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# NEW TECHNOLOGY OF DATA TRANSMISSION: LI-FI

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## ABSTRACT

Motivated by the looming radio frequency (RF) spectrum crisis, this paper aims at demonstrating that optical wireless communication (OWC) has now reached a state where it can demonstrate that it is a viable and matured solution to this fundamental problem. In particular, for indoor communications where most mobile data traffic is consumed, light fidelity (Li-Fi) which is related to visible light communication (VLC) offers many key advantages, and effective solutions to the issues that have been posed in the last decade. This paper discusses all key component technologies required to realize optical cellular communication systems referred to here as optical attocell networks. Optical attocells are the next step in the progression towards ever smaller cells, a progression which is known to be the most significant contributor to the improvements in network spectral efficiencies in RF wireless networks. In this paper we analyzed the Li-Fi system using an optisystem simulation tool. In this analysis, we considered two propagation models. In a LOS propagation model in the receiving end, we can regenerate approximated transmitted signal.

**Keywords:** light fidelity (Li-Fi), visible light communication (VLC).

## INTRODUCTION

In nowadays world, there are about 1.4 million cellular radio stations, base stations with more than 5 billion mobile phones are deployed. Mobile phones transmit over 600 TB of data. Nowadays, wireless communication uses radio waves, and therefore the spectrum of radio waves is one of the most important requirements for wireless communication. With improvements in technology and an increasing number of users, the existing spectrum of radio waves cannot meet this need. To solve the problems of scalability, availability and security, scientists offer the concept of wireless data transmission via light-emitting diodes called Li-Fi, which is the latest modern technology that uses LED, which in its data transmission characteristics is much faster and more flexible than the data that can be transmitted via Wi-Fi. LED lamps are widely used for home and office because they have high light efficiency. Visible Light Communication (VLC) is a new way to wirelessly communicate using visible light. Typical common transmitters such as LEDs and photo diodes, image sensors will be used for Li-Fi communication. In this system, these devices will be used not only for indoor lighting, but also for the new Li-Fi optical wireless communication system.

Li-Fi is a new high speed, low cost and economical solution for the radio frequency spectrum shortage, so it is expected that it will be implemented with the widespread use of optoelectronic LEDs. Due to the mass production of these low-cost devices, they do not have sufficiently clear characteristics. At Li-Fi, light reacts to minor changes in light intensity, so the communication channel will be affected by the non-linearity of the Volt-amper characteristic. Pre-strain methods have been suggested as a solution to this problem to mitigate the effects of non-linear distortion. [1]

Demand for wireless mobile traffic has grown exponentially over the past decade, which in turn has dramatically increased the demand for new next-generation 5G wireless technologies to provide communications services with higher data rates, lower latency and significantly increased service quality. Along with such technologies and Li-Fi, which uses a licensed spectrum of visible light (about 430 - 770 GHz) for bidirectional operation, high-speed and fully networked wireless communication. Compared to the radio frequency antenna, Li-Fi typically uses LEDs as a signal transmitter, which is more cost-effective and energy efficient. Experimental studies have shown a transmission rate of 5 Gbit/s using LEDs of gallium nitride with a maximum optical power of about 3 mW. Also, the bandwidth of 3 dB LEDs usually ranges from 10 to 60 MHz. In the future, laser diodes (LDs) can be used as a promising alternative for even higher data, and it is expected that data transmission rates of more than 100 Gbit/s can be achieved at standard room lighting levels. [2]

It is also relevant that with the existing widespread use of LED lighting in homes, offices and streetlights, Li-Fi can be added to existing data networks as an additional network layer. The advantage is that Li-Fi can significantly increase the overall network bandwidth, as it neither receives nor adds any interference to the network. In addition, since light does not pass through opaque objects, Li-Fi technology has a higher level of information security than radio frequency systems. Given the large number of LEDs installed indoors without access to street light, a typical Li-Fi network is expected to exceed hundreds of Gbps. In this case, optical fibers, with their high bandwidth, will be installed as the basis for high-speed Li-Fi networks. Figure-1 shows a simplified schematic view of the network.

