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EFFICIENT WIRELESS COMMUNICATION ENHANCEMENT THROUGH CARRIER-LESS AMPLITUDE AND PHASE MODULATION IN LI-FI

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ABSTRACT

LiFi (Light Fidelity) technology presents a novel approach to wireless communication, utilizing visible light for data transmission rather than conventional radio waves. This innovative technology offers numerous advantages over traditional wireless communication methods, including enhanced data transfer speeds, heightened security measures, minimized interference, and improved energy efficiency. This document offers a comprehensive examination of LiFi technology, encompassing its benefits, challenges, and potential applications. Beyond that, it explores pertinent research and evaluation methodologies employed to assess LiFi performance. Conclusively, it underscores the ongoing research and development endeavors within the LiFi domain, indicating its continued growth and evolution.

Keywords: *LiFi, optical fidelity, visible light communication, wireless optical communication, LED, optical communication.*

1. Introduction

In modern society, wireless communication technology has entrenched itself as a crucial aspect of daily life. With an ever-increasing need for swifter and more dependable internet connections, scholars are exploring novel wireless communication technologies to address these requirements. Amongst these promising innovations is LiFi (Light Fidelity), which employs visible light for data transmission instead of the conventional radio waves utilized by WiFi and cellular networks. This researcher endeavors to furnish a thorough overview of LiFi technology, encompassing its advantages, obstacles, and prospective applications.

The time period Li-Fi turned into invented with the aid of using a German Professor on the University of Edinburgh, Harald Haas and it refers to mild-primarily based totally communications era that grants high-speed, bidirectional networked cellular communique that's just like Wi-Fi. Light fidelity (Li-Fi) operates withinside the seen mild spectrum of the electromagnetic spectrum .it makes use of seen mild as a medium of transmission instead of conventional radio waves. Figure 1 1 shows the Basic of Working of the Li-Fi module.

