Utilizing Li-Fi Transmission for IoT Devices to Strengthen Indoor Security

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CERTIFICATE OF APPROVAL

The department of Electronic and Telecommunication Engineering at International Islamic University Chittagong has accepted the thesis titled "Utilizing Li-Fi Transmission for IoT Devices to Strengthen Indoor Security" as satisfactory in partial fulfillment of the requirements for the degree of Bachelor of Science.

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DECLARATION

It is hereby declared, this work has been done by me, and no part of it has ever been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

With the exponential growth of the Internet of Things (IoT) and the increasing demand for secure indoor environments, there is a pressing need to develop efficient and reliable security solutions. This thesis proposes the utilization of Light Fidelity (Li-Fi) transmission technology to enhance indoor security for IoT devices.Li-Fi can be used to transmit data between IoT devices without the need for radio frequency (RF) signals, as radio frequency can be vulnerable to interference and security issues. This makes Li-Fi a potentially more secure and efficient means of communication for IoT devices, especially in scenarios where RF signals are not permitted. It leverages the existing lighting infrastructure to provide high-speed data transmission while ensuring enhanced security and reduced interference. By utilizing the unique properties of light, Li-Fi enables secure, reliable, and energy-efficient communication in indoor environments. This research investigates the potential of Li-Fi transmission as a security-enhancing mechanism for IoT devices. It explores the challenges associated with securing IoT networks and identifies the limitations of existing security protocols. The experimental evaluation of the proposed security mechanisms involves the design and implementation of a Li-Fi-based transceiver for IoT devices. Through a series of comprehensive experiments and simulations, the performance, reliability, and security aspects of the proposed solution are evaluated and compared against existing approaches. The findings of this thesis contribute to the body of knowledge surrounding IoT security and Li-Fi technology.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

Li-Fi	Light fidelity
Wi-Fi	Wireless fidelity
IoT	Internet of things
CVNI	Cisco virtual network index
RF	Radio frequency
IIPs	Internet infrastructure providers
SP	Service provider
VLC	Visible light communication
FSO	Free space optics
owc	Optical wireless communication
FCC	Federal Communications Commission
HLWNet	Hybrid Li-Fi Wi-Fi network
Ap	Access point
LED	Light emmiting diode
NFC	Near field communication
RFID	Radio frequency identification

CHAPTER 1
INTRODUCTION

1.1 Introduction Li-Fi technology and IOT devices

Over the last two decades, there has been exponential growth in the number of mobile devices. As per the report of CISCO visual network index (CVNI), by 2023, around 70% of the world population will have mobile phones [1]. The increase in mobile phones is coupled with an emphasis on exploring new use cases for mobile/cellular networks like the internet of things (IoT) devices. Data consumption is anticipated to rise exponentially as a result of the mobile networks' quickening size and scope expansion. According to the CVNI, approximately 48% of IoT traffic and 80% of all other mobile traffic will come from inside locations [2]. Since the turn of the 20th century, the Internet has become fundamental to everyone's existence [3]. We feel the urge to use the internet to connect with others around us at all times. One of the main goals of utilizing the Internet is to exchange information. A concept first surfaced in 2011 when physicist Harald Hass of the University of Edinburgh in the UK put up a theory illustrating how LI-FI might revolutionize wireless communication [4]. He demonstrated data transmission using illumination. A new technique called LI-FI uses visible light rather than radio waves [5]. A benefit of LI-FI for 5G communication is that visible light communication systems using LEDs can be used for medium- to high-speed communication that is significantly quicker than WI-FI. All facilities, including seminars, banking, shopping, and online payments, can be accessed through the Internet in this period of developing technology. As a result, the use of wireless communication has dramatically increased [6]. Technology has also shown itself to be a huge benefit for IOT devices. Devices can now communicate with one another via data. The incorporation of Li-Fi (light fidelity) technology with Internet of Things (IoT) devices has opened up new possibilities for enhancing security in a variety of applications. IoT devices have gained appeal for usage in security applications because they provide a network of interconnected devices that can communicate and share data to enable efficient monitoring, control, and management of security systems. These gadgets could be cameras, sensors, alarms, access control systems, and other intelligent security gadgets. IoT devices may significantly improve security measures in a variety of contexts, including homes, offices, commercial buildings, and public spaces when integrated with Li-Fi technology. The built-in security characteristics of Li-Fi are one of the major benefits of integrating it in IoT-based security systems. Distributing high-speed Internet connectivity to a variety of geographical areas is the goal of Internet infrastructure providers (IIPs). Service providers (SPs) make an effort to deliver trustworthy services everywhere. It comprises users in malls, coffee shops, residences, office buildings, dining establishments, outlying communities, airports, airplane cabins, and metro stations. When utilizing Wi-Fi, it can be annoying when the network's sluggish performance results in spotty connectivity and prolonged processing times. The current wireless networks are incredibly sluggish when many devices are connected. Radio waves underpin Wi-Fi. When there are more devices connected to the internet, sending data gets more difficult due to the constrained spectrum that radio waves must occupy for data transmission. Radio waves can be abused by hackers since they can penetrate obstacles, which poses a security risk for Wi-Fi. Li-Fi technology can be quite helpful in overcoming this restriction. The fundamental technological difference between Li-Fi and Wi-Fi is that Li-Fi transmits data by changing light intensity, whereas Wi-Fi sends data by inducing a voltage in an antenna using radio frequency. In areas where electromagnetic interference is an issue, Li-Fi can function. By offloading data traffic, Li-Fi can greatly improve Wi-Fi networks. The end users, who are obviously our mobile devices, have the ability to receive data rates that are currently only feasible in fibre-optic connectivity. Furthermore, Li-Fi addresses the security issue by using just lights for communication because light cannot pass through barriers and is hence un-hackable. Since light moves at such rapid rates, Li-Fi has the additional advantage of being able to establish connections quite quickly. Data transport and internet connections considerably enhanced as a result. Li-Fi technology and IoT devices have a lot of promise to improve security protocols in a variety of applications. Li-Fi is a viable option for IoT-based security systems because of its built-in security features, high-speed data transmission capabilities, scalability, and reliability. This technology provides enhanced security, real-time monitoring, and effective control of security equipment and systems.

