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Light Fidelity: A Revolutionary Research Paradigm in the Field of Communication

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Abstract---**Wireless internet and cellular mobile services are essential part of our life infect modern world fully relies on wireless communication. Due to increase of users all around the world and rapid developments in different wireless technologies we may face crisis in future because continues increases in demand of data transmission could not be full fill in future keeping in mind the lack of radio frequency bandwidth . This paper aims to demonstrate that Li-Fi which is an emerging branch of optical wireless communication can provide us matured solution of this fundamental problem. Professor Harald Haas who is recognized worldwide as a creator of Li-Fi technology gives his concept of transmission of data with the help of illumination .This procedure consists of sending bundles of information through visible light spectrum via LED light bulb .Now a day's Wi-Fi (Wireless Fidelity) is most commonly use for Wireless indoor communication, which require 2.4 - 5 GHz Radio Frequency to deliver wireless Internet access around our homes, schools, offices and in public places. Li-Fi by using visible light as transmission medium can provide us faster, efficient and secure communication as compare to Wi-Fi with high capacity as its spectrum Bandwidth is much broader than the Frequency of Radio spectrum. This paper discusses all about Li-Fi, importance of visible light spectrum, comparison of Li-Fi with Wi-Fi, Implementation of Li-Fi in Cellular and indoor communication System and summarizes some of the research conducted so far and looks at the different aspects of the communication system.**

I. INTRODUCTION

Li-Fi which is "Light Fidelity" is a gift to human beings by this modern era of science and it is a new Paradigm of revolution in the field of Wireless communication. If we talk about high speed wireless communication, Li-Fi can bring new dimensions in term of data communication speed by utilizing visible light Communication technology. 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 which can be varies even faster than light intensity human eye can observe. Prof Harald Hass had leaded the visible light communication (VLC) research project at Edinburgh's Institute for Digital Communications funded by the Scottish Enterprise 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 visible light communication technology is used to send data with the help of Light Emitting Diode (LED) bulbs which is a source of illumination and simultaneously can be use to transmit data. For this purpose data is encoded on the intensity of the light in such a way that data does not vary rapidly to affect the brightness of light. When we talk about data related with internet traffic, we use a term Li-Fi given by Prof Harald Haas at TED Global Conference when he is presenting his work on Visible light communication. 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.

Prof Harald Hass who is Research scholar from university of Edinburgh United Kingdom says that Technology of Light Fidelity depend on intensity of light coming out of light emitting diodes. The different Limitations of Wi-Fi technology is the main reasons behind invention of Li-Fi. As Wi-Fi is only limited for short range wireless communication ([1], [3]) and it is also effected with interference which may cause degradation in performance .So keeping in mind number of users increase day by day and heavy traffic of data, Li-Fi technology can be use as a solution of these problem to provide users an environment of error free transmission. Li-Fi is designed to work in such places where we cannot use Wi-Fi technology for example under water, air planes and in traffic controls system.

Later in 2013 Chinese researcher team from Fudan University headed by Professor Chi Nan develop their own Li-Fi wireless communication system that can use LED lights to send and receive Internet data on different computers. Her team connects four computers under a one-watt LED light bulb. According to them embedded microchips based transmitter and receiver system with LED light bulb can produce data rates up to 150 Megabits per second. This data rate From Li-Fi system is much faster than the broadband connection [2].

II. A LI-FI NEED OF 21ST CENTURY

I 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. When we talk about Radio spectrum we know that its spectrum bandwidth is limited and also costly. 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 aeroplane and under water we can't use it.

So if we look toward 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, potentially 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.

