A DETAILED VIEW ON LI-FI ARCHITECTURE

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***Abstract*—In today's modern world, wireless communication has become an integral part of our daily lives. Li-Fi (light fidelity) is one such recent advancement in optical wireless communication (OWC). This paper attempts to give a detailed explanation on each and every block of lifi architecture from server to end-user and also focuses more on different modulation techniques involved in Li-Fi and their evolution and also compares the performance analysis of OFDM and FBMC. This paper can help people of all categories to have clear vision on this recent technology thereby fostering better innovations and advancements in Li-Fi.**

Keywords—Li – Fi, architecture, optical wireless communication, lifi transmitter, lifi receiver, lifi detail, multiplexing in lifi, OFDM vs FBMC BER, OFBM AND FBMC for lifi applications, lifi modulation.

I. INTRODUCTION

In today's fast-growing world, Lifi is an interesting and unique type of optical wireless communication that uses LEDs for transmitting the data or a communication that uses light as a medium for transmitting data rather than RF spectrum. Lifi also provides higher data rates compared to existing Wi-Fi data rates (100x) and also has broader frequency spectrum(400-800THz) for traffic less communication but for shorter ranges. The basic concept behind lifi is transmitting 1s and 0s by changing the intensities of light faster than the human eyes can perceive. This was first coined and introduced by a German physicist [1] Harald Hass in a TED talk on the topic visible light communication (VLC) in July 2011. Here a point to be noted is VLC is different from lifi. VLC is more like a point-to-point (p2p) communication on the other hand lifi is a complete bidirectional wireless networking system. Lifi also provides greater security as we can't access the network outside of a room that contains lifi enabled LEDs. Because we know that light cannot pass through the opaque substances.

Lifi is definitely going to be a efficient upcoming technology for better data transfer rates, where the data for all our devices can be received through lights above them and also assures better security.

II. ARCHITECTURE OF LI - FI

The main components of lifi architecture are

(i) Server

(ii) Transmitter block

(iii) Receiver block

(iv) Signal processing unit

(v) End system

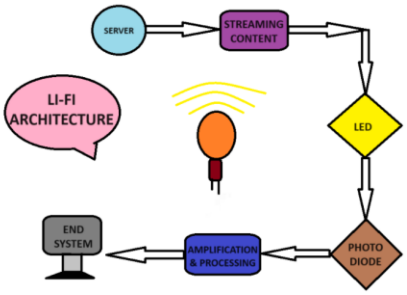

Fig.1.lifi architecture

A. SERVER

A server is like a digital caretaker of in the computer networks terminology. It is responsible for managing and organizing information within a network. It is like a central hub for storing and retrieving information, hosting websites and applications, manages network traffic. It plays a major role in enabling seamless communication and collaboration among devices that are connected to it. It constantly gets requests from different devices and sends back responses accordingly like a busy worker bee. Just like the way we get a wired connection from server to the router at our home for Wi-Fi, we get one for lifi as well. But in lifi terminology we refer router as lifi access point or lifi AP for short. Something noteworthy here is lifi at present is not fully wireless technology but it is dependent on wired connection or other IR/RF spectrum for establishing connection among devices.

B. TRANSMITTER

As mentioned earlier the transmitters in lifi technology are LEDs or lifi enabled LEDs. It can have a single LED or an array of LEDs. The key characteristics of a transmitter LED include radiation pattern, optical spectral response, electro – optical characteristics and electro modulation band width. All the above characteristics define the efficiency of a transmitter LED and also defines field of view (FOV). FOV means refers to the extent of area in which the LED can transmit light efficiently. [1] OSRAM LCW W5SM golden dragon and Vishay tshg8200 are two examples of LEDs which satisfies best of all the above key characteristics and are used in Li – Fi applications.

Lifi enabled leds have transceiver and signal processing unit integrated in them. The LEDs transmit 1s and 0s by changing intensity of light which is known as intensity modulation technique if a wired connection is made between leds and the lifi access point. on the other hand, if lifi enabled LEDs are connected wirelessly using IR/RF spectrum the lifi enabled LEDs uses orthogonal frequency division multiplexing (OFDM) to transmit the data. In both cases leds use light as the transmission medium to transmit the data. As white light is a combination of all colors it can be achieved by using for example a blue led with

phosphorous. Phosphorus causes to produce all colors from visible spectrum which combinedly will be a white color. Specifications of above-mentioned LEDs [2] will be discussed in the table 1. In most of the recent papers the same was used as a transmitter and different usable leds and their respective datasheets were also mentioned.