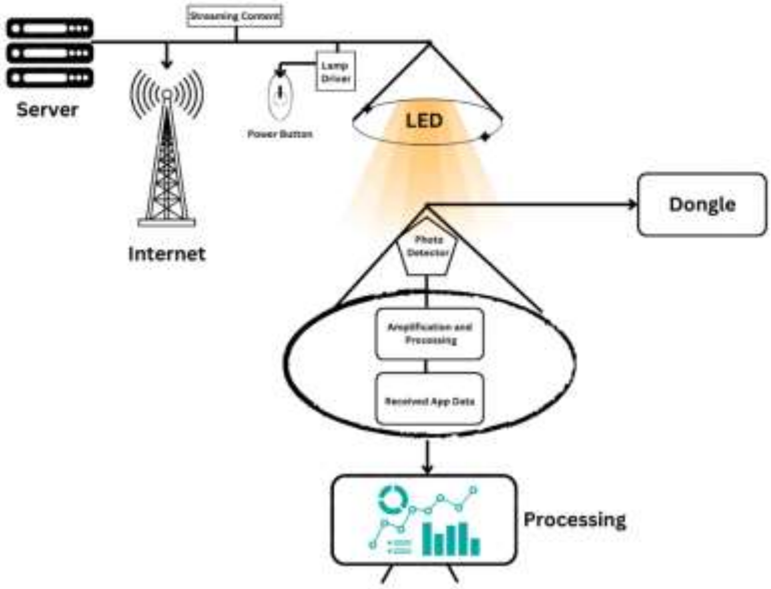

Figure 1.1 Basic working of Li-Fi

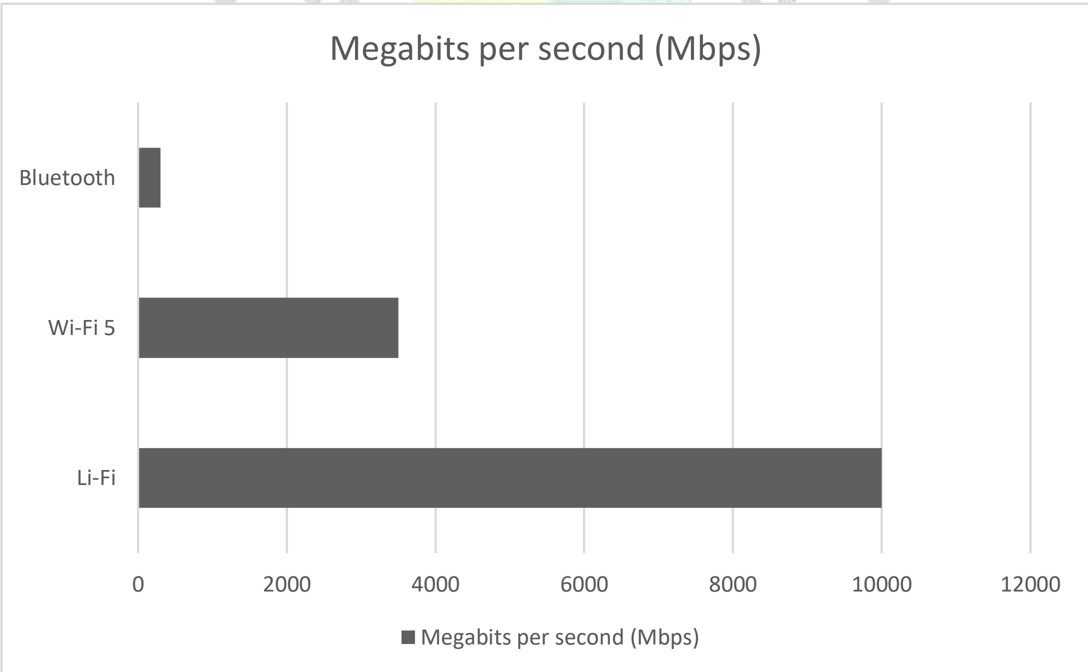

Figure 1.2 Megabits per second

From the Figure 1.2 Li-Fi stands out as a technological marvel, boasting a remarkable data rate of 10,000 Mbps, akin to a supersonic jet in a race. Its swift and efficient transmission capabilities enable users to zip through tasks and reach digital destinations with unparalleled speed. In comparison, Wi-Fi 5, with its respectable 3,500 Mbps data rate, resembles a high-speed train, providing a swift journey but trailing behind the lightning pace of Li-Fi. Meanwhile, Bluetooth lags further behind, akin to a leisurely stroll, with its modest 300 Mbps data rate. While Bluetooth serves its purpose for certain tasks, it pales in comparison to the rapid connectivity offered by both Li-Fi and Wi-Fi 5.

2. Literature Survey

Aman et al. (2021) - Design and analysis of Li-fi underwater wireless communication system. The author explores Design and analysis of Li-Fi underwater wireless communication system", who designed and analyzed a Li-Fi underwater wireless communication system. Presented at the 2021 OES China Ocean Acoustics (COA), their work explores the feasibility of Li-Fi for underwater applications, addressing challenges unique to underwater communication environments.

Arfaoui et al. A. (2021) , Invoking deep learning for joint estimation of indoor Li-Fi user position and orientation. The author explores Invoking deep learning for joint estimation of indoor Li-Fi user position and orientation", who investigated the application of deep learning for the joint estimation of indoor Li-Fi user position and orientation. Published in the IEEE Journal on Selected Areas in Communications in September 2021, their work explores the potential of advanced machine learning techniques to enhance the localization capabilities of Li-Fi systems.

Birsan et al. C. R. (2019), This paper discusses various technologies and algorithms utilized in indoor positioning systems, with a focus on Li-Fi-based localization techniques. The authors explore the advantages of Li-Fi in providing accurate indoor positioning compared to traditional RF-based systems. Performance metrics such as accuracy, coverage, and scalability are evaluated, highlighting the potential of Li-Fi for applications requiring precise localization. However, the study acknowledges limitations associated with multipath interference in complex indoor environments, which may affect the accuracy and reliability of Li-Fi-based localization systems.