III. WORKING PRINCIPLE OF LI-FI TECHNOLOGY

Prof Harald Haas explained the working principle of Li-Fi in a very simple way. The high brightness of light coming out of LED Bulb is the Key for Li-Fi technology .Li-Fi work on simple principle ,When the LED Bulb is turn ON, it will transmit a binary digital "1", if bulb is turn OFF it will transmit a binary digit "0". The LED Bulb can be turn ON and OFF very rapidly so that we can transmit data by using LED. To encode data into LED at different intensity of light a controller circuit is also used [7]. The blinking rate of LED is adjusted according to the data we want to encode. Now a day's More modifications are applied in basic principle to enhance the working of Li-Fi system .For parallel transmission of data we can now use multiple series of LEDs of different colors to change the frequency of light so that we can use to encode each frequency with different data . Photo detector which is a light sensitive device is use at reception side. The Purpose of Photo detector is to receive the light signal and then extract original data from received light signal. The theoretical data rate of this modified Li-Fi system is approximately 10 Gigabit per second which is much higher even then broadband internet system.

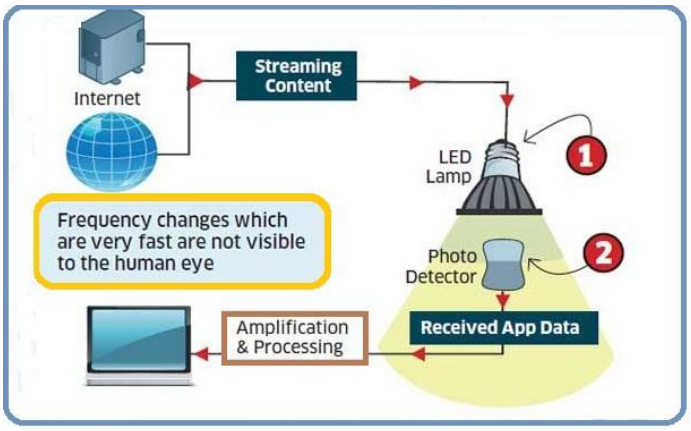

Fig. 2 Working Principle

As Li-Fi Technology works by sending data over the light so for this purpose a LED bulb is flicked from OFF to ON in order to generate light signals. A proper Light Receiver is made for receiving the LED signals. For Processing the data LED bulb is connected with a microchip (As shown in Figure 3) so that LED can be turn ON and OFF with very high speed so that Intensity of light can be modulated in high speeds with varying amplitudes .By using small change in amplitude ,light intensity can be easily utilize to transmit data .

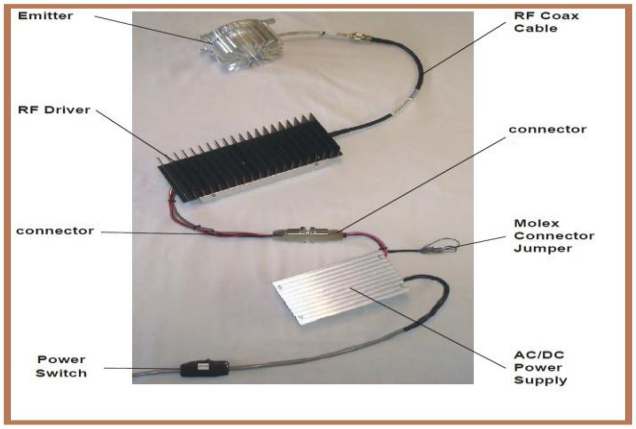

Fig. 3 Basic Li-Fi Transmitter Circuit

A. Modulation Technique and LED's for Li-Fi System

According to Sir Prof Harald Haas intensity of LED can be modulated at very high speeds and exploited with technology to transmit thousands of data streams in parallel through SIM OFDM.

Spatial modulation *Orthogonal Frequency Division Multiplexing* make performance much better as compare to OFDM because it *is a transmission technique* which allow us to transmit parallel stream of data by using different frequency carriers to transmit desire information in such a way that data rates is only limited by the number of LED's used .

Different LED's of different color like red, blue, orange, yellow etc can be use in Li-Fi Communication System. But if we talk about high data rates, 1 Giga bits per second has been reported using phosphor-coated white LEDs [5] and 3.4 Giga bits per second has been red-green-blue (RGB) LEDs [6], the highest speed that has ever been reported from a single color incoherent LEDs is 3.5 Giga bits per second.

