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Review Article

Li-Fi: A Revolution in Wireless Networking for Smart Communication Through Illumination

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Abstract

Currently, wireless internet access is possible thanks to new technologies such as Wireless Fidelity (Wi-Fi). Known as IEEE 802.11, Wi-Fi enables high-speed data transmission with a range of 150 Mbps using WLAN -11n. Faced to many security, transmission capacity and throughput problems, and especially interference, it was necessary to seek more robust wireless access technology to solve these problems. The optical band available is untapped and provides promising solutions by being able to provide tens of gigabit per second specifically suitable for indoor settings. An important revolution through the use of breakthrough technology of Visible Light Communication (VLC) or Li-Fi (light fidelity) could promise much higher data rates and better security and integrity of the data at the physical layer. This new technology called "data by lighting" allows the transmission of data by illumination by sending it via a LED light bulb whose intensity varies very quickly without being perceived by the human eye. This paper, provides an introduction to Li-Fi, the results presented in this paper was realized using MATLAB.

Keywords: Li-Fi; Wi-Fi; Visible Light; Transmission; LED

Introduction

When the web was conceived [1], not much thought was given to security. Indeed, the Internet's whole point was to permit the free sharing and distribution of information [1]. It is only with the increase in the number of interconnected devices and [1], consequently, in the amount and sensitivity of the information stored and distributed on the web [1], that the security of the networks became a challenge [1]. There are two major problems. The first is the need to keep all information confidential so that only authorized parties have access to it [1]. Regardless of whether it is classified government material, sensitive business information [1], or our MasterCard number [1], there is a high motivation to protect any information sent over the network from public scrutiny [1]. This desire goes beyond protecting the information transmitted over the network, and may even cover the safeguarding of files or passwords stored on computers that are connected on-line [1], as well as access to computer resources and programs [1]. Some of the solutions to this problem are the need for keys to log in to users workstations, password protect key documents and digitally sign their emails [1].

The second safety challenge is the protection of the Internet infrastructure [1]. The purposes are to protect against attacks on the configuration of network devices [1], stealing network resources and consequently maliciously jamming nodes or links with spurious data that prevent legitimate messages from passing [1].

Visible light communications (VLC) is the new emerging paradigm of wireless technology proposed in the beginning of 2000s. This technology was designed as a point-to-point wireless communication link between an LED light and a receiver [2], which is equipped with a photo detection (PD) system. The transfer of rate depends on the digital technology used and thus on the light [2]. According to [3], the light communication system (LCS) incorporating white LED illumination has received considerable attention in the last decade. In this paper, the authors propose a handover algorithm for an internal cellular system to extend the bandwidth transmission [3].

Currently, Li-Fi technology is undergoing a major development. There are several studies on security in many aspects, namely physical layer, MAC layer, topologies, indoor communication, outdoor communication, inter-channel interference, etc. However, studies on security issues in Li-Fi communication have focused on the individual attack. In [4], the paper identifies the physical aspects of VLC that are of interest to security and presents a strategic review of safety threats and vulnerabilities with respect to the characteristics of VLC systems [4], and summarizes all the security techniques proposed in the literature for VLC to the present day [4], including physical layer security addressed from an information theoretic view [4], and availability and integrity issues [4].

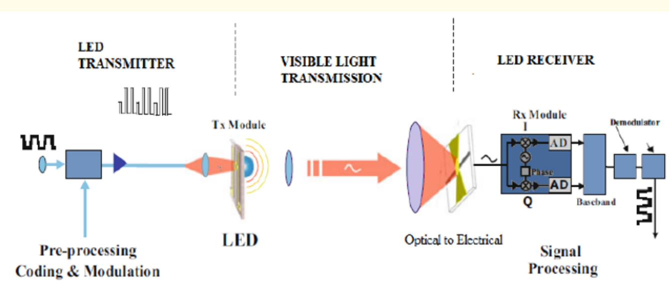


Figure 1: Block diagram of the visible light communication system.

