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The Assessments and Challenges of LED Generated Data Traffic using Li-Fi Technology

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ABSTRACT-- ***Internet today will be highly integrated with many aspects of our daily needs making it a corner stone in modern life. This dependency increased the demand on having internet services with higher Bandwidth, higher Bit Rates and lower Congestion problems. As a result, more and more applications will be widely realized for Internet based in the future, either in custom or dedicated fashion. As a result, the Light Fidelity (Li-Fi) technology - that is considered in this paper - refers to the technology that can transfer data in a faster reliable way; utilizing Light Emitted Diode (LED) bulb which is the source of illumination. The method of communication is through transfer data pulses instead of radio frequencies signals, thus providing an economic advantage by eliminating the need for complex wireless networks.***

Key words: Li-Fi, Light Emitting Diode (LED), Visible Light Communication (VLC), Wi-Fi

I. INTRODUCTION:

Li-Fi technology can be defined as a groundbreaking light-based communication technology that makes use of light waves instead of radio technology for data transmission. [1]. This technology has the features of enabling faster and more reliable internet connections, even when the demand for data usage has outgrown the available supply from existing technologies such as 4G and LTE. Such technology will not replace the classical methods (4G, LTE and Wi-Fi) but will work alongside them. The wide spread use of solid-state lighting offers great opportunity for efficient dual use purposes: lighting and communication systems. Innovation in LED and photon receiver technology has ensured the availability of suitable light transmitters and detectors, while the advancements in the modulation of communication signals for these types of components has been advanced through signal processing techniques and their applications, such as Multiple-Input-Multiple-Output (MIMO) which is used in mobile telecommunications. [2]. The increased demand on networks to carry data in the past few years led to the wide spread of Wi-Fi network infrastructure thus adding more restrains in terms of the number of users and adding more burden on the network throughput also increasing the cost of such services.

Wi-Fi networks uses radio frequencies in the band (2.4-5) GHz with a theoretical bit rate of (50-100) Mbps. As the number of access points increased, the quality of service witnessed setbacks due to technical issues such as interference [3]. All these problems led the network designers to propose a new technology, which is known as Light Fidelity (Li-Fi). Network designer's hopes that this new technology will provide the solutions to the limited Wi-Fi data rate. In addition, to meet the new demands on the carrier network traffics and potentially satisfy low cost by utilizing the Visible Light Communication (VLC) principles.VLC technology was proposed in 2010 by Harald Hass a Physicist at Edinburgh University UK in 2010. In 2011 and during the international TED conference, he proposed to use a LED to establish a light communication system that can be used for both carrying data and lighting closed spaces. This technique is supposed to be used also in the places that radio waves are not able to penetrate by using the principal of line of sight (LOS) between lamps to establish connections. According to Hass, a LED is used in two states: logic "1" for ON and logic "0" for OFF. The switching is performed at a very high speed that a human eye cannot detect it since the switching time can reach up to 1μ second so to a naked eye the light seems to be continuous [4].This technology allows carrying data at a rate of 10Mbps, which means a user can download a movie in 30 seconds. The data in this technology have a binary format then, it can send them through a LED and a detector is used to transfer them back to a binary format at the receiver.

In any communication technology the spectrum is considered a vital factor. The everyday increase in the number of users will cause the spectrum to be fully used in the future to the point where no more users can be added, and because the capacity is exceeded 2TB of data. On the other hand, the fact that Li-Fi uses light to transfer data means that the spectrum congestion related issues are eliminated. In addition, the information and the data can be synchronized with the light, and this method does not suffer the interference by electromagnetic frequencies [5]. The paper layout is organized as follows. Section 2 deals with the idea about the "Li-Fi" Technology. Section 3 shows the general behavior for the communication using the Visible Light Communication Technique. In Section 4, Li-Fi Modulation Technique will be demonstrated including their modulation types, formats as well as their limiting issues. As a standard format, an Open System Interconnections "OSI" model will be used through section 5 to express the state of the art for the "VLC" technique. Section 6 deals with the future applications for the Li-Fi technology. Finally, the final comments and conclusions were given in section 7.