Li-Fi network, integrated with fiber optic communication. The architecture of the center consists of a central office (CA), which is connected to the metro network and a number of Li-Fi access points (APs) via fiber optic lines. Power cables are connected between the power supply and Li-Fi access points to provide power, but not to transmit information. [3]

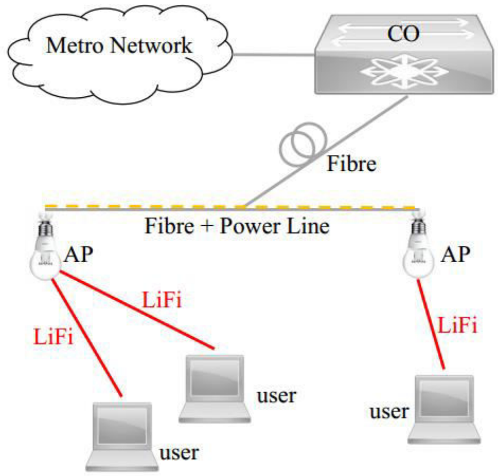


**Figure-1.** Diagram of Li-Fi technology and fiber optic communication.

## WORKING PRINCIPLE

- On the one hand, all data on the Internet will be transmitted to the lamp driver when the LED is turned. The microchip converts the digital data into light.
- A light-sensitive device (photo detector) receives an alarm and converts it back to the original data.

This method uses fast pulses of light in order to transmit information wirelessly, this effect is called Visible Light Message.

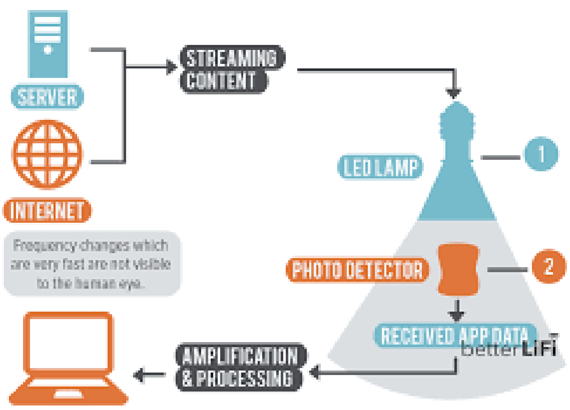


**Figure-2.** How the Li-Fi technology works [4].

The light emitted by the LED lies within a narrow range of the spectrum. In other words, its crystal initially emits a specific color (if we are talking about the visible range LED) - in contrast to the lamp, which emits a wider spectrum, where the desired color can be obtained only by using an external light filter. The emission range of the LED largely depends on the chemical composition of the used semiconductors.

## THE EXPERIMENTAL SETUP

The experimental setup for the VLC system can be analyzed in two cases. The First case is the LOS propagation model and the second one is the Non-LOS propagation model. In LOS propagation model only consider direct path and which is shown in the Figure-3.

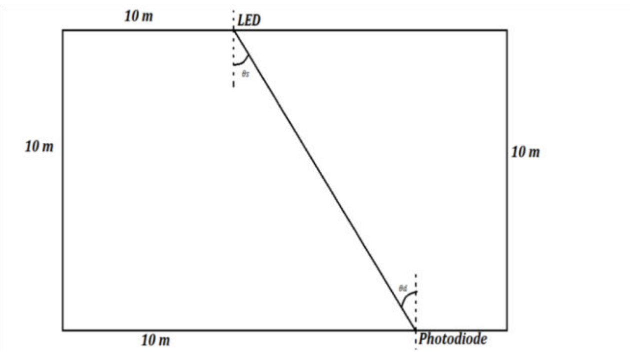


**Figure-3.** LOS propagation model.

Figure-3 shows the arrangement of an indoor VLC setup, for which the room has the dimensions of 10m length, 10m width and 10m height. One LED is placed as a transmitter and in the receiving point we used photodiode as the detector.