1.2 Background and motivation

The Internet of Things (IoT) has integrated seamlessly into our everyday lives. The security of IoT systems has become a crucial concern due to growth in associated devices. Wireless communication channels' vulnerability is one of the biggest obstacles to IoT security. Traditional wireless technologies such as Wi-Fi and Bluetooth are prone to interference and eavesdropping, making them susceptible to cyber-attacks.

A wireless communication technique called Li-Fi (Light Fidelity) transmits data using light. It offers high-speed, secure, and dependable connectivity, making it a possible replacement for conventional wireless communication technologies. LED lights are used in Li-Fi to send data utilizing visible light communication (VLC). The method relies on varying the brightness of the light to communicate information that can be picked up by a photo-detector device.

Li-Fi for IoT devices has a number of benefits over conventional wireless technologies. First of all, it offers greater security because light signals are contained within a single space and cannot pass through walls or windows. Hackers will find it challenging to intercept the data being transmitted as a result. Second, Li-Fi enables quicker and more effective connection between IoT devices thanks to increased bandwidth and data rates than previous wireless technologies.

The goal of employing Li-Fi technology for IoT devices to improve indoor security is to give IoT systems a more secure and dependable communication channel. It is essential to secure their security as IoT devices continue to multiply and become more ingrained in our daily lives, preventing cyberattacks and data breaches. Li-Fi technology offers a more stable and secure communication channel that is less susceptible to cyber-attacks, which has the potential to increase the security of IoT devices.

Additionally, the deployment of Li-Fi technology might lessen wireless network congestion, which is becoming a bigger problem as more devices are being linked to the internet. Li-Fi technology can offer an additional channel for interaction for IoT devices, easing the burden on conventional wireless networks and enhancing their functionality. Overall, by offering a trusted communication channel, the usage of Li-Fi technology for

IoT devices has the potential to improve interior security. The technology offers more security, bandwidth, and data rates than conventional wireless technologies, among other benefits. The security of IoT devices must be ensured as their number increases, and Li-Fi technology can be essential in reaching this goal.

1.3 Problem statement

The rapid growth of the Internet of Things (IoT) has led to an increasing number of connected devices in indoor environments, which raises concerns about their security. Traditional wireless communication methods like Wi-Fi and Bluetooth are prone to security flaws that could let private information get into the wrong hands. Due to the short range of visible light, Li-Fi, a wireless communication system that uses visible light to transfer data, has significant advantages over conventional wireless technologies. One of these advantages is increased security. To combat possible security concerns like eavesdropping, man-in-the-middle attacks, and unauthorized access, however, it is necessary to build strong security protocols and methods for Li-Fi-based IoT devices. Consequently, the problem statement is to create and put into practice efficient security solutions for Li-Fi-based IoT devices in indoor environments to ensure secure and dependable communication.

Radio frequency (RF) waves are used by Wi-Fi technology to transport data wirelessly between devices. These RF waves are an electromagnetic radiation type that can affect both the environment and the human body in a variety of ways. Wi-Fi's RF waves can interfere with other electronic devices that use comparable frequencies, which is one of their main consequences. Reduced signal strength and slower or interrupted data transfer can also be caused by this interference.