II. LI-FI TECHNOLOGY:

Advancement in the field of communication technologies plays an essential role in our daily lives. Li-Fi technology is considered a brilliant method that holds a great potential to transfer huge amount of data with high speed using wireless media via visible light VLC.

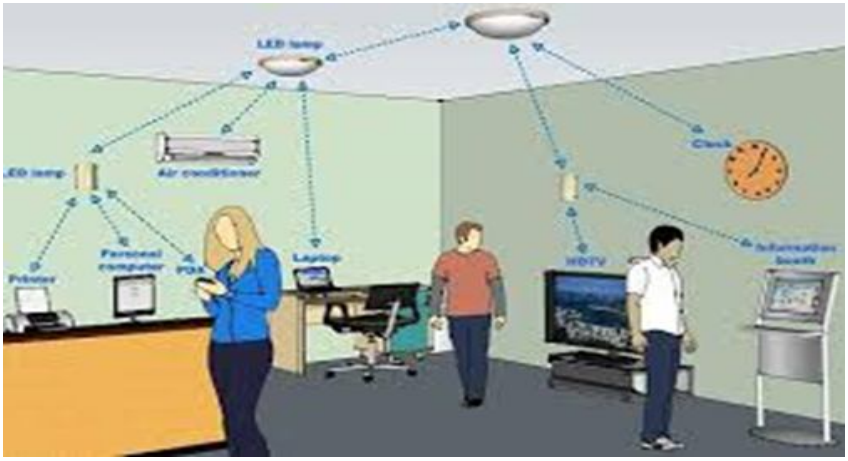

Figure 1: Li-Fi works with existing systems

The concept is based on sending non-visible light signals using LEDs that modulate 0's and 1's using different intensity. This process can be performed at high speeds that provides such system with the ability to transfer data at 1Gbps in which this rate is a 100 times faster than radio based communication systems. Fig.(1) shows multiple devices working based on Li-Fi.

2.1 WORKING PRINCIPLES OF LI-FI TECHNOLOGY

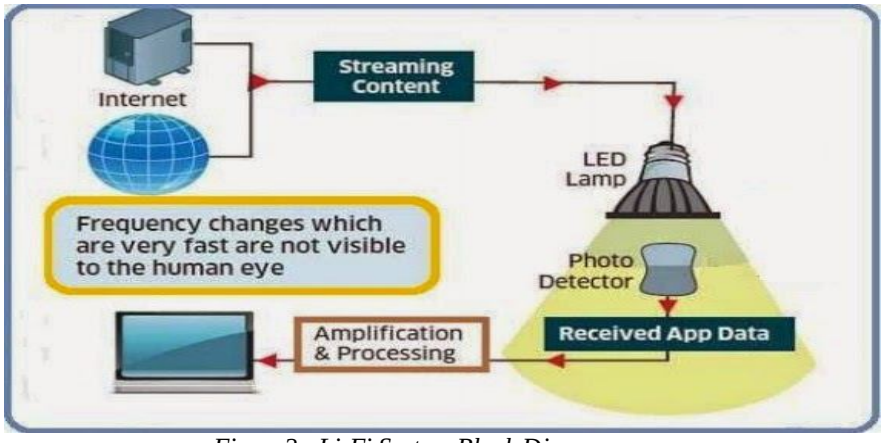

Figure2 : Li-Fi System Block Diagram

There is a clear resemblance between Li-Fi and Wi-Fi technologies; this comes from a fact that both technologies uses electromagnetic waves to transfer data. Clearly the difference is in the wavelength as Wi-Fi uses radio waves and Li-Fi uses VLC. Li-Fi technology makes use of the broad spectrum of the light waves, which is 10000 times wider than the spectrum used by Wi-Fi. This fact gives Li-Fi advantage over Wi-Fi in terms of providing higher bit rates [6]. Another property of Li-Fi is the compatibility of this technology with the high-speed flickering LED signals. Fig.(2) shows the Li-Fi system block diagram.

