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A Review on LI-FI

[1]SUBHRANSU SEKHAR PANDA, [2]JYOSTNAMAYEE BEHERA
1,2, Assistant Professor, Department of ECE, GIFT Autonomous, Bhubaneswar

Abstract -- A person can access the entire world at once through various communication technologies. This paper explores these emerging communication technologies, with a particular focus on Li-Fi. In Li-Fi, the visible light portion of the electromagnetic (EM) frequency spectrum is utilized for data transmission, similar to traditional wireless communication systems like Bluetooth and Wi-Fi, which use radio frequency (RF) signals. In Li-Fi, light sources such as LEDs are used as transmitters, while photosensitive detectors like photodiodes (PD) demodulate the light signals and convert them back into electrical signals as receivers. The intensity of the light is modulated in a way that is imperceptible to the human eye. Li-Fi technology is needed to address the limitations of conventional wireless communication systems. This paper provides an in-depth overview of the need for Li-Fi, its applications, design challenges, future prospects, and recent developments.

Keywords: Li – Fi, VLC, Photodiodes.

I. INTRODUCTION

The widespread use of smartphones, tablets, and other mobile devices has made instant information access an essential part of modern life. It was projected that by 2017, mobile networks would handle over 11 hexabytes of data traffic monthly. This surge in demand has pushed radio frequency (RF)-based wireless systems to their limits, as most of the RF spectrum is already licensed and in use. To support the growing number of users and increasing data loads, researchers have proposed several promising solutions. These can be grouped into three main categories:

- Enhancing spectrum efficiency by leveraging spatial resources,
- Creating heterogeneous networks (HetNets) using small cells for better bandwidth reuse,
- Exploring alternative spectrum resources like millimeter waves or optical wireless bands.

Among these, Visible Light Communication (VLC), which utilizes optical signals in the 380–780 nm wavelength range, has attracted considerable interest.

The concept of wireless communication via visible light dates back to 1880, when Alexander Graham Bell invented the photo-phone, a device that transmitted audio via a beam of light. However, optical wireless communication remained underdeveloped for many years until advancements in semiconductor technology reignited interest in the field.

Today, VLC can be implemented using commercially available white light-emitting diodes (LEDs) as transmitters and standard photodiodes (such as PIN or avalanche photodiodes) as receivers. This technology not only provides lighting but also delivers high-speed data transmission by modulating the intensity of the light. Li-Fi—short for Light Fidelity—is a form of wireless data communication that uses LEDs to transmit data by varying light intensity at speeds too fast to be perceived by the human eye. Harald Haas, a professor at the University of Edinburgh, introduced the term "Li-Fi" during a TED Global talk on VLC, explaining that high-brightness LEDs can be toggled rapidly to transmit binary data.

In essence, Li-Fi functions similarly to Wi-Fi, but it uses visible light instead of radio waves. Instead of conventional modems, Li-Fi systems would use LED lamps with built-in transceivers that both illuminate spaces and enable data communication. This makes Li-Fi an affordable, fast, and practical alternative to traditional wireless technologies. be any number of access points. [11]

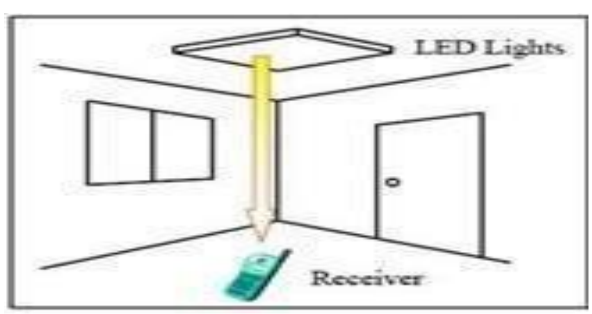

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Fig. 1: - Use of LED illumination as a transmitter

Fig. 2: - Li-Fi integrated conference rooms

II. LITERATURE REVIEW

a) NEED OF Li-Fi:

