An Overview of Secure Li-Fi and Wi-Fi Hybrid Network

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Visible light technology, also known as Light Fidelity (Li-Fi), is a sort of wireless connection that transmits data using LED lights as part of optical wireless communication technology, at a speed that could theoretically reach 224 Gbps. The findings of the study highlight how the combination of LED (Light Emitting Diode) bulbs with Li-Fi technology for Internet of Things networks and cloud applications, Since Li-Fi technology is one of the solutions suggested for the electromagnetic spectrum's saturation, the analysis that has been provided surrounding its integration with Wi-Fi enables us to comprehend the significance of the study done on this technology. The degradation of the signal caused by Wi-Fi in Wi-Fi networks due to their integration with IT makes it challenging to connect devices farther away from the access point. However, improving the overall network coverage is possible by constructing hybrid Wi-Fi and Li-Fi networks. This research presents an approach framework for data transfer using both Li-Fi and Wi-Fi technology where the data throughput, BER (Bit Error- Rate) distribution, SNR (Signal to Noise Ratio), and access points with data rate were subsequently analyzed and improved. It has also been observed that hybrid wireless communication can be accomplished significantly more quickly than Wi-Fi (Wireless Fidelity) alone by evaluating the set parameters (no LED, dimension, users, etc.).Lastly, the simulations were gathered by using NS2.

Keywords: Data rate, LIFI LED, WIFI, SNR (Signal Noise Ratio), BER (Bit Error Rate)

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1. Introduction

The amount of mobile data traffic is anticipated to hit 77 2022 Exabyte per month, with smart technologies contributing 90% of mobile data consumption globally and 80 percent of the total data activity occurring indoors. Although wireless communication technologies including wireless fidelity (Wi-Fi), BT, LTE (Long term evolution), 5G, and 6G are steadily improving in terms of competition and advancement channels since the restricted radiance of radio frequencies resource. [2][22]Li-Fi and Wi-Fi Hybrid Networks, which will achieve a higher Quality of Service than standalone Wi-Fi and Li-Fi, can be offered as a solution to combine high-speed and secure Li-Fi with the wide coverage of Wi-Fi. [34][40] This study on hybrid Li-Fi and Wi-Fi aims to integrate Li-unlimited Fi's spectrum, fast data transmission, and secure privacy with Wi-coverage Fi's and signal dependability.[7] The signal Transmission based on Wi-Fi and LIFI is shown in Figure 1 and the representation of a hybrid Wi-Fi and LIFI network is shown in Figure 2.[20]

Fig. 1. Wi-Fi & Li-Fi Signal Transmission.

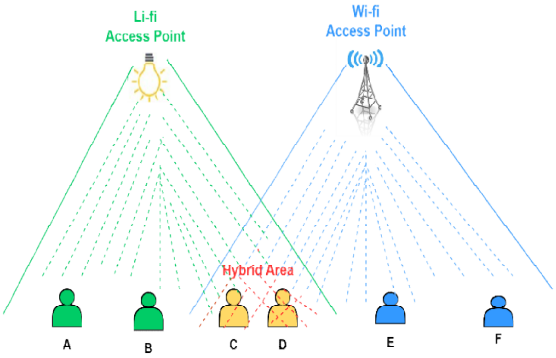

Fig. 2. Hybrid Wi-Fi-Li-Fi Network.

Ensuring reach through a hybrid network gives Wi-Fi-Li-Fi: One of the main drawbacks of Wi-Fi

A hybrid Li-Fi/Wi-Fi network comprises central units (CUs), which combine the two separate networks, and bi-directional communication transceivers for both Li-Fi and Wi-Fi links.[18] [19]Each user in the dual network has a PD to receive both Wireless Internet and Li-Fi signals and an RF antenna.[31][27]

Lighting as a Service (LaaS): Smart lighting is currently on the rise thanks to the Signify Company and its Interact platform, since it allows managing networks of sensors connected to LED lighting, however, thanks to the development of Li-Fi, the concept of LaaS has been created [10][23]. LaaS is the result of the convergence of several technologies: bright lighting, cloud services, IoT, and Li-Fi [33,

34], to achieve greater efficiency and less negative impact derived from the use of energy for lighting. The representation of LaaS representation is shown in Figure 3 respectively [40].