According to Hass, Li-Fi sends a logic one when the LED is on and sends a logic zero when the LED is off. Since Li-Fi transmitter uses visible light for the modulated signal, a Li-Fi receiver will depend on a Photodiode to extract the data. At the transmitter end, the Internet data is transformed to an electrical signal and then this signal is used to modulate the light generated by a LED via a microcontroller.

2.2 Differences between Wi-Fi and Li-Fi technology

Due to the fact of the Wi-Fi is the most common technology in Internet service, it works fine in providing coverage inside buildings. On other side, the fact of the Li-Fi uses light instead of radio waves, which can be considered the ideal solution for high rates of wireless data in the enclosed areas (rooms). Therefore, the two methods (Wi-Fi or Li-Fi) can said to be effective and successful. Table (1) summarizes comparison between Li-Fi and Wi-Fi for several common parameters.

Table (1) : comparison between Li-Fi and Wi-Fi

No.	Parameters	Li-Fi	Wi-Fi
1	Speed for data transfer	Faster transfer speed (>1Gbps)	Data transfer 150 Mbps
2	Medium for data transfer	Used light as a carrier	Used radio spectrum
3	Operating frequency	Hundreds of Tera Hz	2.4GHz
4	Cost	Cheaper than Wi-Fi *because free band do sent need license and it use light	Expensive in comparison with Li-Fi because it use radio spectrum
5	Capacity range	Visible light spectrum has 10000 time broad spectrum in comparison with radio frequency	Radio frequency spectrum range is less than visible light spectrum
6	Security	High Because light dose not penetrate throwing the walls.	Low

III. VISIBLE LIGHT COMMUNICATION TECHNIQUE

VLC technique is used to transfer data throughout the use of visible light – as shown in Fig.3 and the data is received at the other end using Intensity Modulation Direct Detect (IM/DD) method. Such method provides the ability of using the conventional lighting devices as Access Points Transmitting Light (the carrier) at 400THz-800THz. [7]

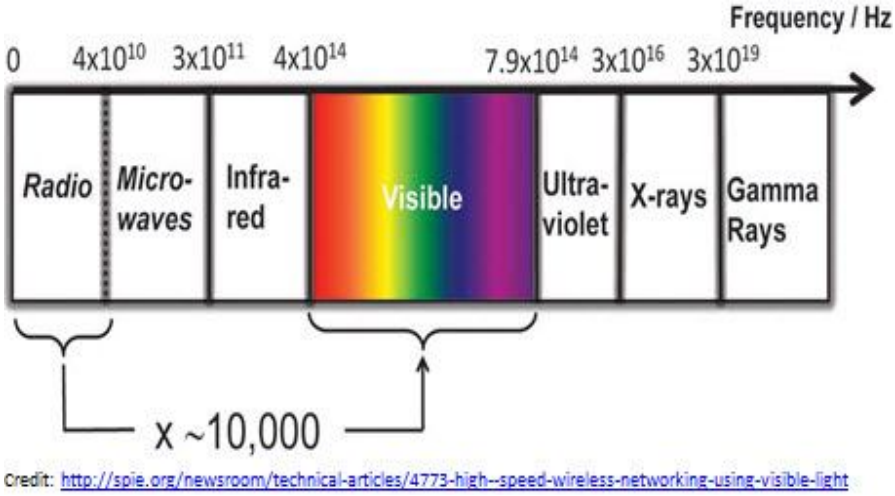

Figure 3: Diagram of Visible light communication

The main concept used in this technique is the modulation of the carrier signal side by side with the emitted light. The light source uses open and closed pulses to define (logic 0 and logic 1) for sending data at speed that can reach thousands of times in one second making this process hard to detect for a human eye. At the receiver, a high sensitivity silicone photo diode is used to transom the light to an electrical signal. This diode produces an electrical signal with a lower current when no light is received during logic "0" state.