Many authors have adopted transmission and modulation techniques in their papers. For example [5] cites data transmission based on various LEDs light emitting modulation methods [5]. Without forgetting the [6] which studies the design of an optical link network architecture; this architecture can provide efficient interconnection for Li-Fi access points [6]; the author proposes a Li-Fi structure to implement OFDM: orthogonal frequency division multiplexing and an optical coding technique [6] to provide multi-user access and enable all-optical processing and transmission in the backbone network. We also mention LED provide multi-user access and enable all-optical processing and transmission in the backhaul network. We also mention the LED based study, which aims to describe the viability of a free-space visible light optical transceiver as the basis for an indoor wireless network and to achieve an acceptable error rate for indoor use with a low-cost system [6].

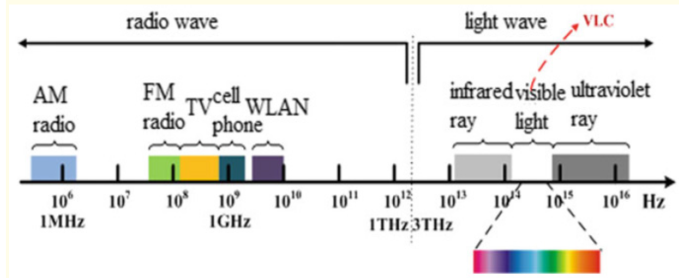


Figure 2: Electromagnetic spectrum.

System model

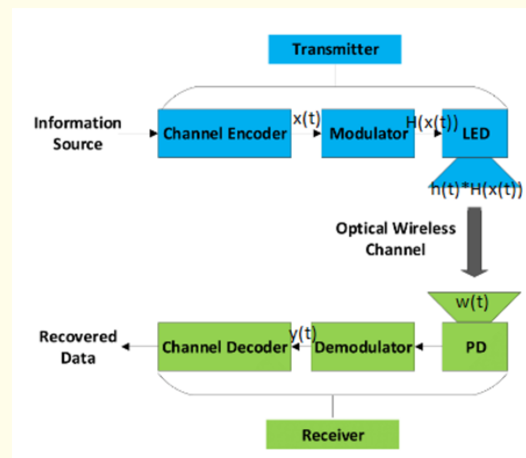


Figure 3: The modified block diagram for Li-Fi system.

The transmitter includes a DSP: digital signal processor and DAC: digital-to-analog converter [7], which modulate the digital information bits and transform them into an analog current signal and to control the optical transmitter [7].

The information carrier signal is converted into optical intensity [8,9]. The digital signal can be passed through an optical system to further form the transmitted beam [9]. An optical amplifying lens [9], collimator or a diffuser is used to focus or expand the beam [9,10]. The optical signal is then transmitted over the wireless optical channel [10]. Objects absorb some of the optical energy in the environment and the rest is diffusely reflected [9,10].

An optical filter [9] can be used to select an interesting part of the optical spectrum [9]. In addition, the optical filter minimizes interference from ambient lighting [9, 10]. Then, the signal passes through a system of optical elements [9], for example to amplify the signal for optimal detection [10-12]. The current signal is then electronically pre-amplified by a trans-impedance amplifier [10]. We use DSP with an analog-to-digital converter (ADC) to convert the analog current signal into a digital signal and demodulate the information [11,12].

Propagation links are classified into two categories: line-of-sight (LOS) and non-line-of-sight (NLOS) links. Taking into account the directionality of the transmitter and receiver, VLC propagation links can be classified into three categories: directed link: the transmitter and receiver are directly oriented towards each other with a narrow half angle and field of view (FOV) [13], undirected link and hybrid link.