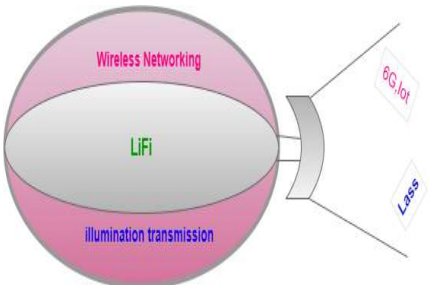

Fig. 3. Light as a service (LaaS).

1.1 Integration of Li-Fi & Wi-Fi

- Implementation of a robust and flexible standard for Li-Fisystems.
- Increase servicecoverage.
- Study of multiple access techniques in a mobile usernetwork.

Applications of Li-Fi integration with the Internet of Things
As connected devices expand, a variety of applications that take full advantage of Intelligent technology emerge through Li-Fi, applications have been made for academic purpose sand various possibilities are being considered for the future in different environments. Below are examples of application environments for Li-Fi integrated with IoT [17, 21]. The representation of the integration of the Internet of Things into smart cities is shown in Figure 4 respectively.

The integration of Li-Fi with IoT also presents challenges and challenges in various aspects such as security, solutions for outdoor sunlight environments, or the hardware components used in the emitting and receiving device, that is why work and research on Li-Fi to take advantage of all the benefits of the visible light spectrum, to spread its operation globally and generate a great demand for the Li-Fi devices that are currently on the market., reduction of energy consumption, and efficiency of telecommunications[25].

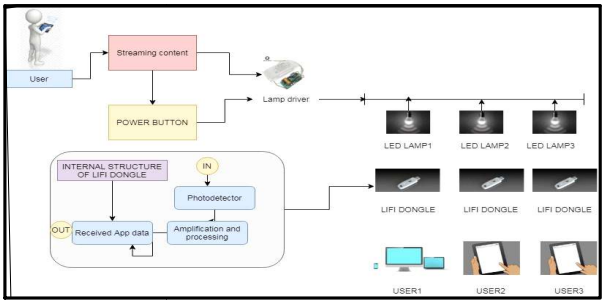

Fig. 4. Integration of the Internet of Things to smart cities.

Motivation to work
In some circumstances, choosing Li-Fi (Light Fidelity) instead of Wi-Fi (Wireless Fidelity) can be advantageous. Li-Fi is an intriguing alternative in some situations since it uses visible light communication, also known as VLC, to send data using LED light sources.[3] Listed below are some

reasons to choose Li-Fi over Wi-Fi. Compared to conventional Wi-Fi, the Li-Fi framework offers the possibility to offer much greater data transfer speeds. High-frequency modulation of visible light makes it possible to achieve data speeds that are greater than that utilized by numerous Wi-Fi implementations. [16]Li-Fi can thus be used for operations that need quick data transfers, like streaming high-definition video, transferring huge files, and data-intensive projects.[26] As related to the microwave frequency spectrum utilized by Wi-Fi along with other wireless communications systems, the electromagnetic range employed in light that is visible communication is significantly bigger and less crowded. This greater spectrum accessibility may result in better spectral efficiency and less interference, which will boost network capacity and improve connection reliability.[15][6]

As we know Li-Fi uses visible light for communication, and it has built-in security advantages.[36][37] The possibility of eavesdropping and unwanted usage of the network is decreased because visible light cannot pass through walls.[39] Li-Fi is thus especially well-suited for locations that demand secure connection, such as hospitals, military bases, and financial organizations.[30][35] Li-Fi uses visible light to function, which isn't disruptive to sensitive RF devices. This is advantageous in locations in which electromagnetic radiation needs to be reduced, such as hospitals and airplanes. [14]Some delicate situations, including hospitals and labs, call for technology that is immune to electromagnetic interference. As a light-based technology, Li-Fi does not produce electromagnetic interference that can interfere with nearby delicate electronics.[21] The possibility of data leaking to unwanted recipients is decreased if Li-Fi signals are restricted to the region that the light source illuminates. Li-Fi can therefore be used in situations where preserving data privacy is essential. [41]LED illumination, a vital component of Li-Fi technical advancements, is energy-efficient and environmentally benign. Initiatives for energy conservation and sustainability can benefit from using LED lights for communication and illumination. Infrared light, which is irradiating and usually regarded as harmless for human health, is a component of Li-Fi.[10] This may be helpful in settings where reducing electromagnetic radiation exposure is a concern. Using Li-Fi can help reduce RF congestion and enhance overall network performance in congested urban areas or locations with a significant number of Wi-Fi networks.[46]