THERE ARE SOME IMPORTANT REQUIREMENTS THAT AN IDEAL PHOTO DETECTOR SHOULD COVER: Sensitive to the wavelength interval associated, long operational life, minimally affected from the temperature fluctuations, efficient accomplishment of noise such ambient & dark, noiseless physical structure, small in size, reliable and cost effective. [8]. This method offers many advantages such as: security as light cannot penetrate walls, no effect on human's life, environment friendly and last but not least it is cost effective with energy efficient value.

IV. LI-FI MODULATION TECHNIQUES

In this section, a brief introduction is presented to a vital part in sending data through the LED, which are modulation techniques. Practically Li-Fi uses the visible light as a carrier signal for transmitting data via short light pulses. The data are sent using either baseband or pass-band scheme however in order to choose a modulation technique certain factors such as: data rates, signal strength, and cost will be considered to determine the best solution.

4.1 COMMON MODULATION TECHNIQUES FOR VISIBLE LIGHT COMMUNICATION

A. ON-OFF KEYING (OOK)

This method is the most common method in control and data transfer which is based on the signal intensity [6] and the intensity of light in the LED lamp operates between the two levels which are known as "0" and "1". Manchester coding can be adopted through this method, so that the pulses in the positive periods are the same pulses in negative periods. [9]. For data communication purposes using Manchester coding, the encoding of each data bit is either low then high, or high then low, of equal time resulting a zero DC bias signal with self-clocking format; which means that a clock signal can be recovered from the encoded data. As a result, electrical connections using a Manchester code are easily isolated using a simple one-to-one isolation transformer.[10][16]

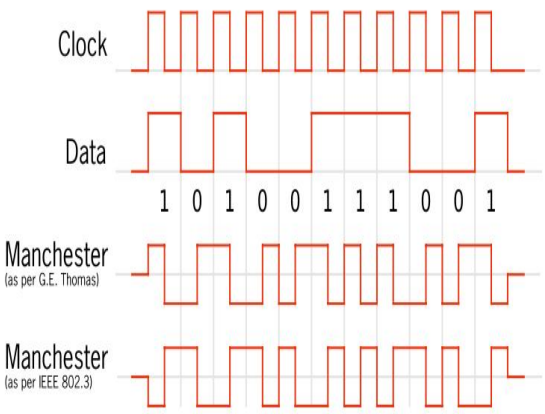

Figure 4: Manchester Codes signaling

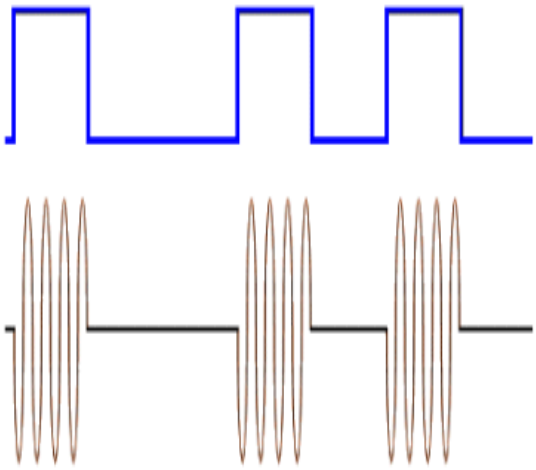

Figure 5: OOK Signal formats

When transferring large bit rates the RLL code works because it is more convenient and supports Dimming despite the limited length.

B. PULSE WIDTH MODULATION (PWM)

This is a modulation technique used in both analog and digital systems in which the message information is embedded in pulse width of the modulated signal [11].