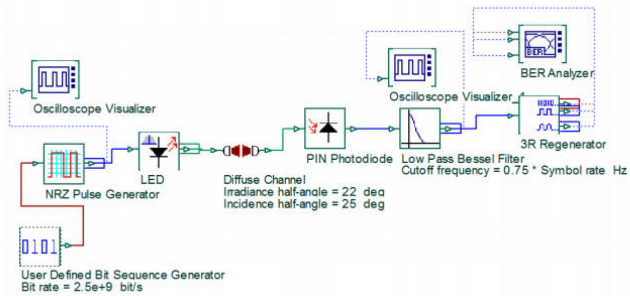


**Figure-4.** Optisystem simulation model of LOS propagation model.

An Optisystem simulation model of LOS propagation model is shown in Figure-4.

In this model the user defined bit sequence generator is followed by a NRZ pulse generator to supply the data signal for the white LED. The LED emits light which encodes the optical information, which is passed through a diffuse channel. At the receiving end, we use a PIN photodiode. The received data is filtered using Bessel filter to remove the optical frequency interference in PIN output. Oscilloscope visualizer is used for viewing input and output. The simulation results are shown in Figure-5.

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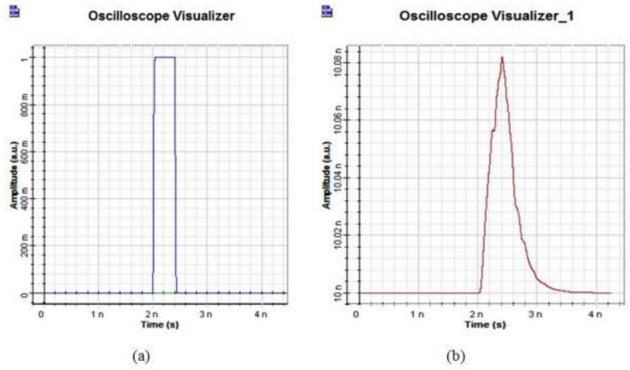


**Figure-5.** (a) input (b) output.

The frequency response of the LED is determined by the dynamics of the carrier (and therefore limited by the lifetime of $T_n$) and the parasitic capacitance of the LED If a small, constant forward shift is used, the effect of the parasitic capacitance of the LED can be neglected. The LED 3-dB optical bandwidth modulation is defined as the modulation frequency at the LED power transfer function is reduced by 3 dB. The LED 3-dB optical bandwidth modulation can be expressed as the modulation frequency:

$$f_{3dB} = \sqrt{\frac{3}{2\pi(T_n + T_{RC_n})}}$$

$f_{3\text{dB}} = \sqrt{3} / 2\pi / (T_n + T_{\text{RCn}})$.

The default lifetime values of the carrier $T_n$ and RC constant TRC are 1 ns and 1 ns respectively. Thus, the frequency of the $f_{3dB}$ portal is about 140 MHz.

Discussion of numerical parameters: e.g. baud rate 300 Mbit/s, sequence length 128 bits, so the time interval is about 430 ns. The selection per bit is 256, so the sampling rate is 76 GHz. Therefore, the default resolution is about 2 MHz. First let's keep the media $T_n$ and RC lifetime in a constant state, which means $f_{3dB}$ constitute about 140 MHz, and analyze the eye chart closing as a measure for system performance. The results for 100 Mbps and 300 Mbps transmissions are as shown in Figure-4. [6].

We would like to demonstrate the properties of LED modulation response.

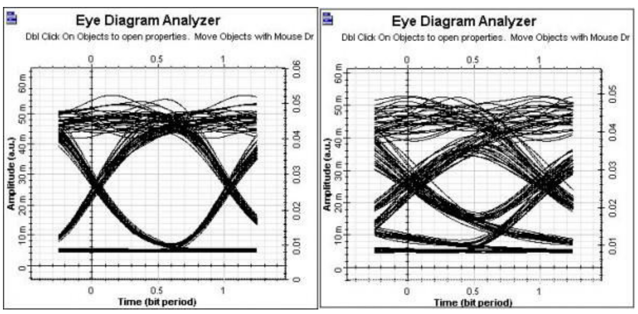


**Figure-6.** Performance of the system with “Eye Chart”.

Obviously, the performance of the digital system is significantly impaired by increasing the data transfer rate above the optical modulation bandwidth of LED 3 dB.