It's crucial to remember that while Li-Fi has these advantages, it additionally comes with its own set of restrictions and difficulties, including the requirement for direct line-of-sight, a constrained range, and mobility-related problems. [5]Instead of completely replacing Wi-Fi, Li-Fi is intended to supplement it in some use cases when its special advantages match the demands of the surroundings.[48] [50]

Problem identification
Several problems need to be identified consisting of high obstacles and line of sight, limited signal range in the network, ambient light source for LIFI, mobility and flexibility, high installation and infrastructure cost, high security and privacy, compatibility and standardization, and high use.[8][32]

2. Literature Review

Cite	Objective	Method	Result	Strength and Weakness	Gaps
44	Physical testbed environment for different indoor scenarios and evaluate its data rate and handover latency performance.	Hybrid Li-Fi/Wi-Fi Network demonstration.	A hybrid Li-Fi/Wi-Fi network's performance is evaluated in terms of Its bit rate and handover latency.	HLWN would provide a higher average rate to static users	The hybrid LiFi/WiFi network performs better in terms of average data rate.
46	The MALB-KKOA model computes an objective function for the minimization of packet loss and delay.	MALB-KKOA technique	The minimization of The packet loss ratio and latency.	The enhanced performance of the MALB-KKOA model	No vertical handover is performed.
	Designing the framework for network	Cross-network technologies	High-speed Li-Fi data	Wi-Fi and Li-Fi networks can mitigate	The aggregate system throughput of Wi-Fi

9	architecture, cell implementation, multiple access and modulation schemes,		transmission and extensive Wi-Fi coverage.	each system's limitations and improve overall system performance,	is limited, and the user The data rate is poor.
43	binary classification problem and (ANN)-based handover scheme	A Novel Handover Scheme (HLWNet)	The suggested approach can reduce The transfer rate by up to 80%, cuts the packet latency by 57% and boosts throughput by about 65%.	significantly increase user throughput by 20.5 – 46.7% and reduce handover rate by around 59.5 – 78.2% as	previous work HLWNet as a pattern recognition problem, More specifically a binary classification problem
47	increases network coverage and enhances the efficiency of mobile devices either within the macro hot spot region or during disaster areas like hurricanes.	The efficiency assessment in MATLAB demonstrates the traditional models for radio frequency relay in hybrid communication	Indoor and outdoor Communication	Throughput gives 90%, f cell load has obtained 75%, and packet throughput in terms of speed has the value of 93%.	we endow with the challenges about the ambient backscatter communication network.
48	Meanwhile, load balancing becomes a challenging issue due to a complete overlap between the coverage areas of LifI and Wi-Fi	Algorithm based on fuzzy logic	The proposed approach can improve system throughput by up to 68%, while achieving very low computational complexity	A novel algorithm based on fuzzy logic is also proposed to reduce the computational complexity that is required to Solve the optimization problem	When users move faster or light-path blockages occur more frequently, the throughput gap between the proposed method and ILB enlarges, reaching up to 68%
13	improve throughput by up to 90% over The conventional load-balancing method	Novel LB	Compared to current LB approaches, the system throughput	The throughput achieved by the proposed method hardly varies with the value of handover overhead.	the proposed method formulates the issue as an optimization problem that maximizes the system throughput over some time

3. Proposed Methodology

The proposed methodology integrates EH-WSNs with hybrid Li-Fi/Wi-Fi communication protocols to secrete a novel EH-HL paradigm for the next generation of intelligent houses and enterprises. "Internet of Things" is the target audience for this design. (IoT) [29] The proposed paradigm could provide high-velocity data transfer for multi-device bi-directionality and energy harvesting for sensor node operation. The relationship model works in both directions. A low-cost wireless connection was made possible by using RGB LEDs to coordinate device transmissions, transfer data, and establish a wireless connection. To accomplish this, it will be necessary to both reduce the sensor node's energy usage and locate a different energy source.