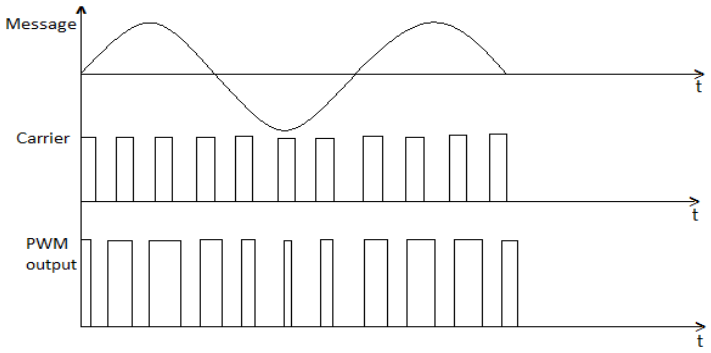

Figure 6 : PWM Waveform Generation

The main advantage of PWM is that the power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel. This method is energy efficient and allow good tolerance to analog noise. Light dimmers for home applications employ a specific type of PWM control. Such dimmers typically include electronic circuitry that suppresses current flow during defined portions of each cycle of the AC line voltage. Brightness adjustment of light emitted by a light source is then merely a matter of setting – through a triac switch- at what voltage (or phase) in the AC half-cycle the dimmer begins to provide electric current to the light source.

C. COLOR SHIFT KEYING (CSK)

Color Shift Keying (CSK)used to represent the data sent from a LED in the physical layer gradually using the variation between the three main colors red, green and blue light via light intensity modulation [12]. Color tunable LEDs such as the red, green and blue LED (RGB - LED) can illuminate with different colors based on the intensity applied on each LED element. The IEEE 802.15.7 standard proposes color shift keying (CSK) as a modulation technique for Visible Light Communication [12]. The incoming bits are mapped into a constellation of colors from the chromatic CIE1931 color space, as shown in Figure (7) The CIE 1931 is the widely used illumination model for human eye color perception. The chromaticity dimension [x, y] can represent any color in the model.

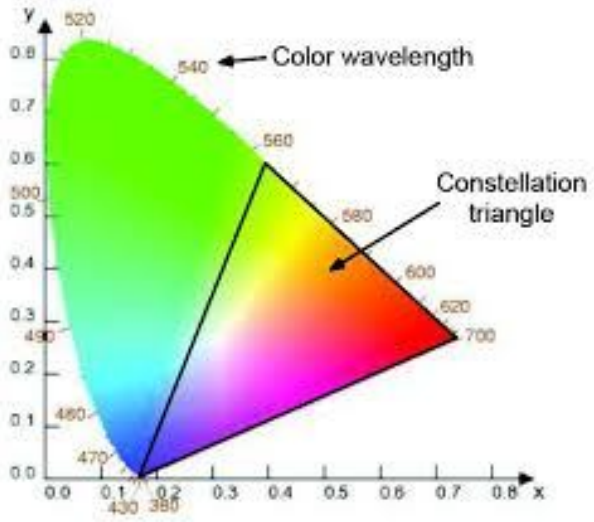

Figure 7: Incoming bits using CSK modulation

In CSK, the overall intensity of the output color is constant; however, the relative intensities between the multiple used colors are changed. Therefore, the instantaneous color of the multicolor LED is modulated. Seven wavelengths are defined in IEEE 802.15.7 specify the vertices of a triangle where the constellation point lies in. The intensity of each RGB-LED element is changed to match the constellation point while maintaining a constant optical power and a constant illumination color. [13]. Thus, it is possible for getting the data through light because of the intensity of light is fixed knowing that CSK used constant power envelope. In addition, the other result of the modulated intensity of artificial light in flickering will not fluctuate and this is a good indication for not getting health problems for humans.

D. PULSE POSITION MODULATION (PPM)

The PPM is a form of signal modulation in which "M" message bits are encoded by transmitting a single pulse in one of 2^M possible required time-shifts. During a repetition time of "T" seconds, the transmitted bit rate is M / T bits per second. PPM technique is primarily useful for optical communications systems, where there tends to be little or no multipath interference.