IEEE 802.15.7 is the standard for optical wireless communications use in Li-Fi system which is use to explain physical layer represent as "PHY" and media access control layer represent as "MAC".

IV. VISIBLE LIGHT COMMUNICATION WORKING ENVIRONMENT

VLC serve two simultaneous functions:

(a) Illumination. (b) High speed wireless communication.

Visible light communication Working Environment may be consists of indoor communication and any outdoor communication.

A. Indoor Communication using VLC

Characteristics of Indoor Communication using VLC are High Density, Free, unlicensed spectrum, Not affected by RF-noise, Secure and it Mitigates RF health concerns

One of the examples of Indoor Communication system using VLC is shown below. In this example 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.

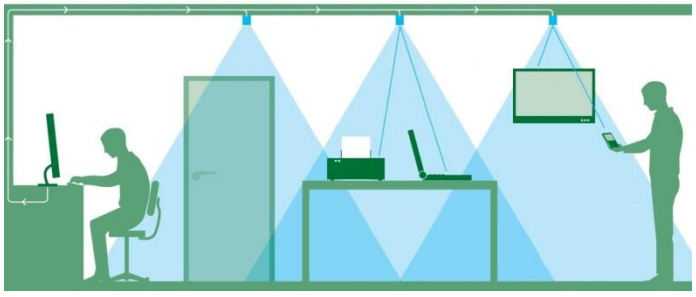

Fig. 4 Indoor Communication

In other Example 2 users can access Internet via Li-Fi Access Point which is connected with Internet servers. This example show Interference free environment in VLC because Li-Fi light signal can't penetrate through walls which enable high data rate per area.

1 .Modulation Techniques for Li-Fi

Most of the modulation Techniques such as ON-OFF keying also called "OOK", PPM, Pulse Width Modulation also called "PWM", Pulse Position Modulation also called "PPM" and

Unipolar M-ary Pulse Amplitude Modulation also called "M-PAM" start to suffer from the undesired effects of intersymbol interference (ISI) due to the non-flat frequency response of optical wireless communication channel. Therefore OFDM can be use for Li-Fi because it allows adaptive bit and energy loading of different frequency sub-bands according to the communication channel properties.

OFDM signals are complex-valued and bipolar in nature. 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; in result unipolar modulation scheme is obtained known as DC-biased optical OFDM (DCO-OFDM).

If the light sources are used for illumination at the same time, the light output as a result of the DC bias is not wasted as it is used to fulfill the illumination function. Only if illumination is not required, such as in the uplink of a Li-Fi system, the DC bias can significantly compromise energy efficiency. Therefore, researchers have devoted significant efforts to designing an OFDM-based modulation scheme which is purely unipolar. Some well-known solutions of this problem are by using Asymmetrically clipped optical OFDM called "ACO OFDM", Unipolar OFDM "UOFDM", Pulse Amplitude Modulated Discrete Multitone Modulation "PAM-DMT" and Flip OFDM. From a networking perspective, OFDM offers a straightforward multiple access implementations as subcarriers can be allocated to different users resulting in orthogonal frequency division multiple access (OFDMA).

