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LiFi Technology Review

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ABSTRACT

Light Fidelity (LiFi) is a visible light wireless communication technology that addresses the challenges of 5G. This white paper covers the basic needs of LiFi over WiFi. It explains how LiFi works and gives a brief description of the various modulation techniques that LiFi technology uses for data transmission. It also provides an overview of the history of visible light communication technology from ancient times to the LiFi era. The paper described his application of LiFi in various fields that help expand new research areas for this technology.

Keywords—LiFi, Visible Light Communication (VLC), Light Emitting Diode (LED), Photo Detector

I.INTRODUCTION

Wireless data communication has become an integral part of our personal and professional lives. In recent decades, the demand for wireless communications has grown exponentially, making the radio spectrum below 10 GHz insufficient [1]. As the industry expands the wireless spectrum beyond 10 GHz, path loss will occur [1, 2]. According to the Fries equation LiFi2, L is the path loss and f is the frequency. Higher radio frequencies can create two other problems. H. Blocking and shadowing [1,2]. To solve such problems, radio waves are replaced with visible light [3]. LiFi uses LEDs for wireless communication. A single micro LED can transmit 3 gigabits per second [4]. The term LiFi was first introduced by Professor Harald Haas in his TED Global Talk in 2011 [5]. Disadvantages of radio waves compared to visible light pointed out by Professor Haas in the Global Talk are as follows.

1. Capacitance – Since the spectrum of radio waves is 10,000 times smaller than that of visible light [5], the capacity of radio waves is less than that of visible light.
2. Availability - sensitive locations such as hospitals, airplanes, etc.

Additionally, vehicle headlights and taillights can be used for data communication on the road [7].
1. Efficiency – 1.4 billion radio stations are used for wireless communication [7] and most of the energy is used to cool the base stations as radio waves give off heat [5] . LEDs, on the other hand, can not only illuminate a room, but also transmit data at the same time [8].
2nd SAFE - Visual lights are safer than radio waves because radio waves pass through walls and generate radio waves.

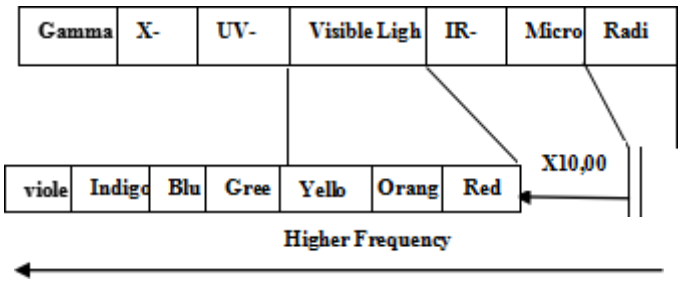

Figure 1. Electromagnetic Spectrum

On the other hand, visual light cannot penetrate walls [9].His four points above describe his need for LiFi over WiFi. II. Evolution of Visible Light CommunicationIn ancient times, visible light was used to send messages in the form of fire [10]. This section briefly describes the evolution of optical communication technology from semaphore line-based optical communication systems to LiFi.

Table I describes the journey of visual light communication.

TABLE I. HISTORY OF VLC

YEAR	DESCRIPTION
1790	Optical communication systems based on semaphore circuits were developed in France [10] during the French Revolution to enable faster and more reliable military communications.
1792	Claude Schapp of France, along with his four brothers, invented the first visual telegraph system [11,12].
Early 1800s	US military invented a wireless solar telegraph known as Heliograph [10], which reflect the sunlight in flashes with the help of moveable mirror [13].
1880	First wireless telephone was developed by Alexander Graham bell, which sent voice signal with the help of light beams [14], the device was named Photophone.
1930	Heinrich Lamm sent an image from a bundle of optical fibers but this idea was given by John Logie Baird in 1920 [15].
YEAR	**DESCRIPTION**
1970	Coming Incorporate (An American Multinational Technology Company) developed a single mode optical fiber [15]. GaAs (Gallium Arsenide) semiconductor laser was also developed around the same time which was used for long distance communication [10].
2003	The transmission of data using LED was first demonstrated at Nakagawa Lab, Keio University, Japan [10].
2011	LiFi term was first given by Prof. Harald Haas in TED Global Talk [5].

be noticed by human eye and the core functionality of LED is not muddled [7].