Chandran T.R.S. et al. (202), the author explores the application of Li-Fi technology for transmitting audio signals, expanding its potential beyond traditional data communication. The technical aspects of implementing Li-Fi for audio transmission, including modulation techniques and experimental results. The team research contributes to advancing the understanding and application of Li-Fi technology in audio applications, offering valuable insights for researchers and practitioners interested in this emerging field.

Chergui et al. (2020) , The author explores, design and implementation of a VLC system tailored for Li-Fi applications. The authors focus on optimizing the coverage, data rate, and scalability of the VLC system to meet the requirements of Li-Fi communication. Performance metrics such as coverage range and scalability are evaluated, demonstrating the potential of VLC in providing high-speed wireless connectivity. However, the study notes limitations related to the line-of-sight communication requirements of VLC, which may restrict its mobility and flexibility in certain environments.

Conti et al. R. (2019) , The author explores firm strategies in intermediate markets and their implications for business specialization. While the specific details of Li-Fi technology and its applications are not provided, the paper may offer insights into strategic considerations and market dynamics relevant to the adoption and commercialization of Li-Fi technology.

Faulkner et al. (2016), The author presents a study on LED-based wavelength division multiplexing (WDM) techniques for achieving high-speed data transmission over visible light. The authors demonstrate the feasibility of WDM in increasing data rates and channel capacity for VLC systems. Performance metrics such as data rate and spectral efficiency are evaluated, showcasing the potential of WDM in enhancing communication throughput. However, the study highlights the complexity associated with implementing WDM schemes, which may pose challenges in practical deployments.

Gupta et al. S. (2022) , The author explores the efficient transfer of data via Li-Fi technology, particularly focusing on its application in smart home appliances. The authors employ Carrier-less Amplitude and Phase Modulation (CAP) for data modulation, ensuring high-speed and reliable data transmission. Performance metrics such as throughput, latency, and reliability are considered, highlighting the advantages of Li-Fi in enabling seamless connectivity within smart home environments. However, the study identifies limitations related to the limited coverage range of Li-Fi due to line-of-sight communication requirements, which may pose challenges in large-scale deployments.

Huang et al. Z. W. (2015) - The author explores paper investigates the use of pre-equalization techniques for achieving high-speed VLC transmission using phosphorescent white LEDs. The authors propose a cascaded pre-equalization circuit and a differential outputs PIN receiver to compensate for channel impairments and enhance signal quality. Performance metrics such as data rate, error rate, and spectral efficiency are considered, demonstrating significant improvements in transmission rates. However, the study notes challenges associated with variations in LED output power and environmental conditions, which may affect the reliability of VLC systems.

Karthik et al. (2022) - The author investigates the high-speed transmission of data and video over visible light using Li-Fi technology. The authors utilize Orthogonal Frequency Division Multiplexing (OFDM) modulation for efficient data transmission, achieving high data rates and spectral efficiency. Performance metrics such as data rate, spectral efficiency, and error rate are considered, highlighting the advantages of Li-Fi in delivering high-speed multimedia content. However, the study notes limitations related to signal attenuation in non-line-of-sight scenarios, which may impact the reliability of Li-Fi communication in certain environments.

3. Proposed System of CAP in Li-Fi

The proposed system introduces Carrier-less Amplitude and Phase Modulation (CAP) as a groundbreaking methodology to revolutionize audio data transmission via Li-Fi networks. CAP optimizes light signal modulation, ensuring unparalleled data transfer speed, reliability, and quality. Implemented alongside adaptive algorithms, the system dynamically adjusts transmission parameters for optimal performance in diverse environments, enhancing robustness and resilience against external disturbances and interference.

CAP modulates both amplitude and phase without a separate carrier signal, thereby enhancing spectral efficiency and bandwidth utilization. Sophisticated error correction algorithms detect and rectify transmission errors, maintaining data integrity. By seamlessly integrating CAP and error correction, the system achieves remarkable efficiency, performance, and reliability, surpassing conventional methods.