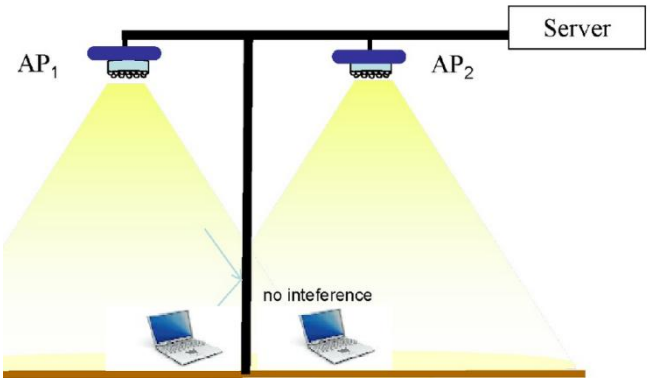

Fig. 5 Interference Free Environment

B. Implementation of Li-Fi in Cellular System

The small cell concept of wireless cellular communications can easily be extended to VLC in order to overcome the high interference generated by the close reuse of radio frequency spectrum in heterogeneous networks. The optical AP is referred to as an attocell [4]. Since it operates in the visible light spectrum, the optical attocell does not interfere with the macro cellular network. The optical attocell not only improves indoor coverage, but since it does not generate any additional interference, it is able to enhance the capacity of the RF wireless networks. Li-Fi attocells can be deployed as part of a heterogeneous VLC-RF network because they do not cause any additional interference to RF macro- and picocells, and can hence, be deployed within RF macro, Pico and even femto cell environments. This allows the system to vertically hand-off users between the RF and Li-Fi sub-networks, which enables both free user mobility and high data throughput. Such network structure is capable of providing truly ubiquitous wireless network access.

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. The most suitable Duplex technique in Li-Fi is wavelength division duplexing (WDD), where the two communication channels are established over different electromagnetic wavelengths. Using infrared (IR) transmission is one viable option for establishing an uplink communication channel. There is also the option to use RF communication for the uplink [4] .In this configuration, Li-Fi may be used to do the "heavy lifting" and off-load Data traffic from the RF network, and thereby providing significant RF spectrum relief.

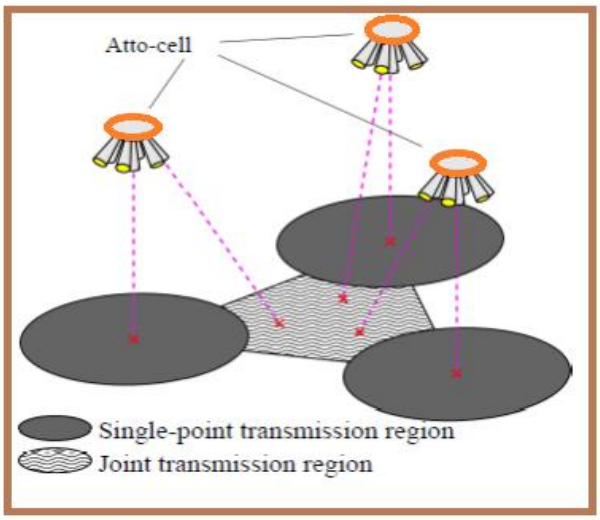

Fig. 6 Li-Fi in Cellular System

2. LED's for Li-Fi

The most likely candidates for front-end 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 the intensity of the emitted light, while the actual phase and amplitude of the light wave cannot be modulated. This significantly differentiates VLC from RF communications.

V. COMPARISON BETWEEN LI-FI AND WI-FI

Comparison between two technologies are given below in figure

Comparison Between Li-Fi & Wi-Fi

S. No.	Parameters	Wireless Technologies	
		Light Fidelity	Wireless Fidelity
1.	Speed for data transfer	Faster transfer speed (>1 Gbps)	Data Transfer speed (150 Mbps)
2.	Medium through which data transfers occurs	Used Light as a carrier	Used Radio spectrum
3.	Spectrum Range	Visible light spectrum has 10,000 time broad spectrum in comparison to radio frequency	Radio frequency spectrum range is less than visible light spectrum.
4.	Cost	Cheaper than Wi-Fi because free band doesn't need license and it uses light.	Expensive in comparison to Li-Fi because its uses radio spectrum.
5.	Network topology	Point to point	Point to point
6.	Operating frequency	Hundreds of Tera Hz	2.4 GHz

Fig. 7 Comparison

VI. APPLICATIONS OF LI-FI IN OUR DAILY LIFE

Li-Fi is useful in situations where traditional Wi-Fi connections are banned because radio frequencies cannot be used for fear of interfering with electronic circuitry, such as in hospitals or onboard aircraft.