Color of emission	white
Operating temperature	-40 to 125 degrees Celsius
Typ. radiation	120 degrees
wavelength	590 – 625 nm
Forward current	50 – 1500 mA

Table.1. transmitter specifications

Osram KW HHL631.TK	[8]
Osram LUV HWQP	[9]
Osram KW HHL532.TK	[10]
Osram KW HLL531.TE	[11]
Osram KW HKL531.TE	[12]

Table.2. List of leds and datasheets

B. II. MODULATION

Information can be encoded into the intensity of light known as intensity modulation. It is said in [1] that previously single carrier modulation (SCM) methods like OOK, PAM, PPM etc... were used to encode the data onto light wave for lifi enabled transmitters. However, as the demand for higher data rates which require higher modulation speeds and the number of connected devices increased these modulation techniques faced challenges like inter symbol interference (ISI) which in turn causes bit errors. So OFDM came into implementation as a solution to these problems. OFDM enables efficient and reliable data transmission even in the presence of interference or multipath propagation. It also allows for adaptive bit and power loading of different frequency sub bands according to the channel properties. OFDM provides with simple method for implementing multiple access as different users get assigned to different subcarriers.

B.III. RELATED WORK

In paper [6] Nivetha et al gave a comprehensive overview of lifi technology and its modulation techniques, focusing on the performance evaluation of different modulation schemes based on BER VS SER plots including single carrier modulation techniques such as BPSK, QAM and color modulation techniques. Their simulation results demonstrated that QAM modulation techniques exhibit better performance in terms of bioterror rates and spectral efficiency.

In this paper we have done comparative analysis of OFDM and FBMC (filter bank multicarrier) with QAM under various SNR conditions. FBMC is a multicarrier modulation technology developed from OFDM and it makes better use of channel capacity and provides high data rates. OFDM is a type of multiplexing technique where data is encoded on multiple sinusoidal carriers which are orthogonal to each other.

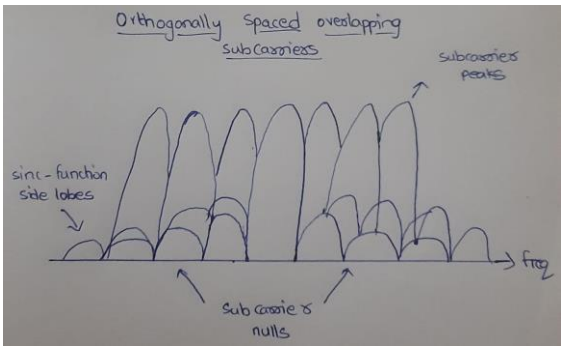

Fig.2.OFDM representation

As represented in fig.2, when a carrier magnitude is at peak, the other carriers are almost equal to null. This is achieved by the orthogonal orientation of the multiple carriers. But the problem in OFDM is the side lobes of each carrier are not purely null which causes some distortion and errors in signals at higher specifications.

FBMC is then developed out of ODDM with multiple carrier filter banks at Tx and Rx that gives smaller and sharper side lobes in frequency spectrum compared to OFDM which helps in providing clearer and cleaner carrier signals. FBMC conserves bandwidth and has high spectrum sensing resolution as it doesn't have any spectral leakage.

Power spectral density function plot for OFDM and FBMC was also done in MATLAB from its resources. [18] The comparison is done to elevate the low out band leakage of FBMC which allows it for higher utilization of allocated spectrum which in turn leads to better spectral efficiency.

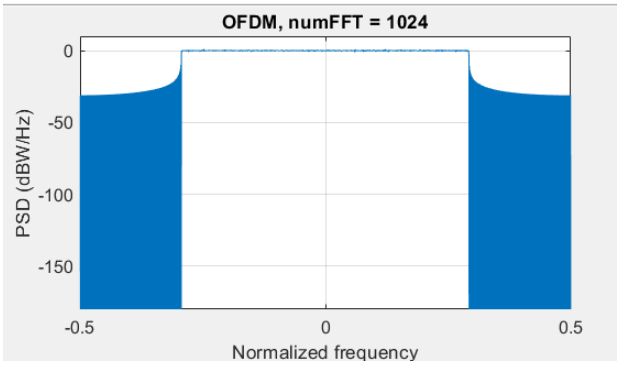

Fig.3. OFDM PSDF

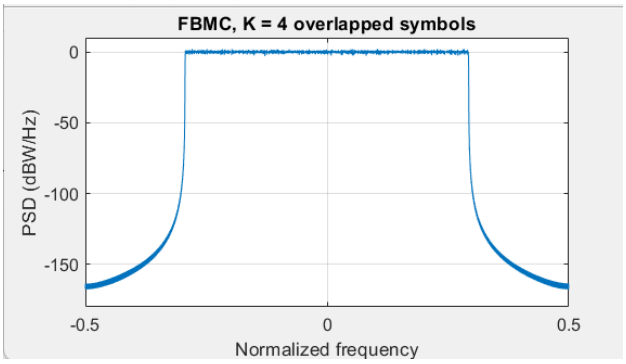

Fig.4.FBMC PSDF

As it is mentioned in [6] that QAM gave better BER in OFDM, we have decided to compare the BER of OFDM AND FBMC using QAM. The simulation has been done in MATLAB to plot the BER vs SNR graphs for both the modulation techniques. The simulation results were given in Fig.7 & Fig.8 for OFDM and FBMC respectively.