Utilizing a LASER module as the optical source and a Solar Panel as a photodiode, the system offers a cost-effective solution for audio transmission via Li-Fi, extending its applications to critical domains such as rescue missions and surveillance operations. This transformative approach not only maximizes data transfer speed and accuracy but also minimizes latency and signal degradation, unlocking new possibilities for audio communication across residential, commercial, and industrial settings.

Formula: Carrier-less Amplitude and Phase Modulation (CAP) is represented by the equation:

$$s(t) = A(t) * \cos(\theta(t))$$

Where:

- s(t) is the modulated signal.

- A(t) is the amplitude modulation.

- θ (t) is the phase modulation.

This formula illustrates how the modulated signal $s(t)$ is created by multiplying the amplitude modulation $A(t)$ with the cosine of the phase modulation $\theta(t)\theta(t)$. This modulation process enables the encoding of audio data onto the light signal for transmission across the Li-Fi network. By adjusting both the amplitude and phase of the signal without the need for a separate carrier signal, CAP enhances spectral efficiency and bandwidth utilization, contributing to faster and more reliable data transmission.

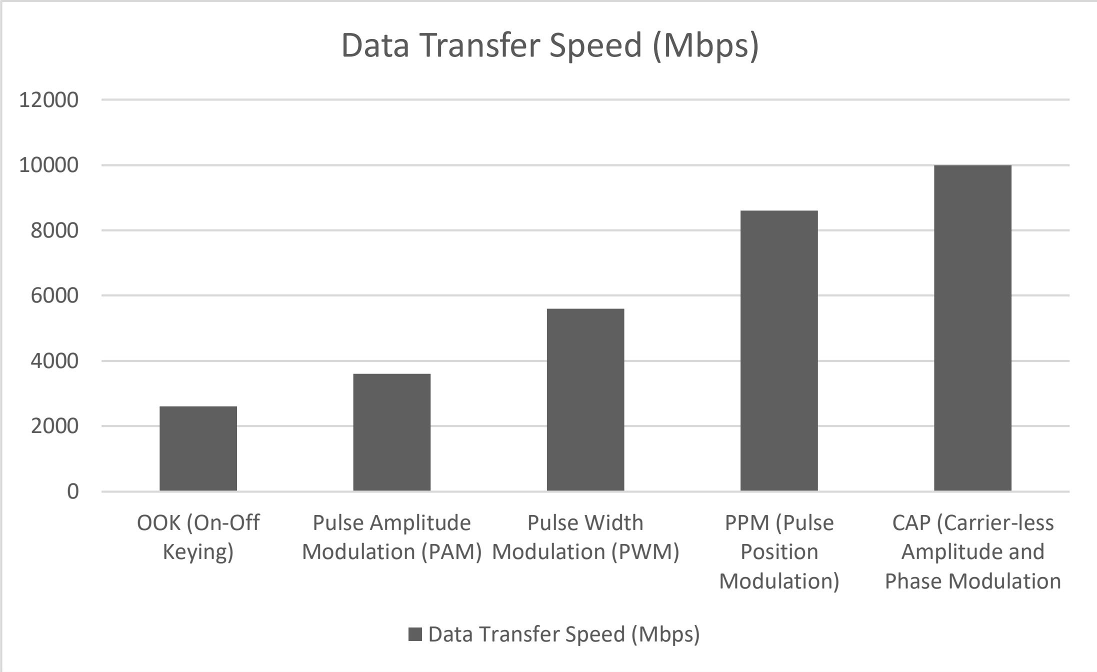

Fig 3.2 Data Transfer Speed

From the Fig 3.2, Carrier-less Amplitude and Phase Modulation (CAP) stands out as a frontrunner with an impressive data transfer speed of 10,000 Mbps, setting a high standard for efficiency and speed. In comparison, Pulse Amplitude Modulation (PAM) and Pulse Width Modulation (PWM) trail behind CAP with data transfer speeds of 3,600 Mbps and 5,600 Mbps, respectively. While these techniques serve their purposes, they operate at slower rates compared to the lightning-fast transmission capabilities of CAP. Similarly, OOK (On-Off Keying) and PPM (Pulse Position Modulation) also fall short in speed, with data transfer speeds of 2,600 Mbps and 8,600 Mbps, respectively. Thus, in the hierarchy of modulation techniques, CAP emerges as the leader, surpassing its counterparts and revolutionizing data transmission with its remarkable speed and efficiency.