Li-Fi can be implemented in our daily life for many applications:

Localization services: Li-Fi can be use for localization services in warehouse, retailers and hospitals by providing Indoor Global Positioning System (GPS), Asset Analysis, Resource Tracking and Product Placement.

High Density Communication: High Density Communication is possible in Conference Halls, Transportation Hubs and Convention Centers by using Li-Fi Technology.

Controllable LED Lighting: Li-Fi is not only capable of providing light bulb based wireless hotspots but also a source of Controllable LED Lighting in Hotels, Offices and stadiums.

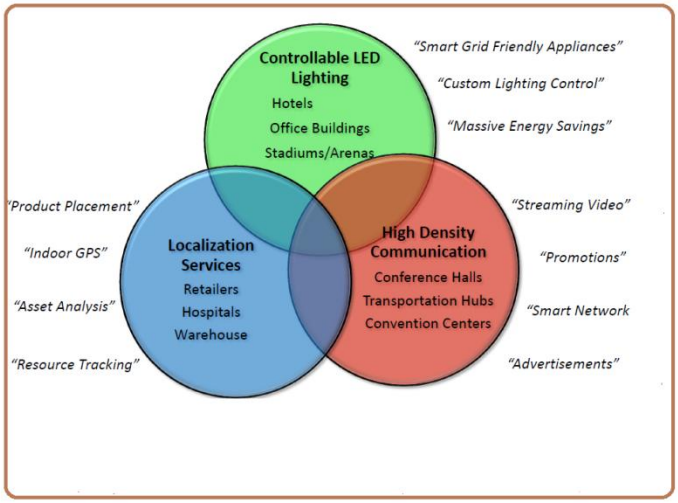

Fig. 8 Applications of Li-Fi Technology

LIMITATIONS OF LI-FI

Li-Fi technology is not without drawbacks. As there is Inability of light to penetrate solid surfaces, so transmitter and receiver need to be aligned in order to establish a peer to peer connection. Service Providers while providing VLC services has to consider major issues like reliability and availability of system. Companies also need to consider how to maintain coverage area of network. The communication can be restricted due to the Interferences coming from different sources for example sun light, normal bulbs and any non-transparent materials in the path of transmission. VLC system has high Initial Installation cost but when it is implemented at large scale area it can accommodate us by its less operating cost like electricity bills ,less operational staff and limited maintenance charges as compare to RF system.

VII. CONCLUSION

World Nowadays shows a lot of interest toward Li-Fi Technology because 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 number of users and their devices to use internet are increasing very rapidly so as a result 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. As for 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 practical use.

REFERENCES

[1] Network Security: Li-Fi: Data On light Instead of Online, Mr .Vinod Saroha, Ritu Mehta, International Journal of Engineering and Computer Science ISSN: 2319-7242 Volume 3 Issue 1, Jan 2014.

[2] China achieves wireless Internet access via light bulbs Ryan Huang ZD NET October 18, 2013.

[3] "Visible-light communication: Tripping the light fantastic: A fast and cheap optical version of Wi-Fi is coming", Economist, dated 28Jan 2012.

[4] Light Fidelity (Li-Fi): Towards All-Optical Networking Dobroslav Tsonev, Stefan Videv and Harald Haas Institute for Digital Communications, Li-Fi R&D Centre, The University of Edinburgh, EH9 3JL, Edinburgh, UK.

[5] Khalid, A. M., Cossu, G., Corsini, R., Choudhury, P and Ciaramella, E "1-Gb/s Transmission Over a Phosphorescent White LED by Using Rate-Adaptive Discrete Multitone Modulation," IEEE Photonics Journal 4, 1465–1473 (Oct. 2012).

[6] Cossu, G., Khalid, A. M., Choudhury, P., Corsini, R., and Ciaramella, E., "3.4 Gbit/s Visible Optical

[7] Wireless Transmission Based on RGB LED," Optics Express 20, B501–B506 2012.

[8] Haas, 'Wireless data from every light bulb', TED Global, Edinburgh, July 2011.