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# Understanding the Communication through Visible Light and its Application

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*Abstract— Wireless optical technology like visible light communication is a new approach in terms of security, speed, usability, bandwidth and flexibility for data communication. More and more people with their devices access wireless internet today, due to which clogged airwaves are going to make transmission slow and is full of interference. The solution to this problem of slow speed is that data is to transmitted through light i.e. through "illumination" which means taking the fibre out of fibre optic and sending data through an LED light bulb that varies in intensity very quickly. It uses the similar idea that is used in infrared remote controls. Transmission through light is more powerful. This paper is the study of the transmission of data through light emitting diode i.e. visible light communication and its applications.*

*Keywords: Visible Light Communication, Light Emitting Diode, Wi-Fi, Li-Fi., mm waves.*

## Introduction

Wireless Fidelity uses 2.4-5 GHz radio frequency signal to deliver wireless Internet at our homes, schools, offices and in other public places. Wi-Fi bandwidth is typically limited to 50-100 megabits per second which is a good alternate to speedup the most current used Internet services, but Wi-Fi is not sufficient for transferring large data files like movies, video games and music files etc. in required bandwidth with good speed. Radio frequency technology like Wi-Fi is not the optimal of way of transmission to overcome the problems of good bandwidth and speed. In addition, Wi-Fi may not be the most efficient way to provide good capabilities such as precision indoor positioning and for recognition of gesture. Optical wireless technologies called visible light communication which is referred as Li-Fi offers a new solution in wireless technologies in terms of communication with high speed, good bandwidth, flexibility and usability. Li-Fi is now part of the Visible Light Communications (VLC) PAN IEEE 802.15.7 standard [3].

## Light Fidelity

A wide range of frequencies and wavelengths, from the infrared through visible and down to the ultraviolet spectrum are the parts of Li-Fi. It includes sub-gigabit and gigabit-class for communication of data with high speeds for short, medium and long ranges and both unidirectional and bidirectional data transfer using line-of-sight or diffuse links, reflections and

many more. It is not limited to LED or laser technologies or to a particular receiving technique. Li-Fi is a framework for all of these providing new capabilities to current and future services, applications and end users [2]. Li-Fi can be thought of as a light-based Wi-Fi which uses light instead of the radio waves to transmit information. Li-Fi uses transmitter and receiver fitted on LED lamps instead of Wi-Fi modems that not only light up a room but also helps to transmit and receive the information. Since simple light bulbs are used, there can technically be any number of access points. This technology uses a part of the electromagnetic spectrum that is still not greatly used i.e. Visible Spectrum. Light is in fact very much part [3] of our lives from years and does not cause any major health illness. This brilliant idea was first given by Harald Haas from University of Edinburgh, UK, in his TED Global talk on VLC. So if the LED is ON, digital 1 is transmitted, if it is OFF 0 is transmitted. The LEDs can be switched ON and OFF very quickly, which gives nice opportunities for transmitting data. For Li-Fi some LEDs and a controller are required that can code data into these LEDs. The rate at which the LED's flicker depends upon the data to be encoded. Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of colored LEDs like red, green and blue LEDs to alter the light's frequency with each frequency encoding a different data channel.