Figure 2 shows that the information is transmitted in the form of signals from transmitter to the data modulation unit where it is converted to digital signal by using different modulation techniques, then LED transfers the information in binary form by using visual light. This visual light is captured by photodetector where the light signal is converted to electric signal [8] and this electric signal is demodulated in the demodulation unit and then finally received by the receiver.

WORKING PRINCIPLE OF LIFI TECHNOLOGY

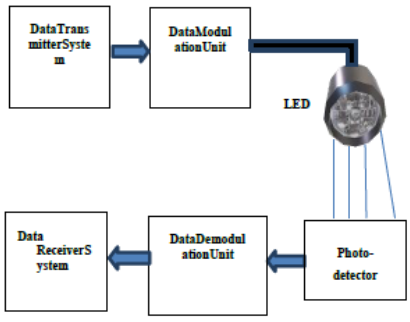

Figure 2. Basic Working Methodology of LiFi

LiFi uses the visible light spectrum for optical wireless communication. The visible spectrum ranges from 300 GHz to 700 GHz [2]. Visible light is used in our daily life because the human eye can only see the wavelengths of visible light

among electromagnetic waves. Visible light communication is based on the binary system, sending a '1' when the LED is on and a '0' when it is off [16].

IV. The phenomenon of LEDs turning on and off cannot be too vivid. Modulation technique used by LIFI

. Many modulation techniques developed for radio communication have been modified for optical wireless communication [17].
A. Single Carrier Modulation - In this type of modulation, data is carried by a single main carrier. This technique is more energy efficient than multicarrier modulation [1]. The single carrier modulation techniques [1] most commonly used in wireless communications are:
• ON-OFF Keying (OOK)
• Pulse Position Modulation (PPM)
• Pulse Amplitude Modulation (PAM)
OOK is one of the best known modulation schemes, also known as Amplitude Shift Keying. increase. OOK indicates a 0 bit when not signaled and a 1 bit when signaled. OOK has two drawbacks. (a) susceptible to additive white Gaussian noise [2] and (b) unable to achieve high data rates [17]. At
PPM, the amplitude and width do not change, and the position of the pulse changes according to the reference pulse of the input signal [2]. PPM is more energy efficient and less spectrally efficient than OOK [1].
PAM maps signal data to select LEDs [17]
It is a secure modulation technique in optical communication systems for the following reasons [18].
(a) advantage of low complexity, (b) flexible implementation, (c) simple structure.
B. Multicarrier Modulation - OOK, PPM, and PAM are not suitable for high data rates. As data rates increase over LiFi networks, all the above techniques suffer from problems such as nonlinear signal distortion and intersymbol interference [1]. 19]. For these reasons, multi-carrier modulation techniques are gaining traction for high-speed communications [17]. It is also more bandwidth efficient than single-carrier modulation [1]. The most commonly used multicarrier modulation technique in optical wireless communications is [17].
• Orthogonal Frequency Division Multiplexing (OFDM)
• Wavelength Division Multiplexing (WDM)

• Multiple Input Multiple Output Techniques (MIMO)
OFDM technology is based on the Fast Fourier Transform [20]. Therefore, the implemented signal processing is computationally efficient. In OFDM, data streams are transmitted simultaneously using orthogonal subcarriers [1,16]. The communication channel is divided into subchannels equal to orthogonal subcarriers [16].
C. Specific Modulation for LiFi Color Shift Keying (CSK) Modulation is a specific intensity modulation technique for visual light communication [19]. Using a yellow phosphor and a blue LED to produce white light reduces the LED's switching ability [10]. Another way to generate white light is to use three different LEDs, red, blue and green [1,10]. CSK's prerogatives [1] over traditional intensity modulation techniques include:
This modulation scheme improves the data rate compared to other modulation schemes.