Many of us are well-acquainted with Wi-Fi (Wireless Fidelity), which relies on 2.4–5 GHz radio frequencies to provide wireless internet access in homes, offices, schools, and public areas. This service has become essential to modern life, yet it comes with notable limitations. Although Wi-Fi can typically cover an entire building, its data speeds—currently around 50 to 100 Mbps using the IEEE 802.11n standard—are often inadequate for transferring large files such as high-definition videos, music libraries, and video games. As we increasingly depend on cloud services and media servers to store our digital content, the demand for faster, higher-bandwidth communication continues to grow. Consequently, traditional RF-based wireless technologies like Wi-Fi are not always ideal, especially for emerging applications like precise indoor positioning and gesture control.

In contrast, optical wireless technologies—referred to as Visible Light Communication (VLC) and more recently as Li-Fi (Light Fidelity)—present a fresh approach to wireless data transmission. These technologies offer enhanced speed, adaptability, and practical benefits compared to conventional RF systems.

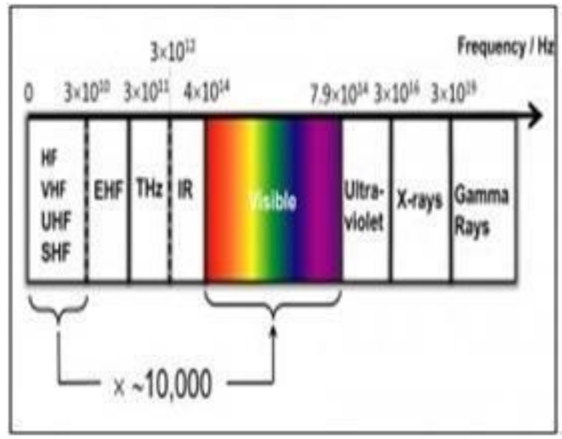

Fig. 3: - The visible spectrum

b) Li-Fi MODULATION TECHNIQUES:

Unlike RF modulation methods, VLC adopts the intensity modulation to carry binary data by turning LED on and off quickly, in which the amplitude and phase information are lost. Besides, modulation is a critical challenge for VLC since it directly affects the illumination quality, which will potentially lead to human health complications, such as nausea or epilepsy, related to fluctuations in light intensity. For fulfilling user satisfaction, dimming and illumination are the first concerns for the VLC design. For the VLC transmitter LED, dimming can be obtained by controlling the drive current because the LED junction current is proportional to the brightness. Analog dimming, which adjusts the current continuously, is the simplest type of dimming control. However, it will affect the emitted light wavelength to bring the chromaticity shift problem. To this end, digital dimming schemes are proposed. They can be achieved by adjusting the average duty cycle or signal density, thus producing the same average LED drive current. Furthermore, the time average power from an LED should not be lower than a threshold value defined by the dimming factor. Pulse position modulation (PPM) encodes information by transmitting a pulse in different time shifts. Each slot contains a unique bit combination for each symbol.

Therefore, the average power is constant with time, which solves the flicker problem. A modification to this PPM technique is called the Variable-PPM (VPPM), which is proposed in the IEEE 802.15.7 standard for VLC. It uses binary PPM to send data and changes the pulse-width to control the dimming level. Another feasible VLC modulation technology is to control the width of the pulse based on the signal information which is known as pulse width modulation (PWM). Considering the efficient dimming control, multi-path PWM (MPWM) has been proposed, in which multiple LEDs are used and the average current through each LED array is pulse width modulated. In order to increase power and spectral efficiency, multiple PPM (MPPM) is proposed that the transmission symbol. On-off keying (OOK) is presented to satisfy arbitrary dimming and code rate requirements [4] [11] [3] [1].

III. FEATURES OF LI-FI

Li-Fi offers several advantages in terms of capacity, energy efficiency, safety, and security, making it a powerful complement to Wi-Fi rather than a replacement. Below is a breakdown of its key features:

a) Capacity:

Bandwidth: The visible light spectrum offers a massive advantage, providing approximately 10,000 times more bandwidth than the radio frequency (RF) spectrum. It is also unlicensed and freely available.