**Advantages and Disadvantages**

Li-Fi has the following advantages over other competing radio technologies, such as Wi-Fi and cordless cellular phones. Li-Fi has the highest speed not currently available to other systems because the frequency is higher than 3 GHz. What if all the lights in your rooms communicate with each other and build a bridge from wireless networks that provide Internet access? Li-Fi - that would be the technology. It's the best solution compared to Wi-Fi technology, which can also be used to extend wireless networks in your home network or in your office or university for data transfer at 10 Gbps, 100 Mbps "on the go" data rate.

At the heart of this technology is a new generation of high brightness LEDs. Visible Light Communication (VLC) is a potential solution for global wireless communications based on the visible light transmission method. Visible light does not penetrate through thick and opaque materials such as walls and partitions, which is a disadvantage. At the same time, however, the advantage is that visible light does not pose a health risk to the human body or eyes. Visible light also has the following advantages compared to infrared communication technology:

- Visible light can literally be seen in a way that a person notices, where the data is being transmitted from.
- LED lighting is widely used in the construction of all types of buildings, providing visible light communication.
- Easy to implement Li-Fi technology today.

One of the main disadvantages of this technology is that artificial light cannot penetrate into walls and other opaque objects and materials that are capable of radio waves. So, Li-Fi included in the terminal device (through its built-in photo receiver) can never be as fast and convenient as a device with support for Wi-Fi outdoors. In addition, another disadvantage is that it only works when in direct contact with light. But still, Li-Fi will definitely be the best choice to access the internet in a limited room at a lower price. [6]

LiFi uses light emitting diodes (LED’s) to make full connections in wireless network systems. Each LED in a LiFi system acts as an access point, and due to the size (order of millimeters) of the AP’s, their networks are called attocell networks, unlike WiFi femtocell networks., ese improvements in the attocell networks provide the necessary infrastructure for the IoT technologies and contribute to the fifth generation 5G of cellular systems.

LiFi arises from a worldwide need, the scarcity of spectrum bands available for wireless-fidelity (WiFi) technology use of LiFi systems in indoor applications could represent the largest field of action of this technology in the coming decades since it could become a

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solution for massive deployment of nodes, making use of bandwidth-efficient and secure connections in the Internet of things. As a result of many experimentations in modulation, color and power, the use of LiFi has been envisioned to be used in urban, marine, and in outer space environments. To this date, the use of LiFi is mainly focused for indoor environments where illumination conditions are rather stable, where nodes have low or no mobility and there are few obstacles between transmitters and receivers.