V. Literature Review

In this section, we have discussed some existing research on LiFi technology to help us better understand the recent growth of LiFi.
A visible light image transmission approach was proposed by Mahendran [8]. He used an ARM microcontroller with serial communication capabilities for data transfer. His
image transmission using LiFi technology was also discussed by Mohit Vasuja, A.K. Mishra et al. Proposed. [2]. The authors used infrared (IR) light for image transmission and a photodiode for image reception. The selected image is first converted to black and white format and scaled to fit the size of the graphical liquid crystal display (GLCD). The microcontroller converts the image data into binary format using OOK modulation technique. IR-LED transmits the binary data received from the photodiode. Then in the decoding unit the microcontroller converts the binary data and displays the image on his GLCD. Performance is evaluated by calculating bit error rate (BER) and bit rate (76,800 bps). Enables vehicle-to-vehicle (V2V) communication using the headlights and taillights of cars running on the road. By using V2V communication, it can detect emergency vehicles such as ambulances, fire engines, and police cars, send warning messages to traffic lights, and help control traffic.
If developed in the real world, emergency vehicles could arrive on time and save many lives. In the paper [7], an emergency vehicle detection and clearance system was proposed.

Today, many researchers are investigating various areas of underground mining processes where visible light communication is more efficient than his WiFi. Many people are injured or die in mines for many reasons, such as falling rocks, negligence, and banging. Many tragedies could be averted if these people were warned in a timely manner.Communication via radio waves is not suitable for mining, as there are many environmental problems in which radio waves are interrupted. Therefore, the authors of this paper proposed a decision-making system that uses various

sensors to make the right decision and uses Light Fidelity to transmit that decision to kill people in mines. The combination of IoT and LiFi technologies is growing rapidly. IoT is a framework that embeds sensors in physical devices to collect data and transmit it over networks. Today, LiFi technology is preferred over WiFi technology for sharing data. Jayant, Swapnaja, and Roopali [22] proposed a system that acts as an intermediary between cloud service providers and organizations that use the cloud to store their data. IoT devices are used to collect real-time and continuous data to make better business decisions and improve customer satisfaction. In certain systems, data stored in the cloud is encrypted using the ASE algorithm, a 128-bit symmetric key encryption algorithm.
A role-based access control approach is used so only authorized clients can access the data.
Another application based on VLC was developed by his Xiaoxuan Qi, Li Du et al. [23] was developed. They developed glasses for the visually impaired to solve the problem of arranging objects indoors. A microcontroller unit is used to store the position coordinates of indoor objects. LEDs transmit these coordinates in the form of light signals. The optical signal is converted into an electrical signal by the receiver and the current position is recorded. The glasses are equipped with an audio player to guide the visually impaired to the location of indoor objects. To avoid external noise, the glasses are equipped with a headphone function. It also has a charging port for artificial charging and can also be charged with solar energy. With the help of LiFi technology, this technology uses solar panels to receive light so it can harvest energy.
PK Sharma, Y.S. John Unt J
H. Park [19] proposed a smart home and industrial communication model based on a combination of energy harvesting wireless sensor networks (EH-WSN) and hybrid LiFi/WiFi communication technology. This is called the EH-HL model. In this model, energy is derived from renewable sources such as thermal energy, solar energy, and wind power, and used for wireless sensor networks. Combining LiFi and WiFi technology, data is transmitted at high speed for two-way multi-device.
modulation technology will play an important role in the further development of LiFi technology. Various modulation techniques have been developed as described in Section IV. M.D. Soltani, Harald Haas et al. [17] proposed a two-way

optical spatial modulation technique for his mobile users. Their study examined the effects of mobility, random orientation, and blocking on LiFi network performance. The problem of high channel correlation was solved by using a Multidirectional Receiver (MDR) on the downlink and a Multidirectional Transmitter (MDT) on the uplink. The results analysis in this paper shows that MDR/MDT offers excellent performance in terms of signal-to-noise ratio (SNR), bit error rate, and power efficiency. LEDs are used not only for communication but also for lighting, so the better the light quality of the LEDs, the better.
After applying different modulation techniques, the light quality can be measured in three aspects [24]. -
• Correlated Color Temperature (CCT).
• Chromaticity.
• Color rendering index (CRI) metric.
Evangelos and Waisu [24] developed a framework for finding the effects of modulation techniques on the light quality of LEDs. We also discussed the relationship between LED operating current and light quality.