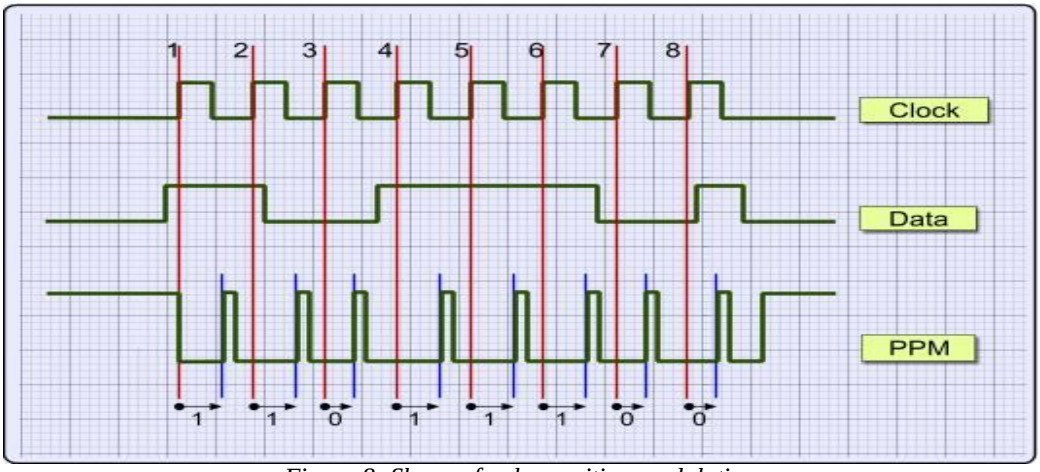

Figure 8: Shape of pulse position modulation

In this type of modulation, the encoding of data is based on the pulse potion. In each pulse slightly more than one bit is transmitted within a frame. This type cannot be applied to analog systems due to interference problems. Regarding the width and the amplitude of the transmitted pulses they are constant one advantage of this technique is the ease of sign separation from noise [14].

E. ORTHOGONAL FREQUENCY DIVISION MULTIPLEX (OFDM)

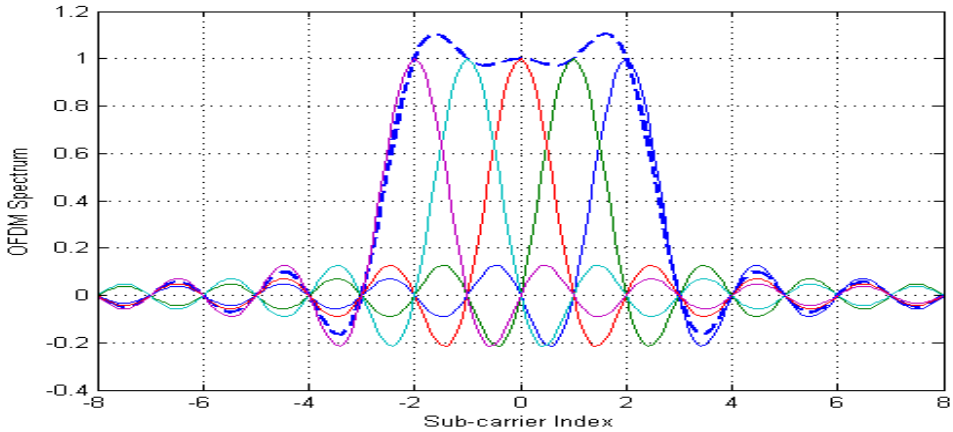

Figure 9: OFDM modulation subcarrier

This method performs encoding digital data on multiple carrier frequencies.

The development of OFDM has focused into a popular schemes for wideband digital communication and applications such as digital television and audio broadcasting, DSL Internet access, wireless networks, power line networks, and 4G mobile communications. In OFDM, a large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme known as (quadrature amplitude modulation or phase-shift keying) with a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

The advantages and disadvantages related for OFDM technique can be given as shown in table (2).

TABLE (2): MAIN ADVANTAGES AND DISADVANTAGES FOR OFDM

OFDM ADVANTAGES	OFDM DISADVANTAGES
• High spectral efficiency as compared to other double sideband modulation schemes.	• Sensitive to Doppler shift.
• Easily adaptation to severe channel conditions without complex time-domain equalization.	• Sensitive to frequency synchronization problems.
• Robust against narrow-band co-channel interference, inter-symbol interference (ISI) and fading caused by multipath propagation.	• High peak-to-average-power ratio requiring linear transmitter circuitry, which suffers from poor power efficiency.
• Efficient implementation using fast Fourier transform.	• Loss of efficiency caused by cyclic prefix / guard interval.
• Low sensitivity to time errors.	• The OFDM signal has a noise like amplitude with a very large dynamic range.
• Tuned sub-channel receiver filters are not required.	• It requires RF power amplifiers with a high peak to average power ratio.
• Facilitates single frequency networks (SFNs) (i.e. transmitter using macro diversity).	• It is more sensitive to carrier frequency offset and drift than single carrier systems.