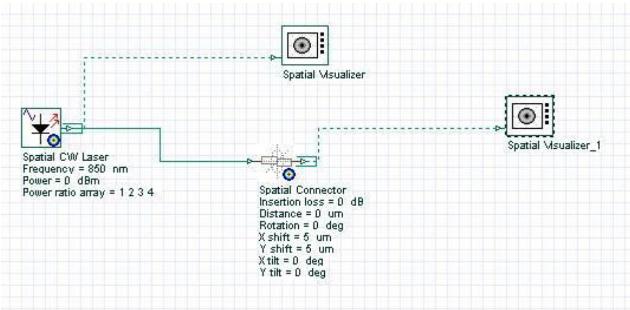
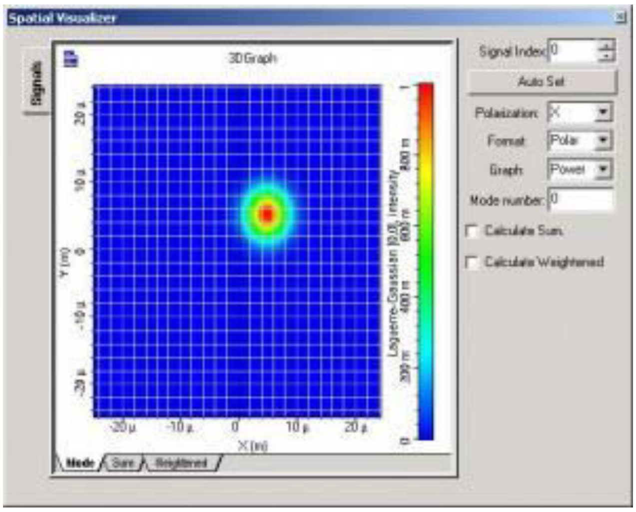
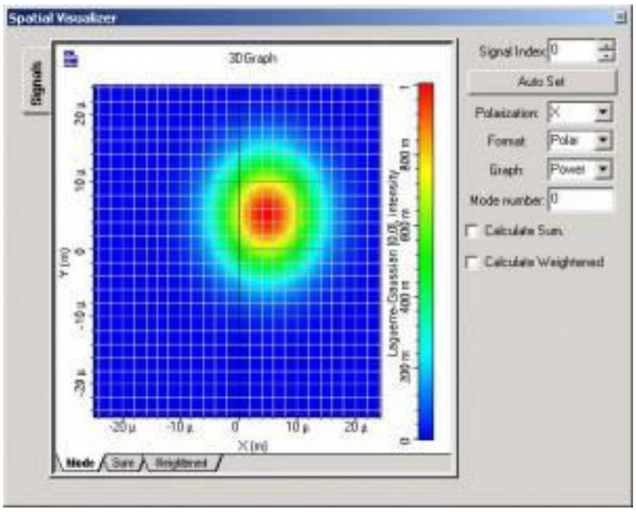



**Figure-7.** One laser propagation model.

Spatial visualizer displays the transverse mode intensity after a shift of 5 µm in both X and Y directions. Figure-8 compares the transverse mode intensity before and after applying 200 µm of propagation in free-space, you can see that the second beam is larger.




(a)




(b)

**Figure-8.** Optisystem spatial visualizer.

## PRACTICAL IMPLEMENTATION

One of the distinguishing characteristics of VANETs is the content-centric distribution, the content is important, the source is not. This is in marked contrast to the Internet where an agent demands information from a specific source. For example, traffic information floods a specific area and vehicle retrieves it without concern for the source of it, while an Internet request for highway traffic information is directed to a specific site. [8] Vehicle applications collect sensor data and vehicles collaborate sharing sensory data. Sensory data is collected by vehicle-installed cameras, by on-board instruments. For example, CarSpeak allows a vehicle to access sensors on neighboring vehicles in the same manner in which it can access its own. Waze is a community-based traffic and navigation application allowing drivers real-time traffic and road information.

## METHODOLOGY

The sensor gives its data to the Analog to Digital Convertor (ADC) to convert the analog values to digital values. The microcontroller stores these values and transmits the data to the UART (Universal Asynchronous Receiver /Transmitter) which used for serial communication between the transmitter and receiver. The UART is one of the most important tools used when debugging is serial input or output. Serial is very easy to implement, and it allows you to send/receive any data you need from your microcontroller to a computer's serial port so it can be viewed using a terminal emulator for simulation purpose. This method of serial communication is sometimes referred to TTL serial (transistor-transistor logic). Asynchronous transmission allows data to be transmitted without the sender having to send a clock signal to the receiver. [10] The buzzer circuit is switched on when the sensor detects any obstacles or if the person has consumed alcohol or closure of eyes is being detected by the eye blink sensor. The VLC transmitter transmits the binary data to the VLC receiver and it’s been given to the

TTL (Transistor Transistor Logic) to UART and been displayed in the LCD display. [11]