Because of an obstruction, such as a wall in the room, the transmitter and receiver communicate by means of a single reflection off the ceiling or another wall in the room. In NLOS communication, the signal arrives at the receiver after one or more bounces off objects in the room. The two NLOS scenarios are differentiated by the directionality of the transmitter. In the first case, directed NLOS, the transmitter has a very narrow beam characteristic, projecting the light onto a single point on the ceiling which serves as a new transmitter. It relays the light to the receiver according to its reflection characteristic. This results in a single reflection component with high light intensity. In the second case, undirected NLOS, the emitter has a broad radiation characteristic, irradiating a large part of the reflecting surface. In a closed room, it is likely that the radiated light arrives at the receiver after one or more reflections from the surfaces [14].

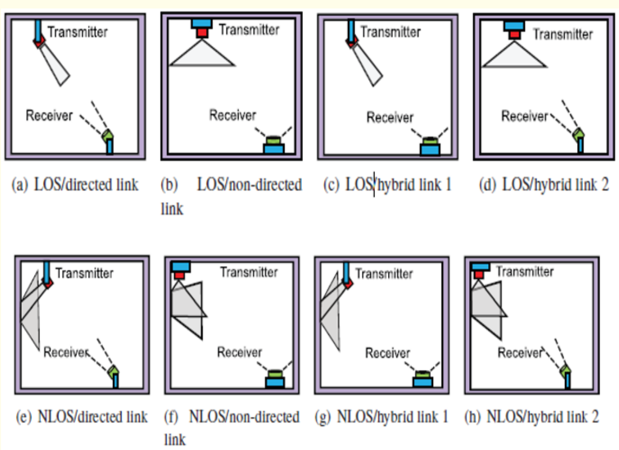


Figure 4: Classifications of the propagation links.

The transmitter and the receiver incorporate optical as well as electrical components, where the respective electrical-to-optical (E/O) and optical-to-electrical (O/E) conversions take place [14].

The main characteristics of the emitter are the radiation pattern, the optical spectral response, the E/O transfer characteristic and the electrical modulation bandwidth. The radiation characteristic of a single LED is usually modelled using a generalised Lambertian radiation pattern [12,15]. The radiation intensity can be expressed as:

$$R(\theta)\frac{m+1}{2\pi}\cos^{m}(\theta)P_{LED}$$

Where P_{LED}: the total radiated power, which is given by:

$$P_{LED} = \int_{\lambda}^{m} P(\lambda)d\lambda$$

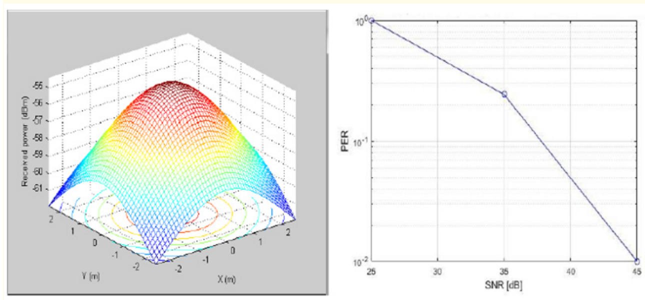
Where P(λ): the spectral power distribution and m: the order of Lambertian emission, which depends on the semi angle at half luminance of the LED 1/2, i.e:

$$m = -\frac{\ln 2}{\ln \cos\theta\ (\frac{1}{2})}$$

The coefficient (m+1)/2π guarantees that the integration of the radiant density on the surface of a hemisphere is equal to the total optical power:

$$E_e(d) = \frac{R(\theta)}{d^2}$$

For the optical receiver, the detected optical power is proportional to the effective signal-collection area.



a) LOS: semi-angle at half power, b) directed NLOS: 802.11n PER simulation 2x2 channel model [30]

Figure 5: Results of the propagation links.

The main characteristics of the receiver are the detection model, the optical spectral response, the O/E transfer characteristic, the bandwidth of the electrical modulation and the noise figure. The detection characteristic of a single PD is usually modelled using a Lambertian detection model [15,16], which is a generalized model of the VLC link in the time domain.