V. OPEN SYSTEM INTERCONNECTION (OSI) LAYERS IN VLC MODEL

In the science of networks when it required sending data, two important parts must be available to perform data transfer, which are the sender and receiver module kit. The first part concerns with LED technique that uses Visible Light Communication (VLC) as the sender, which is controlled quickly through a signal transmitted by switching on and off. In part two, the receiver uses the photodiode for detecting the incoming signal. In the system of OSI VLC model, the work will be focused on two main layers: Physical Layer (PHY) and Data Link Layer (DLL). The MAC is considered as the backbone of the process of the transmitter and receiver, adding to that OSI is used as service each layer service layer Supreme.

5.1 PHYSICAL LAYER:

In a system VLC, the function of this layer is the same as in the OSI model through which it determines the physical and electrical specifications of the devices used. The standard IEEE 802.15.7 is a basic standard for VLC technique, which supports the PHY Layer and the Media Access Control (MAC) layer for the Wireless short-range communication. All data rates in external and internal layers ranging between 11.67Kbps-96Mbps. Table (3) summarizes the standard physical layers with different data rates.

TABLE (3): STANDARD PHYSICAL LAYERS WITH DIFFERENT DATA RATES.

PHYSICAL LAYER	I	II	III
Data Rates	(11.67-267.6) kbit/s.	(1.25 – 96) Mbit/s.	(12- 96) Mbit/s.
Notes	Out-door Applications	In-door Applications	Emissions sources with CSK.

The modulation formats adopted for Layer I and Layer II are on-off keying (OOK) and variable pulse position modulation (VPPM). The Manchester coding used for the PHY I and PHY II layers includes 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".

5.2 DATA LINK LAYER:

Working in service of the physical layer of the sending and receiving data as a formula (bit) through a communication channel. Although, the IEEE 802.15.7 standard defines the physical layer (PHY) and media access control (MAC) layer; this standard is able to deliver enough data rates to transmit audio, video and multimedia services. Data Link Layer can be divided into two sub layer as follows [15]:

I. OPTICAL WIRELESS LOGICAL LINK (OWLLC) : To strengthen and controls the logical links between devices on a network. Through the DLL it allows the connect of other techniques and gives services to network layer.

II. OPTICAL WIRELESS MEDIA ACCESS CONTROL (OWMAC) : The communication via media may be simplex, half duplex or full duplex, OWMAC dominate over it using of OWMAC protocol working through terminals and connected devices which is the common style.

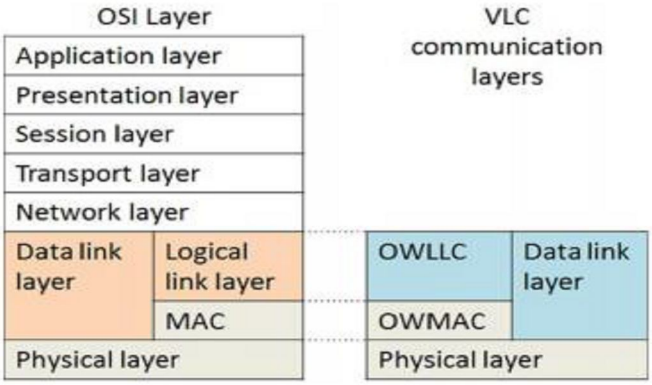

Figure10:OSI reference model for VLC communication

VI. APPLICATIONS OF LI-FI

Li-Fi applications are varied because of its key features, such as directional lighting, energy efficiency, intrinsic security, high data rate capability, signal blocking by walls and integrated networking capability. Each light fixture in the application environment becomes a separate data channel. These channels can supply different data into each separate pool of light, delivered at the full rated download speed for that channel. Such applications involve the following fields:

A. SECURITY

With minimal precautions to avoid leakage from windows, etc., security is fundamentally enhanced as compared with Wi-Fi.