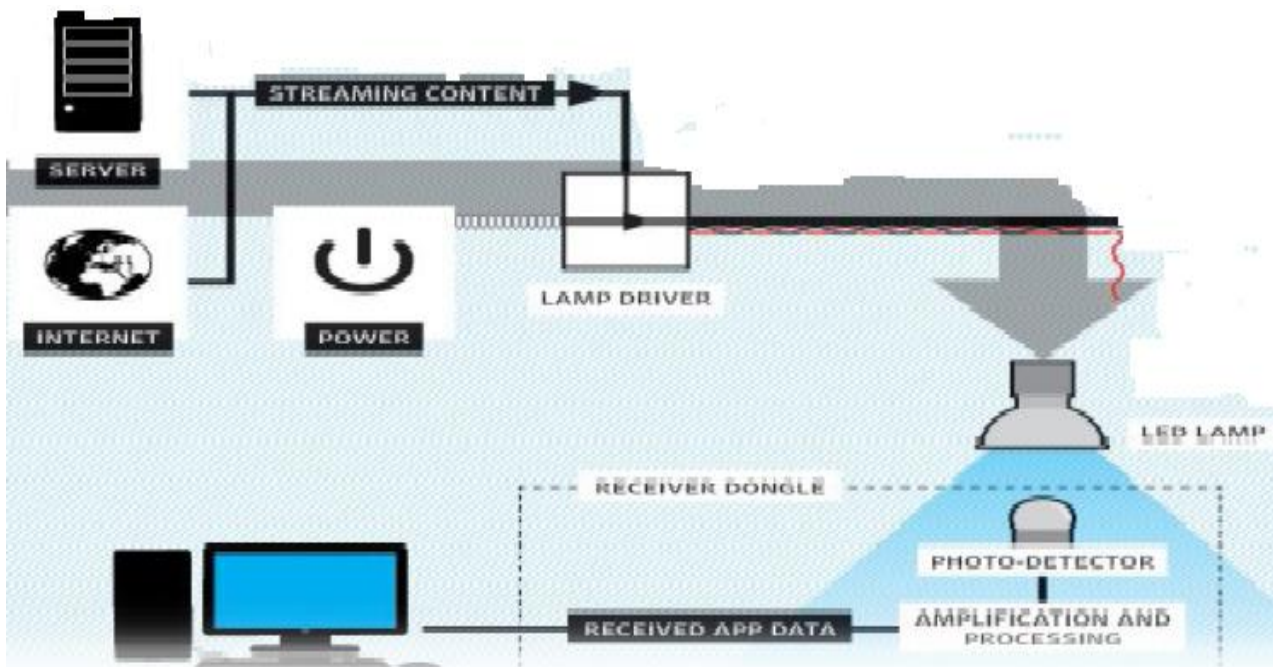


Fig.1 Principle components of Li-Fi

### Visible Light Communication (VLC)

Light Fidelity is very cheap high speed improved optical version of Wi-Fi, which is based on Visible Light Communication (VLC). VLC is a data communication medium, which uses visible light between 400 THz and 800 THz as carrier for data transmission and illumination [4]. It uses fast pulses of light to transmit information wirelessly. In Visible Light Communication white LED acts as a source of communication. Response to visible wavelength is given by photodiode of silicon that serve as a receiving element. Digital strings of 1s and 0s can be obtained by switching ON or OFF of the LEDs or varying the flickering rate of LEDs. A data rate of greater than 100 Mbps is possible by using high speed LEDs with appropriate multiplexing techniques. Data rate can be increased by parallel data transmission using LED arrays where each LED transmits a different data stream. The visible light spectrum is available in 100s of THz of license free bandwidth, which is 10,000 times more than the entire RF spectrum up to 30 GHz, including the mm Wave spectrum. Optical radiation does not interfere with the operation of sensitive electronic equipment and other radio waves [8, 9]. So Li-Fi is good technology for wireless coverage in areas

which are sensitive to electromagnetic radiation [8, 9] like hospitals, airplanes, petrochemical and nuclear power plants, etc. Moreover, the inability of light to propagate through walls offers better level of network security.

### Signal Modulation in VLC

The building block devices in VLC are incoherent solid-state lighting LEDs due to their low cost. Due to the physical properties of these components, information can only be encoded in term of light intensity emitted by LEDs, while the actual phase and amplitude of the light wave cannot be modulated. This significantly differentiates VLC from RF communications. VLC can only be realized as an IM/DD (inter modulation direct detection) system, which means that the modulation of signal should be both real valued and unipolar. Techniques such as on-off keying (OOK), pulse-position modulation (PPM)[4], pulse-width modulation (PWM) and unipolar M-ary pulse-amplitude modulation (M-PAM) can be applied. As the modulation speeds are increased, all these modulation schemes begin to suffer from the undesired effects of inter symbol interference (ISI) due to the non-flat frequency response of the optical wireless communication channel. Hence, a more significant technique like OFDM is required [8, 9]. OFDM allows adaptive bit and energy loading of different frequency sub-bands according to the communication channel properties. This leads to optimal utilization of the available resources. OFDM achieves the throughput capacity in a non-flat communication channel even in the presence of nonlinear distortion [1]. Such channel conditions are introduced by the transfer characteristic of an off-the-shelf LED that has a maximum 3 dB modulation bandwidth in the order of 20 MHz [12][13]. Conventional OFDM signals are complex-valued and bipolar in nature. Therefore, the standard RF OFDM technique has to be modified in order to become suitable for IM/DD systems. A straightforward way to obtain a real-valued OFDM signal is to apply a Hermitian symmetry constraint on the sub-carriers in the frequency domain. However, the resulting time-domain signal is still bipolar. One way for obtaining a unipolar signal is to introduce a positive direct current (DC) bias around which the amplitude of the OFDM signal can vary as shown in Fig. 2 and Fig 3. The resulting unipolar modulation scheme is known as DC-biased optical OFDM (DCO-OFDM) [16]. The addition of the constant biasing level leads to a significant increase in electrical energy consumption. This can be easily visualized when Fig.2 and Fig. 3 are just apposed.