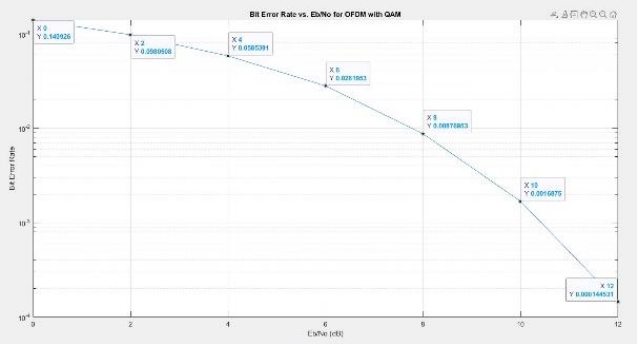

Fig.5.OFDM BER vs SNR plot

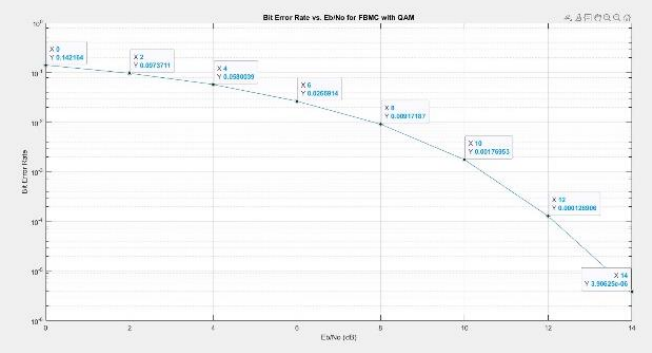

Fig.6.FBMC BER vs SNR plot

Both the plots were almost same int terms of BER at different SNR conditions. But FBMC gave lower BER at higher SNR conditions compared to OFDM which proves that FBMC is also a potential multiplexing technique and even better than OFDM at higher SNR conditions.

C. RECIEVER BLOCK

Photodiodes/PDs for short are used at the receiver side to detect the light and decode the data which is encoded on the intensity of light wave. They are semiconductor devices that convert light into electrical signals. This conversion happens because of the photoelectric effect, where in the incident light/photons on the photodiode surface causes it to generate electron – hole pairs. These e-h pairs migrate under the electric field generating current. Receiver also has some key characteristics like detection pattern, optical spectral response, O/E transfer characteristic and the noise figure [1]. Usually, a large area of receiver is built by an array of PDs to allow angular acceptance and also to collect more of radiated light. omnidirectional receivers can also be built for such requirement to achieve efficient data reception. [1] Vishay TEMD5110X01 PD and normal avalanche photodiodes are few examples that we use to design and construct a receiver. An example of visible light photodiode is given in figure 3 and their specifications were also mentioned in table 2. [3].

Spectrums detected	visible light
Wavelength detection	420 – 620 nm
Operation temperature	-40 to 110 degree Celsius
Half angle sensitivity	± 65°
Reverse light current	2.9 – 4.8 uA

Table.3. receiver specifications

Hamamatsu S39706	[13]
Vishay VEMD5510FX01	[14]
OSI PIN-RD100	[15]
MICROFC-10020-SMT-TR1	[16]
Hamamatsu S3931	[17]

Table.4. List of photodiodes and datasheets

D. END SYSTEM

The electrical signals produced by the receiver will undergo some signal processing like amplification, filtering and equalization to enhance their quality and to ensure compatibility with the end system's electronics. A threshold will be applied to the incoming signal to differentiate the signal levels between 1 and 0. Then the binary format will be processed and undergoes digital to analog conversion by system electronics and hence requested service can be accessed. At present we have to use lifi dongles to receive and send data as Li - FI enabled end systems just like Wi-Fi enabled end systems, are not yet developed. PURE LIFI is the company that is currently leading by taking advancements in lifi technology. Can go through their website for the use cases they have developed.

So, this a brief explanation on how a lifi works from server to end system explained by taking home architecture as an example in such a way that fresher ug students can also understand easily.

III. CONCLUSION

In this paper, we have presented a detailed explanation on lifi architecture by setting home wifi architecture as a base example. Also, different LEDs and photodiodes were mentioned in the paper after some market survey for initiating some basic projects. We have also discussed different modulation techniques that are used in lifi and their evolution till date and presented the performance analysis of OFDM and FBMC multiplexing techniques using QAM in terms of PSDF and BER vs SNR plots in the MATLAB simulation platform. Simulation results have concluded that FBMC is also a better and potential multiplexing technique for lifi applications compared to OFDM. Target audience for this paper are young tech aspirants to have a clear vision on upcoming and booming lifi technology. Li-fi will surely be a efficient and promising communication technology in coming days. Light is not just illumination but communication that unlocks the potential of light to connect us, illuminating pathways to brighter and more connected future.

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