power plant can add up to hundreds of thousands of dollars. Li-Fi could offer safe, abundant connectivity for all areas of these sensitive locations. Not only this would this save money related to currently implemented solutions, but also the draw on a power plant's own reserves could be lessened if they haven't yet converted to LED lighting [1].

Network availability under sea

Underwater ROVs (Remotely Operated Vehicle) used by treasure seekers that operates from large cables that supply their power and allow them to receive signals from their pilots above. ROVs work great, except the limitation of length to explore an area, or in case of stucking on obstacles. If their wires were cut and replaced with light — say from a submerged, high-powered lamp — then they would be much freer to explore. The headlamps could be used to communicate with each other, processing data autonomously and referring findings periodically back to the surface. Hence, leading to better water surfing conditions.

Learning

Lecture Halls could be made better by providing; the notes and other referral material being downloaded to every student at the same time that too in few seconds during the progress of lecture itself. Imagine how interactive the classroom could be with real-time interconnectivity between 500 devices [9]. This level of fast transfers can only be possible in the vision of Li-Fi.

6. Comparison between Li-Fi and Wi-Fi

1. **Speed**: Li-Fi offers data rate of 10Gbps whereas according to IEEE 802.11b it provides data rate of 54 Mbps.

2. **Availability**: Li-Fi can be used where Wi-Fi can't be operated such as airplanes, petrochemical industries. There is no such place where LIGHT is not available.

3. **Capacity**: Li-Fi has more capacity than Wi-Fi owing to the fact that it uses visible light between 400 THz (780 nm) and 800 THz (375 nm) as optical carrier for data transmission. With the spectrum crunch looming, bandwidth of radio waves is depleting day by day therefore Li-Fi can be used to increase the capacity.

4. **Efficiency**: Maximum throughput with minimal wastage of energy since LED's are the least energy consuming light sources known so far as compared to the massive radio masts used for conventional communication which use up most of the energy in cooling down.

5. **Security**: It is easy enough to take care of security issues. User just needs to switch off the lights and there is no way any intruder can intercept with data transmission. Added to that is the fact that Li-Fi uses Line of Sight (LOS) communication, rendering it even more difficult to be intercepted in contrast with Wi-Fi.

6. **Future Work**: Li-Fi technology gives a way ahead to internet of things (IoT) or web of things where every electronic device can be connected and access via internet which was a humungous task had Wi-Fi been the spotlight

Table 1: Comparison between Li-Fi and Wi-Fi

Parameter	Li-Fi	Wi-Fi
Speed	High	High
Range	Low	Medium

Data Density	High	Low
Security	High	Medium
Reliability	Medium	Medium
Power Available	High	Low
Transmit/Receive Power	High	Medium
Ecological Impact	Low	Medium
Device-to-device connectivity	High	High
Obstacle Interference	High	Low
Bill of Material	High	Medium
Market Maturity	Low	High

7. Conclusion

Although Li-Fi cannot be a complete replacement to the existing RF technology, but it can be a well contributed gift to the Internet era. It could turbo charge the development of wireless television and make it easier to throw a wireless signal across an entire house. At present, finding the ideal position for a wireless router is a troublesome task. If the signal could be passed via VLC from Point A to Point B inside a home, small local routers at both points could create local fields with less chance of overlapping and interfering with each other. Also, large scale areas that are drenched with radio signals or that don't allow them for security reasons could use Li-Fi as an alternate high-speed wireless network solution.

The possibilities are numerous and can be explored further. The advantages of this technology can be tapped well for usage of creating a Li-Fi hub. If this technology can be put into practical use, every bulb can be used something like a Wi-Fi hotspot to transmit wireless data and we will proceed towards the cleaner, Greener, Safer and Brighter future.

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