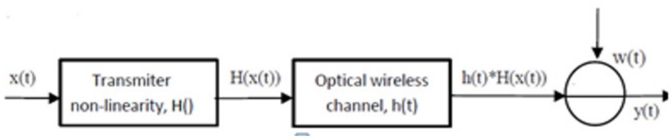


Figure 6: Block diagram generalized of the VLC in the time domain.

The VLC is diagrammatical by continual-time model for a noisy communication link: y = *h* * H(x) + w wherever y(t) is that the received distorted duplicate of the transmitted signal x(t), [20] that is subject to the amplitude distortion operate H(x(t)) [17], of the transmitter forepart [17]. The non-linearly distributed transmitted signal is convoluted with the channel impulse wave response h(t) [17], and is distorted by the white Gaussian noise w(t) [17], at the receiver, that contains the background and thermal noise. Here, * indicates linear convolution [17].

The generalized model of the OWC link within the time domain is illustrated in figure 6. As the OWC system is realized by employing a DSP, the subsequent equivalent distinct model for a loud communication link is employed within the system description:

$$y = h * H(x) + \omega$$

Where * denotes distinct linear convolution. Here, the transmitted signal vector, x, contains Z_x samples, the channel impulse response vector, h, has Zh samples, and, as a result, the AWGN vector, w, and therefore the received signal vector, y, have Zx + Zh - 1 samples [18]. The distinct signal vectors are obtained by sampling of the equivalent continuous time signals.

VLC system noise

Noise in VLC systems may be classified in two categories: lightweight noise, together with the gauge boson variation noise of the optical signal itself, and receiving device noise, like dark current noise, thermal noise and 1/f noise. many sorts of noise may be thought of as shot noise within the wireless optical link, like dark current noise, quantum noise and background noise [20].

Quantum noise

Photon fluctuation noise is because of the distinct nature of the photons from the optical supply. once the optical power of the sunshine supply remains unchanged, the quantity of incoming photons is statistically constant over an extended amount of your time and follows a Poisson distribution, i.e,

$$P(n = k) = \frac{\lambda_k}{k!} e^{-\lambda} \; k = 1,2, \ldots.$$

Where λ: the average number of arrival photons per interval and n: the number of arrival photons in a given time interval.

Since intensity-dependent modulation is mostly utilized in VLC systems, the quantum noise continuously seems to be background, that incorporates a one-sided power spectral density in units of A_2/Hz a:

$$\sigma^2 = 2qi_{pc}$$

Where q: the electronic charge, i_{pc}: the photo-current and we have $i_{pc} = RP_{LED}$, where R: the photodiode responsivity and P_{LED}: the supply luminosity.

Background radiation noise

The background noise or close lightweight noise is caused by the reception of photons from the setting. The background is freelance of the signal and might be modelled as additive, white and Gaussian because of its high intensity. Within the case of AN NLOS link wherever a good field-of-view receiver is employed, the received signal/noise ratio is restricted by the radiation background that is way stronger than the quantum noise of the optical supply likewise as alternative noise sources, even with the adoption of optical filters. Once the spectral radiance Le ($W.m^{-2}.sr^{-1}.Hz^{-1}$) is assumed to be freelance of the wavelength, the received background power may be expressed as [20]:

$$P_{bg} = Le\Omega sAT_0 g(\psi) B_{opt} \frac{\cos(\psi)}{\cos(\theta)}$$

Where Ω_s: part of the FOV subtended by the background source at the receiver, T_0: the atmosphere transmittance, and B_{opt}: the optical filter information measure. From the equation below, the background power depends on the FOV and also the optical information measure of the receiver and its variance is given by:

$$\sigma_{bg}^2 = 2qB_{pd}RP_{bg}$$

Where B_{pd}: the information measure of the photodiode.