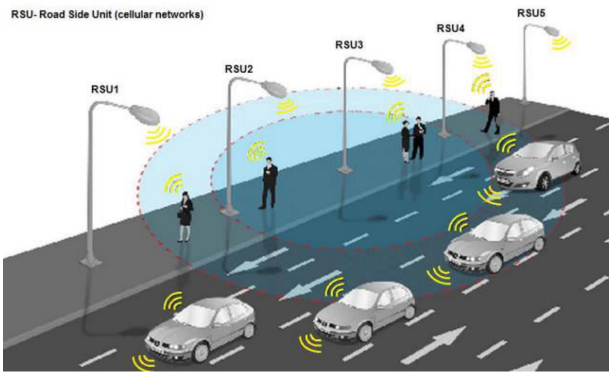



**Figure-9.** Li-Fi technology for VANET.

VANET communication protocols are similar to the ones used by wired networks, each host has an IP address. Assigning IP addresses to moving vehicles is far from trivial and often requires a Dynamic Host Configuration Protocol (DHCP) server, a heresy for ad hoc networks that operate without any infrastructure, using self-organization protocols. Vehicles frequently join and leave the network and content of interest cannot be consistently bound to a unique IP address. A router typically relays and then deletes content. [12]

## CONCLUTIONS

In this article we analyzed the Li-Fi system using an optisystem simulation tool. In this analysis, we considered two propagation models. In a LOS propagation model in the receiving end, we can regenerate approximated transmitted signal. A LiFi system is proposed to be used in order to make a bandwidth-efficient system by making use of different frequencies than the ones used in cellular, WiFi, and Bluetooth which are overcrowded and will experience even more traffic when 5G communication systems get deployed. Conversely, the proposed LiFi system takes advantage of visible light already used in traffic lights and front and tail lights in vehicles. Also we illustrate the practical implementation Li-Fi technology for VANET communication protocol.

## REFERENCES

[1] Mohamed Sufyan Islim and Harald Haas. 2016. Magazine ZTE Comunications. (2): 34-38.

[2] Liang Yin, Mohamed Sufyan Islim, Harald Haas. 2017. Li-Fi: transforming fibre into wireless. pp. 2-8.

[3] Komine T. and Nakagawa M. 2003. Integrated System of White LED Visible-Light Communication and PowerLine Communication. pp. 71-79.

[4] Li-Fi. 2017. Science magazin LanTorg.com. Light is transmiting the Internet. No. 3

[5] R. Karthika, S. Balakrishnan. 2015. Wireless Communication using Li-Fi Technology. International Journal of Electronics and Communication Engineering. 2(3).

[6] optiwave.com. optical system led modulation response. 2016 y.

[7] Alwin Poulose. 2017. Kyungpook National University. An Optisystem Simulation for indoor visible light communication system.

[8] Y. H. Kim, W. A. Cahyadi and Y. H. Chung. 2015. Experimental demonstration of LED-based vehicle to vehicle communication under atmospheric turbulence. In proceedings of International Conference on Information and Communication Technology Convergence (ICTC), Jeju, pp. 1143- 1145, 28th-30th October.

[9] F. Miramirkhani and M. Uysal. 2019. Channel modeling and characterization for visible light communications. Journal of IEEE Photonics. 7(6): 1-16.

[10] P. Ji, H. M. Tsai, C. Wang and F. Liu. 2019. Vehicular visible light communications with LED taillight and rolling shutter camera. In proceedings of IEEE Vehicular Technology Conference (VTC), Seoul, pp. 1-6, 18th-21th May.

[11] Gerardo Hernandez-Oregon,1,2 Mario E. Rivero-Angeles, 1 Juan C. Chimal-Eguıa, Arturo Campos-Fentanes, Jorge G. Jimenez-Gallardo, Ulises O. Estevez-Alva, Omar Juarez-Gonzalez, Pedro O. Rosas-Calderon, Sergio Sandoval-Reyes and Rolando Menchaca-Mendez. 2019. Performance Analysis of V2V and V2I LiFi Communication Systems in Traffic Lights.

[12] R.V. Kirichek, D.K. Nguen, E.M. Gerasimova. 2015. Comparative review of technologies Li-Fi and outlook for the practical use of the Internet of things.