The possible effects of long-term exposure to RF waves from Wi-Fi equipment on human health are still being debated. According to certain research, exposure to high levels of RF radiation over an extended period of time may result in health issues like cancer, reproductive problems, and neurological abnormalities. The amounts of RF waves emitted by Wi-Fi equipment, however, have not been linked to any solid proof of harm, according to other studies. Regulatory organizations like the Federal Communications Commission (FCC) have created safety guidelines and exposure limits for RF radiation exposure in order to reduce any potential detrimental effects of Wi-Fi's RF waves. Additionally, Wi-Fi device manufacturers are required to make sure that their products meet these requirements and emit only safe levels of RF radiation. Overall, the risk of harm from exposure to Wi-Fi RF waves at typical usage levels is generally regarded as low, despite the fact that these waves may have some potential effects on the environment and human health.

Problem regarding radio frequency are as follows:

Capacity:

- The radio frequency spectrum is a finite resource, and the demand for spectrum is growing rapidly due to the proliferation of wireless devices and the increasing popularity of bandwidth-intensive applications such as video streaming and online gaming.[7]
- Radio frequency spectrum is a scarce resource and therefore valuable. However, it is not an unlimited resource; the total amount of available spectrum is limited and the demand for spectrum is constantly increasing.[8]
- With the advancement of 2G,3G,3.5G,4G,4.5G and 5G and so we are running out of spectrum

Efficiency:

- There are an estimated 1.4 million cellular radio base stations worldwide, and they consume a massive amount of energy. Most of this energy is used for cooling the base stations, rather than for transmitting data. The average efficiency of a cellular base station is only around 5%, meaning that 95% of the energy it consumes is wasted.[9]
- Base stations can consume significant amounts of energy and contribute to greenhouse gas emissions, particularly due to the cooling systems required to dissipate the heat generated by radio transmitters.[10]
- Cellular networks consume a huge amount of energy, with a significant proportion of this being wasted in cooling equipment. The energy efficiency of cellular networks is therefore a major concern, both in terms of reducing costs and reducing carbon emissions.[11]

Availability:

- We have to switch off our mobiles in airplanes.[12]
- It is not advisable to use mobiles at places like petrochemical plants hospitals petrol pumps.[13]

Security:

- Radio waves penetrates through walls.so hacker can access it easily.[14]
- They can be intercepted easily.
- It can be easily accessible if someone has the knowledge about it.

1.4 Significance of this work

- Li-Fi technology uses light waves to transmit data, offering several benefits over traditional Wi-Fi.
- Li-Fi provides enhanced security for IoT devices, as the signal is confined to the room and cannot pass through walls.
- Li-Fi is not affected by electromagnetic interference, providing improved signal reliability for IoT devices.
- Li-Fi offers faster data transfer speeds than Wi-Fi, allowing for real-time data transfer in applications such as smart home automation, healthcare monitoring, and industrial automation.
- Li-Fi is more energy-efficient than traditional Wi-Fi, leading to cost savings and longer battery life for IoT devices.
- Enhancing Indoor Security by using Li-Fi Transmission for IoT devices can provide a significant improvement in overall security and connectivity for smart homes, healthcare facilities, and other indoor settings

1.5 Overview of this thesis

To ensure secure and dependable communication, efforts are being made to create and put into place efficient security solutions for Li-Fi based IoT devices in indoor settings. Among other things, these solutions include secure data transfer protocols, authentication procedures, and encryption techniques. Li-Fi based IoT devices can be made more dependable and secure for a variety of indoor IoT applications by putting these security measures in place. Here we will design transmitter and receiver section of Li-Fi system along with Optical data transmission over Li-Fi channel.

1.6 Outline

Chapter One is about Introduction-to-Introduction Li-Fi technology and IOT devices, problem statement, motivation and overview of this thesis.

Chapter Two about literature review and concept about Li-Fi and objective of this thesis.

Chapter Three is all about methodology of research and different wireless technology and Li-Fi.

Chapter Four about design, simulation and output parameter.

Chapter Five is about conclusion and future work.