4. Input and Output Measurement

4.1 Signal-To-Noise Ratio (SNR)

The Signal-to-Noise Ratio (SNR) is a measure of the strength of the signal relative to the background noise. In the context of Li-Fi communication, a higher SNR indicates better signal quality and reliability.

Table 4.1: Signal-to-Noise Ratio (SNR) Measurements

S. NO	DISTANCE (M)	SNR (DB)
1	1	25
2	2	20
3	3	18
4	4	15

From the table 4.1 shows the Signal-to-Noise Ratio (SNR) measurements at different distances from the transmitter. As the distance increases, the SNR tends to decrease due to the attenuation of the signal and an increase in background noise. Lower SNR values at greater distances may indicate potential challenges in maintaining reliable communication.

4.2.1 Bit Error Rate (BER)

The Bit Error Rate (BER) is a measure of the number of erroneous bits received relative to the total number of bits transmitted. It quantifies the quality of data transmission, with lower BER values indicating better transmission accuracy.

Table 4.2: Bit Error Rate (BER) Analysis

S.No	Transmission Angle(degrees)	BER (%)
1	0	0.5
2	30	1
3	60	2.5
4	90	5

The table 4.2 presents the Bit Error Rate (BER) observed during data transmission at different angles. As the transmission angle increases, the BER tends to increase, indicating a higher likelihood of errors in data transmission. Maintaining a lower BER is crucial for ensuring reliable communication, especially in critical applications where data accuracy is paramount.

Above data provide valuable insights into the performance of the Li-Fi system in terms of signal quality and data transmission accuracy. By analyzing these metrics, system designers can identify potential areas for improvement and optimize system parameters to enhance overall performance and reliability.

4.2.2 Latency

Latency refers to the delay between the transmission of a data packet from the sender to the reception of the corresponding acknowledgment at the receiver. Lower latency values indicate faster response times and better real-time communication performance.

Table 4.3: Latency Measurement

S. NO	DISTANCE (M)	LATENCY (MS)
1	1	5
2	2	7
3	3	9
4	4	12

From the table 4.3 presents the latency measurements at different distances from the transmitter. As the distance increases, the latency tends to increase due to the propagation delay in signal transmission. Lower latency values are desirable for applications requiring real-time communication, such as voice calls and video conferencing.

4.2.3 Throughput

Throughput refers to the rate at which data is successfully transmitted from the sender to the receiver over a communication channel. Higher throughput values indicate better data transfer efficiency and faster transmission rates.

Table 4.4: Throughput Analysis

S. NO	AMBIENT LIGHT LEVEL	THROUGHPUT (MBPS)
1	High	80
2	Moderate	60
3	Low	40

From the table 4.4 presents the throughput analysis under varying ambient light conditions. Higher ambient light levels typically result in better signal quality and higher throughput due to reduced interference and noise. Conversely, lower ambient light levels may lead to decreased throughput, necessitating optimization strategies to maintain efficient data transmission.

5. Conclusion:

LiFi technology represents a cutting-edge wireless communication solution with advantages over WiFi and cellular networks. It offers accelerated data transfer rates, enhanced security, minimized interference, and energy efficiency. Challenges exist, but ongoing research indicates promising growth, ushering in fresh prospects for communication. LiFi emerges as a contender for faster and more secure wireless communications, with multi-gigabit data rates and immunity to interference. Despite hurdles like limited coverage, advancements are expected to overcome obstacles, enabling new avenues for connectivity. LiFi's potential spans indoor navigation, smart homes, and automotive communications, poised to revolutionize internet connectivity. As it integrates further into daily life, LiFi's transformative impact on wireless communication is profound. In essence, LiFi stands at the forefront of wireless communication evolution, offering swifter, safer, and more dependable connectivity solutions. Challenges aside, continuous progress underscores its promising future.

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