Based on EH-WSN and hybrid Li-Fi/Wi-Fi techniques, we offer an effective EH-HL communication paradigm for smart homes and industries. The needs of the Internet of Things are met by this design (IoT).

An effective and affordable hybrid Li-Fi/Wi-Fi communication paradigm for the smart residential and industrial sector based on EH-WSN. [29]For this reason, it is suitable for two-way communication between various devices because of its efficient data transfer capabilities and high transfer rate. Sensing nodes are powered by a solar panel network by converting modulated light into an electrical signal [11]

To synchronize device transmissions, transfer data, and enable inexpensive wireless communication, the scientists suggest adopting RGB LED color beams.[21] Multiple Radio frequency-powered relays based on a hybrid Wi-Fi and Li-Fi network to secure data transmission consist of two mechanisms that operate simultaneously using their different methodology according to their respective characteristics but tend to get a result simultaneously by analyzing each condition of a node in a step-to-step manner.[44][26]The descriptive block diagram shown in Figure 3 below shows the complete flow of the transmission channel.[38]Multiple radio frequency-powered relays function consists of two processes that operate simultaneously using their separate methodologies but tend to get a result simultaneously by:

3.1 Initialize the system

1 Node initialization for its respective channel propagation.
2 The link between the complete systems tends to get established through the proper transmission of data established before applying the following hybrid theory.[9]
3 Hybrid functions (Wi-Fi and Li-Fi) networks methodology established from which all the resulting conditions tend to get applied according to their desired condition and behavior.[13]

For Wi-Fi

- Dynamic layout for link generation through which the system tends to produce modulates start [10] and then move to data transmission for another level.
- Convert the resulting source of desired data to frame through frame creator by applying a band bass filter through which it stops unwanted propagative data and passes only the desired range.
- After passing through all these steps the resultant data moves to the transfer block for final propagation

For Li-Fi

- The layer of link tends to get established by passing it through the EH-HZ model that satisfies the necessity of the depending on frequency response system.
- Transfer of data took place to propagate the data after extracting out from the resulting module solution and then the data moves for final propagation.

4 After getting passes the data from both the frequency modulation techniques data tend to get moved into another layer of the propagation module
5 Now, pass the resultant signal to the low pass filter to eliminate the remaining contradictory or unwanted signal from the mechanism.
6 Then move to another level of data acquisition to gather the initial level and module of the data.[43]
7 After completing all the steps, finally the data is properly received, and then it must be acknowledged by checking its parameter and domain match from the initial signal. The representation of the block diagram of the proposed approach is shown in Figure 5.

3.2. Wi-Fi and Li-Fi Modeling

A hybrid network includes two-way transceivers, Li-Fi, and Wi-Fi with a control device that merges their functions. Limitations, strength, privacy, and unwavering quality are all provided by the hybrid system, which is essential in the context of the constantly evolving Internet in terms of linked devices and data flow. The next part details the EH-HL communication strategy to initiate the dialogue EH-HL model sends connection requests per the EH-HL model. After receiving a request from the sensor,

the controller will begin associating it [29]. After that, the controller's blue response frame sends the sensor initialization confirmation.[42]

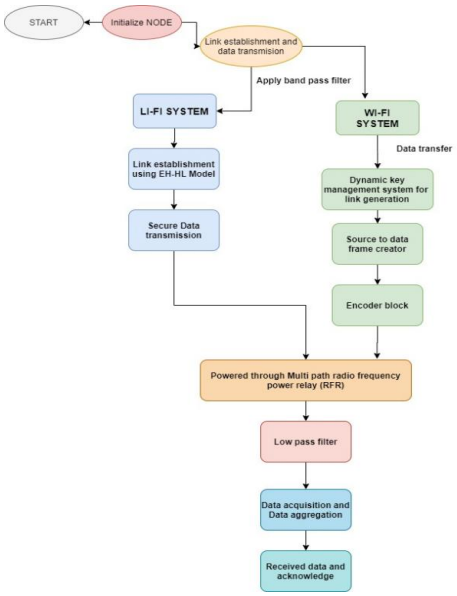

Fig. 5: Block Diagram of Proposed Approach Layout.