Data Density: Li-Fi enables much higher data density than Wi-Fi, as visible light can be focused within a small, defined area. In contrast, RF signals tend to disperse and may cause interference.

High Speed: The technology supports extremely fast data rates due to minimal interference, the wide bandwidth of optical devices, and the high intensity of LED light sources.

Infrastructure Planning: Network capacity planning is more straightforward, as lighting systems are usually present where communication is needed, and signal strength is visibly evident.

b) Efficiency:

Cost-Effective: Li-Fi requires fewer hardware components compared to traditional RF-based technologies.

Energy Saving: Since LEDs are already energy-efficient for lighting, the added energy consumption for data transmission is minimal.

Environmental Adaptability: Li-Fi performs well underwater, unlike RF systems which struggle with signal propagation in such environments.

c) Safety:

Biologically Safe: Because life on Earth has evolved under visible light, Li-Fi poses no known health or safety risks.

Non-Interfering: Li-Fi avoids RF radiation, making it ideal for environments where radio signals might interfere with sensitive electronic equipment.

d) Security:

Signal Containment: Li-Fi signals are confined within a specific lighting area and do not pass through walls, making them hard to intercept.

Direct Communication: Data can be transmitted directly between devices within sight, and users can visually confirm the data path, reducing the need for extra security measures like Bluetooth pairing.

IV. APPLICATIONS OF LI-FI

Visible light communication (VLC) offers promising applications in location-based services and innovative graphical user interfaces that merge visual content with data transmission. These applications allow users to receive specific information from a VLC transmitter. When such transmitters are installed on buildings or fixed locations, they can also provide accurate location data The LIFI applications can be useful in many sectors such as Underwater Communication, Healthcare, Aviation, Secure Communications, Industrial Automation, Education.

V. FUTURE SCOPE

a)Aviation Communication:

Air travel often encounters challenges with communication systems since they largely rely on radio waves. To address these limitations, Li-Fi technology can serve as a better alternative in aviation communications.

b) Enhanced Medical Safety:

Medical environments have traditionally been cautious with wireless technology due to concerns about radiation interference with medical equipment. For example, Wi-Fi is typically restricted in operating rooms. Li-Fi overcomes these challenges since it relies on visible light, which is safe and permitted in surgical environments, making it ideal for use in such sensitive areas.

c) Improved Network Visibility:

With visible light communication, devices or nodes on a Li-Fi network are physically visible to the network host, enhancing monitoring and network safety.

d) Simultaneous Multi-User Access:

Li-Fi supports broadcasting, enabling multiple users to access and share information at the same time. This facilitates efficient, real-time communication across users.

e) Advanced Power Plant Monitoring:

Traditional wireless signals can pose risks in sensitive environments like power plants. However, these facilities require reliable, high-speed data transmission for monitoring key operations such as energy demand, system stability, and nuclear core temperature. Li-Fi presents a safe and efficient solution for data communication in such locations. Moreover, adopting Li-Fi in conjunction with LED lighting could reduce operational costs and energy consumption.

VI. CONCLUSION

The potential of Li-Fi technology is vast and continues to grow. It is currently being developed so that every light bulb could function as a Wi-Fi hotspot, enabling wireless data transmission. This advancement paves the way for a cleaner, greener, and safer future—free from the harmful effects of radio waves on living organisms. Li-Fi, which uses LED-based optical wireless communication, can stream data, audio, and video efficiently. As a groundbreaking innovation, it promotes the development of environmentally friendly and safe technologies.

Although Li-Fi may not completely replace traditional radio communication, it has the power to significantly enhance wireless applications like streaming and data transmission across homes. Unlike current Wi-Fi setups, which require careful router placement for optimal coverage, Li-Fi could allow data to travel via visible light from one point to another. Local routers at those points could then generate smaller, non-overlapping wireless zones, reducing interference. Furthermore, Li-Fi could serve as a high-speed alternative in locations overwhelmed with radio signals or where RF use is restricted due to security concerns.

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