B. DENSE URBAN ENVIRONMENTS

Dense urban environments by their nature tend to have complete artificial lighting coverage. High-speed wireless communication would be available in every room since the light waves do not propagate through walls. This results in interference-free wireless communication, and spectrum does not have to be shared among a large number of users in the rooms.

C. CELLULAR COMMUNICATION

For external urban fields, the use of Li-Fi enabled street lamps would provide a network of internet access points. Therefore, street lamps could provide both, illumination during night, and high-speed data communication for 24/7.

D. EMI SENSITIVE ENVIRONMENTS

Specifically; on aircraft, Li-Fi enabled lighting will allow high data rate access for each passenger. Allowing connectivity at all times, without creating electromagnetic interference (EMI) with sensitive radio equipment on the flight deck. In addition, any reduction in cabling requirement means a lighter aircraft.

E. AUGMENTED REALITY

Museums as well as galleries exhibitions are illuminated with specific lighting. Li-Fi enabled lighting can provide localized information within that light. Thus, visitor's camera or mobile phone can be used to download further information regarding the object being viewed from the light that illuminates the exhibit.

F. LOCALIZED ADVERTISING

This will allow the merging of the high street and online shopping experience, and provide novel retail business models to emerge. Catalogue information, discount coupons, and advertising videos could all be provided to shoppers.

G. UNDERWATER COMMUNICATION

Radio waves are quickly absorbed in water, preventing underwater radio communications, but light can penetrate for large distances. Therefore, Li-Fi can enable communication from diver to diver, diver to mini-sub.

H. SAFETY ENVIRONMENTS

Using of Li-Fi to pass data will simplify the configuration of data networks in explosion hazard environments, and can enable new systems to enhance security in these environments instead of using the mobile phones that they are restricted.

I. INTELLIGENT TRANSPORTATION SYSTEMS

The replacement of car headlights and taillights with LED versions offers the prospect of car-to-car communication over Li-Fi, allowing development of anti-collision systems and exchange of information on driving conditions between vehicles. In addition, this prospect gives the ability for car-to-car system computer to download information from the network, performing real time information sharing on optimal routes to take, and update the network conditions recently by individual vehicles.

J. CONNECTIVITY

Using the fact of the "internet of everything" inside homes equipped with LED lighting devices, the Li-Fi enabled lighting will transform the applications that can be envisaged, not only the interconnection of devices, such as televisions, computers and Hi-Fi, but also connecting ordinary domestic appliances, such as fridges, washing machines, microwaves and vacuums. Such applications is a typical solution for what is known as a "Smart Homes".

K. SENSITIVE DATA

Hospitals are a specific case of an environment where both EMI sensitivity and security of data are issues. Li-Fi can enable the better deployment of secure networked medical instruments, patient records, etc.

L. INDOOR NAVIGATION

By identifying each light (for example, through the use of the widely used MAC codes used by data routers and computers) it is possible to provide a smart means of navigating through urban environments. The identification of each code would be linked to a specific location. For example, light received from the closest fixture can indicate to a mobile user their exact position as they travel along a corridor.

VII. CONCLUSION OF LI-FI

Today technology is witnessing major changes; it is predicted that Li-Fi will make a big leap in Internet services it is a practical and successful substitute to traditional Wi-Fi that uses radio waves. This makes Li-Fi the future of wireless Internet service. Practically every LED can be considered as a Li-Fi Access Point "AP" which means wherever there is light, there will be Li-Fi service (i.e. Internet Services). Line of Sight "LOS" is considered to play a major limitation in Li-Fi services thus more research is required to overcome this obstacle in order to make Li-Fi much easier to install and apply. As a future trend, Li-Fi will be considered, majorly, an ideal in terms of high data rate transfer for internet and their services. The Li-Fi new vision is based on real solutions to spectrum broadness and to achieve the coverage in certain places where radio signals can reach.

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