Thermal noise

Thermal noise, or in other terms Jonson-Nyquist noise, is caused by the random fluctuation of charge carriers (usually electrons) in any conducting medium at a temperature on top of temperature. the ability spectral density of the thermal noise that's white remains constant over a good vary of frequencies all the way down to the close to frequency. Considering the freelance lepton agitation, the thermal noise follows a normal distribution consistent with the central limit theorem. The variance of the thermal noise within the vociferous electrical device in A_2· Hz−1 is given by:

$$\sigma^2_{thermal} = \frac{4kt}{R_F}$$

Where R_F is that the resistance.

1/f noise

1/f noise is an intermediate between racket and Brownian noise caused by Brownian movement, whose power spectral density is given by:

$$S_{\frac{1}{f}}(f) = \frac{c}{f^{\alpha}}$$

Where c: constant and α : the exponent satisfying $0 < \alpha < 2$ (usually close to 1). 1/f noise is not a white luminence and becomes strong at low frequencies.

Dark current noise

The dark current in p-n junction devices consists of the surface and bulk currents that are caused by the random generation of electron and hole pairs thermally or by tunneling between the conduction band and the valence band.

Hence, it's associated with the charged bias voltage and also the temperature of the photodiode [19-22].

The dark current may be categorised into the surface dark current, which contains the surface generation combination current and also the surface discharge current, and also the bulk tunnel current, which has the majority diffusion current, the majority generation combination current and also the bulk tunnel current. Since the dark current causes random fluctuations within the average photocurrent, it always seems as a background with a variance of:

$$\sigma_d^2 = 2qB_{pd}\, i_d$$

Where i_d : the dark current.

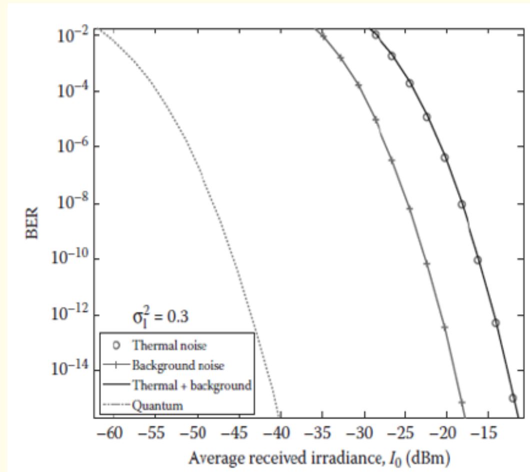


Figure 7: BER against the average received irradiance in weak turbulence under different noise-limiting conditions for R = 155 Mpbs and σ^2= 0.3.

Conclusion

The main future use of Li-Fi seems to be the mitigation of the various wireless networks: 3G, 4G, Wi-Fi. In this perspective, there is a technology currently being studied: 5G. This technology will use these 4 types of networks so as not to clutter them up. For example, if someone gets Wi-Fi or Li-Fi at home, goes out and goes to work, the most powerful and appropriate network will take over. In this case, it is certain that once outside, they will be able to use 3G or 4G [23].

With the spread of the COVID-19 virus, the world is on high alert. In hospitals, patients in intensive care units must be closely monitored at all times and require special equipment to maintain normal body functions. The problem is how to monitor each patient while ensuring the confidentiality of their information. In this article, we presented the new block of our Li-Fi system which will be based on the modulation of the light of the LEDs, we also talked about the noise in the Li-Fi systems. Our objective is to develop an application based on Li-Fi technology in hospitals especially and have a positive result for the process. The idea is to take advantages of the Berlekamp-Massey algorithm for to the One Time Pad for the generation of pseudo-random keys and whose algorithm has been modified by adding a degree of security. We will be able to modify the algorithm so that with each communication and creation of key the value of k changes, what makes that the algorithm will never be broken on the network, since our idea depending on the value of k. For the transmission of the message, the sender and the receiver will encode and decode the message with the same protocol.

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