vi. CHALLENGES OF LIFI TECHNOLOGY

Everything in this world has two sides. One is a success and the other is full of challenges. Similarly, the LiFi concept has two sides. While it helps in efficient and secure data transfer, there are some issues that need to be resolved.
A review of the available literature on LiFi reveals the following challenges to the LiFi concept:
A Flicker – This is the effect caused by switching LEDs on and off because they are playing two roles at the same time: illumination and communication [25]. When data is sent from an LED, variations occur due to the ON-OFF modes that affect the lighting process of the LED. This is one of the biggest challenges for LiFi to overcome as flicker affects human vision.
B. Line of Sight – LiFi efficiency can only be achieved with line of sight communication.
Communication errors can occur if one of the receivers/transmitters moves from its intended position [7].
C. Interference from external light sources can disrupt communication processes [26].
D. Light cannot penetrate walls or solids, so individual LEDs must be used for each room. For the bright future of LiFi technology, we need to solve the above challenges. This technology is one of the development technologies for data transmission. Researchers are very keen to solve all the above problems to make LiFi
technology efficient and successful.

VII.Application

LiFi is an alternative to Wi-Fi as it provides high speed internet as Wi-Fi. Therefore, LiFi can replace all areas where WiFi is used, but this section only covers areas where WiFi is not allowed or serviced.
A. In hospitals: WLANs are not allowed in sensitive areas of hospitals for the following reasons:
• May interfere with medical equipment.
LiFi uses light for data transmission, so LiFi can replace WiFi in medical applications for safety reasons
B. By Air: When traveling by air, flight crew will ask you to keep your mobile phone in airplane mode as radio

frequencies can interfere with the aircraft's navigation system. LiFi is therefore a secure alternative to her WLAN on board the aircraft.
C. Underwater: WiFi technology fails completely for underwater communication because radio frequencies are easy to carry underwater. A Tethered Remotely Operated Vehicle (UTROV) is used for underwater communications [10]. UTROV is an application of VLC technology.
D. Disaster Preparedness: In the event of a natural disaster such as an earthquake, tsunami, or hurricane, your WiFi may not work as towers may warp during a natural disaster. Covers a wide area as a single tower. LiFi can easily replace his WiFi if LED bulbs are used for street lighting. Because street lights are placed a few meters away. So the communication system is alive after a natural disaster. The idea of using streetlights to transmit data can be used to build smart cities
E. On Defense:

Defense is the fourth pillar of India's development. Providing a secure communication system for defense is very important. Jammers can block radio frequency signals and cause disturbances in communication systems. LiFi technology uses light that jammers cannot block.
LiFi is the most secure and effective alternative to WiFi in all of the above areas.

VIII. Comparison

This section describes the comparison of LiFi and WiFi in technical terms: -
• IEEE Standards: -802.15.7 is the IEEE standard for LiFi and 802.11b is the IEEE standard for LiFi. Standard. WiFi [27].
• Network Topology: LiFi uses point-to-point topology, while WiFi uses point-to-multipoint topology.
• Bandwidth: LiFi's frequency band is 100 times greater than terahertz, while WiFi's is only
2.5 GHz [27].
• Range: LiFi can be used within a range of 10 meters, while WiFi range is approx.

CONCLUSION

A survey of existing research on LiFi technology concluded that visible light could be used as a medium for wireless data communication. Safer and more efficient than WiFi technology. As this technology gains global acceptance and challenges are overcome, we are moving towards a faster, greener and more secure wireless future.

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