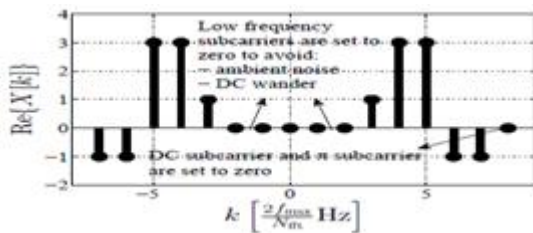


Fig. 2 Real part of positive and negative frequency

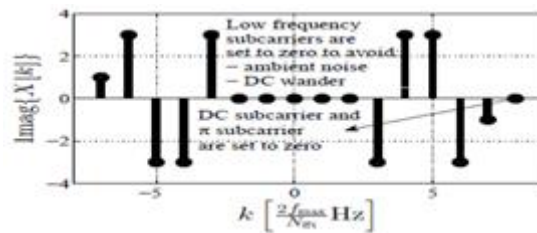


Fig. 3 Positive & negative frequency of Imaginary part

Research has primarily focused on maximizing the transmission speeds over a single unidirectional link [12, 16]. However, for a complete Li-Fi communication system, full duplex communication is required, i.e., an uplink connection from the mobile terminals to the optical AP has to be provided. Existing duplex techniques used in RF such time division duplexing (TDD) and frequency division duplexing (FDD) could be considered, where the downlink and the uplink are separated by different time slots, or by different frequency bands respectively [1]. Therefore, the most suitable duplex technique in Li-Fi is wavelength division duplexing (WDD), where the two communication channels are established over different electromagnetic wavelengths.

**Comparison between various wireless communication techniques**

Li-Fi describes visible light communication technology applied to high speed wireless communication. It is similar to that of Wi-Fi. It uses light instead of radio waves. Wi-Fi plays a great role in terms of speed for general wireless transmission within buildings, and Li-Fi is super for high density wireless data coverage in confined area and ideal for getting rid off radio wave interference issues. The two technologies can be considered complimentary to each other and of great use. The table contains the comparison of current wireless technologies that can be used for transmission of data. Wi-Fi currently offers very high data rates. Li-Fi technology uses LEDs for the transfer of data. The transmission of the data can be done with the help of all kinds of light, no matter to which part of the transmission spectrum they belong. The light can belong to the invisible, ultraviolet or the visible part of the spectrum. Also, the speed of the internet is incredibly becoming high with Li-Fi. This technology removes limitations that have been put on the user by the Wi-Fi. Table 1 shows the comparison of various data transmission techniques.

Table 1

Technology	Speed
Fire Wire	800Mbps
USB3.0	5Gbps
THUNDERBOLT	2×10Gbps
Wi-Fi(802.11 N)	150Mbps
BLUETOOTH	3Mbps
IrDA	4Mbps
Li-Fi	>10Gbps
Wi-Gig	2Gbps
Giga-IR	1Gbps

**APPLICATIONS OF Li-Fi**

Visible light communication technology had made its place theoretically felt in late 2013 now has gain fame into a practical application in smart devices. It is assumed that gadgets made by using Li-Fi (IEEE 802. 15 standards) will be able to transfer data at an very high speed of 150 mbps using LED lights, which will be faster than the current Wi-Fi technology (IEEE 802.11). For a long time, medical technology has lagged in using wireless communication. Operating rooms in hospitals do not allow the use of Wi-Fi due to radiation concerns, and there is also a problem of dedicated spectrum. Wi-Fi is used in many hospitals. The problem of Interference from cell phones and computers can block signals from monitoring equipment. Lights are allowed in operating rooms, which also tend to be the most glaring fixtures in the room. Li-Fi has 10,000 times the spectrum of Wi-Fi, so maybe red light gets priority in medical data. In operation theatre Li-Fi can be used for modern medical instruments. In traffic signals Li-Fi can be used which will communicate with the LED lights of the vehicles and number of road accidents can be decreased. Thousands and millions of street lamps can be transferred to Li-Fi lamps as hotspots for the transmission of data which will also be a glaring feature. Li-Fi can be used for data transmission in aircrafts and passengers will be offered with connections that have high speed on some airlines. Wi-Fi and many other radiation types are bad for sensitive areas like those surrounding power plants. But power plants need fast speed, inter-connected data systems to monitor things like demand, grid integrity and to monitor the core temperature in nuclear plants. Li-Fi could offer safe, abundant connectivity for all areas of these sensitive locations with high speed. It can be used in petroleum or chemical plants where other transmission or frequencies could be hazardous.

**Conclusion**

This technology is gaining fame in practical use, every bulb can be used like a Wi-Fi hotspot for transmission of wireless data and which will proceed toward the cleaner, greener, safer and

brighter future. The concept of Li-Fi is currently attracting a great attention. It may offer a genuine and very efficient alternative to radio-based wireless. Today number of user has grown up many folds and accordingly their access to wireless internet has also been risen, the airwaves are being logged, making it more and more difficult to get a reliable, high-speed signal. This issues of shortage of radio-frequency bandwidth is coped up by Li-Fi and this technology allow internet where traditional radio based wireless isn't allowed such as air craft or hospitals. One of the shortcomings however is that it only work in direct line of sight.

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