To analyze further a working mechanism is shown in Figure 6 which shows the propagation path between the user and the EH sensor.

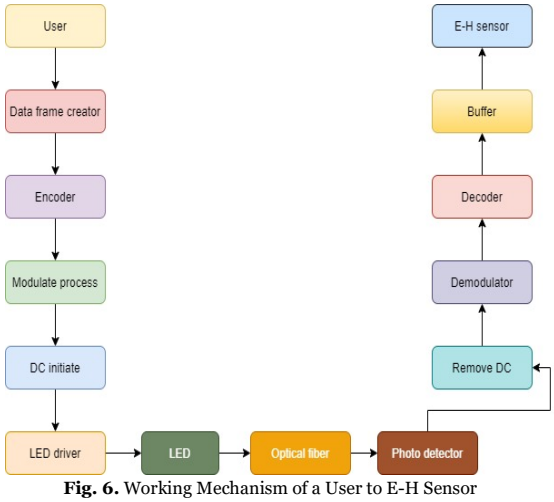

Fig. 6. Working Mechanism of a User to E-H Sensor

As shown in Figure 6 the propagation path follows the certain characteristics

1 As shown in the block diagram, the method begins with a user sending data for the data frame maker to extract into the frame. From there, it continues to another layer.
2 The extracted data finally moves to encode to prevent tapping and therefore the data gets coded into a secretive solution.
3 After passing it from encoding the resultant data is said to get modulated, by applying properties of modulation.
4 Now, DC bias is set to get initiated.
5 Then, it moves to the LED driver to ignite the place LED in the system methodology.
6 Connected optical fiber sends the resultant signal to a photodetector which is in the reverse bias condition
7 Then, remove the dc bias from the process.
8 The resultant signal then moves to the demodulator to extract the original process.
9 A buffer is placed to sort the required generated signal.
10 Finally, the data moved to the E-H sensor.
11 The set of parameters used for this research is shown in Table 1.

Table. 1. The evaluation parameter required.

Parameter	Value
Transmission room required area	9m*9m*2m
Receiver end	3 from the ceiling and 0.3 margins above the ground
Tx. Receiver position	{2m,2m,3m}, {2m,7m,3m}, {4m,4m,3m}, {7m,2m,3m}, {7m,7m,3m}
LED emission power	55mW
Angle view at the receiver end	73°
No. of LED (red, green blue)	450
Photodiode(l*b)	Approx. 1(cm*cm)

4. Discussion

However, each technology also comes with its limitations that need to be carefully considered based on the specific use case and security requirements. Integrating security mechanisms between Li-Fi and Wi-Fi can be challenging due to their distinct communication methods and protocols. [24]Achieving secure handovers between Li-Fi and Wi-Fi networks as users move between areas covered by different technologies can be complex.

A secure and efficient key management system needs to be established to ensure the confidentiality and integrity of transmitted data in both technologies.[28] Maintaining consistent security policies across both Li-Fi and Wi-Fi networks is crucial.[47] [49] User behavior can impact the overall security of the hybrid network. Interference or jamming attacks targeting Wi-Fi networks could still disrupt Li-Fi communications in shared environments integrating and maintaining security measures for both technologies in a hybrid network can be complex. [4]

The comparison of the previous studies is mentioned in Table 2 and the diagrammatic representation is shown in Figure 7 respectively.

Table. 2. Comparative Analysis of Different Techniques in Li-Fi and Wi-Fi

Author	Year	Index	Technique	Wi-Fi	Li-Fi
Zhihong Zeng et.al	2020	IEEE	1.OFDM 2.CSMA/CA	√	√
Ardimas Andi et.al	2019	IEEE	OFDM		√
Xiping Wo et.al	2019	Optical communication on Networking	HLW Nets MALB-ST MALB-MT	√ √	√ √
Young Sik Jeong et.al	2018	IEEE	EH-WSN	√	√

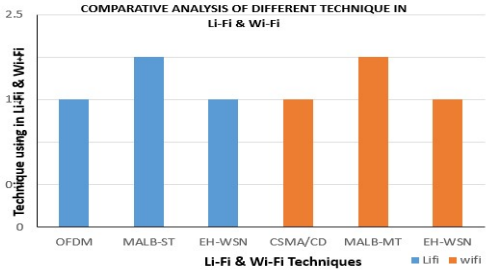

Fig. 7. Comparative analysis of Different Techniques in Li-Fi &Wi-Fi.

5. Results

EH-Sensor retrieves information from the buffer that was previously stored by the sensor node. To create the distributed information chip and determine the device's code length, the input data stream of each gadget is dispersed. A sequential data stream is generated by multiplexing the data chips in the devices. Before modulation of the data processors for transmission, the controller generates a data frame using the circuits under the mentioned frame structure.

For the suggested hybrid communication strategy in the EH-HL model, simulated and analyzed indoor and outdoor environments. [24][45] Experimental measurements were made to determine the proposed hybrid system's data rate and average BER (bit error rate).[12][1] To create and analyze the proposed model's performance, we employed a simulation on MATLAB/NS2, where a program like OptSim can also be employed in. As a result, we developed our own MATLAB/Network Simulator 2 methods to perform a co-simulation using NS2 by using the evaluated parameter that is mentioned in Table 1 efferent. We have performed three experiments on BER (Bit error rate), SNR (Signal noise ratio), and the number of accessible users where the relation of these parameters is compared with the data rates.

It has been observed that there was a variation between the data rates. While comparing data rates and the number of users, it has been seen that at a stagnant rate, the no of users can be accommodated and can use the service. It has also been observed that a powerful signal compared to

noise results in a signal that is cleaner and more dependable. This is shown by a greater SNR. A lower SNR, on the other hand, denotes that noise predominates and may cause inconsistencies and loss of signal. The representation of the data rate to several users is shown in Figure 8, the representation of the data rate and the chosen access points is shown in Figure 9, and the representation of bit error rate and the signal noise ratio is shown in Figure 10 respectively.

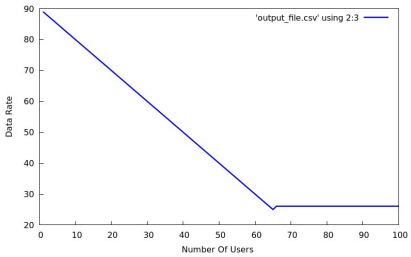

Fig. 8. Relationship between data rate and the number of users.

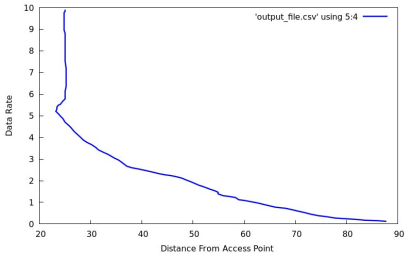

Fig. 9. Relationship between data rate and distance from access points.

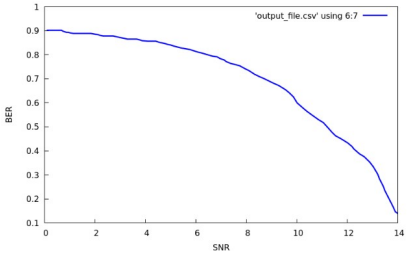

Fig. 10. Relationship between BER and SNR.

6. Conclusion

The EH-HL MODEL approach and DYNAMIC KEY management system provide both transmission and support and end-user security. The paper deals with the unique communication Hybrid Li-Fi/Wi-Fi transmission model by integrating EH-WSN, to make smart homes and businesses more effective and environmentally friendly for the Internet of Things. The simulation's results show that, in terms of the data throughput and BER distribution, the suggested methodology is reliable and efficient for multi-access in commercial and smart home settings. Simulation results demonstrate that the hybrid networks use high security, throughput also packet drop ratio. There are several potentials for future

study in this field, including the ability to examine security issues in outdoor settings and improve the modulation scheme's ability to handle many users and IoT devices.

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