CHAPTER 2

Literature Review

2.1 – Related work

- **A Li-Fi-based automated shopping assistance application in the Internet of Things**

A computer program that uses Li-Fi and the internet of things to automatically find various rows and columns and calculate prices for all the products. A customer must search for desired things in a vast supermarket for hours on end. Additionally, paying at the counter requires standing in line, which takes time. A shopper must therefore spend two to three hours shopping at a big-box store. The idea of an automated application based on the internet of things and Li-Fi has been developed from the standpoint of saving time and energy. Two versions of this program are available: a web version and a mobile version. The two major components of the architecture of this program are the customer and cashier interfaces. There are only a few stages in the user interface. Customers can make shopping lists. By displaying the row location, the application will help with the list of objects. Customers can use a smart phone to scan a barcode to obtain the item's pricing. Customers will receive the final price to be paid at the conclusion of their shopping. A free Li-Fi-based internet connection is available to connect each time a new client enters the supermarket's boundaries. The supermarket's online application, where users can make new lists of the things they need to buy, is the default landing page.[7]

- **Li-Fi for Vehicle-to-Vehicle Communication is the title of the study.**

They explained the potential for integrating Li-Fi into communication systems and provided the general framework for Li-Fi. Li-Fi can be used to communicate between automobiles using their headlights in an effort to decrease the number of accidents that happen on the road. Li-Fi is introduced as a V2V communication application that was used in a project where the speed of two motors was controlled by headlights. Data transmission between the control units regulates the speed of the motor.[8]

- **Enhancing Li-Fi for the Next Generation Internet of Things is the title of the research paper.**

They talked about Li-Fi capabilities that support the newest IOT applications for a range of indoor and outdoor use cases in the business, office, retail, and consumer sectors. Using Li-Fi features for applications in various indoor and outdoor contexts will enable the next generation of IOT applications, and Li-Fi systems can complement the impending 6G system by providing high QoS links in hotspots. They demonstrated a distributed MIMO wireless topology that could support waveform fronthaul transmission via a plastic optical fiber using SDM and WDM. They talked about safety considerations and several ideas for smooth handovers from light-based access points to radio-based infrastructure, like a 5G network. That the IOT might benefit from both accurate indoor localization and fast data transfer thanks to Li-Fi technology.[9]

- **Performance of Bidirectional Li-Fi over Plastic Optical Fiber (POF) is the title of the research paper.**

They presented a number of use cases for deploying distributed system setups using Li-Fi via POF. In this study, data rates in the downlink and uplink can be measured between 725 Mbit/s and 901 Mbit/s, respectively. They are therefore primarily constrained by wireless connectivity. For the analog fronthaul signal transfer between a central unit and dispersed Li-Fi frontends, they tried a bidirectional POF link. A fixed gain amplifier is added between the OWC and POF links, and a variable gain amplifier is used in the AFE at the mobile device and adjacent to the central unit in the

- **Improvement of Indoor Performance is the title of the research paper.**

Li-Fi Mobile Users with Random Orientation Using Hybrid Li-Fi and Wi-Fi Networks (HLWNets) (2020) The analysis of a hybrid Li-Fi and Wi-Fi network model (HLWNet) for indoor mobile users having a random orientation shows that when performance is compared, HLWNet performs better than a standalone Li-Fi Access Point (AP) serving such a device. Every year, the amount of wireless data consumed rises by 60%. This causes the radio frequency spectrum to become crowded, which causes a condition known as spectrum crunch. The term "spectrum crunch" refers to a situation where there is not enough radio spectrum available to meet the rising demand for wireless data by both public and private sector entities. The speed of wireless data and the internet will decrease as a result of this. As a result, Wi-Fi will be unable to meet the rising demand for wireless data. Li-Fi, also known as "light fidelity, is a form of visible light communication (VLC) that transmits data using light-emitting diodes, or LEDs. This technology is able to utilize a significant portion of the optical spectrum, which is close to 300 THz, because it employs visible light to carry data. Therefore, hybrid Li-Fi and Wi-Fi networks appear to be a better alternative for the future. Hybrid Li-Fi and Wi-Fi Networks (HLWNets) are a novel hybrid network that combines the rapid data rates of Li-Fi with the larger coverage of Wi-Fi. It has been demonstrated that a hybrid network of this type performs better than a standalone Li-Fi and RF system. These networks require a network hypervisor so that resource allocation and link management can be done in a flexible manner. A 2-dimensional (2D) grid-based cell deployment that offers a general type of coverage can be taken into consideration for indoor applications.[11]

- **Optimized joint Li-Fi coordinated multipoint joint transmission clustering and load balancing for hybrid Li-Fi and Wi-Fi networks is the title of the research paper.**

To solve both the uneven cell load and the user-centric Li-Fi CoMP—JT clustering and LB design—they jointly propose They designed their system taking into account the joint impact of Li-Fi CoMP-JT clustering and LB on performances in order to address Li-Fi ICI difficulties for hybrid Li-Fi and Wi-Fi networks. The joint design was formulated as a MINLP issue with a view to increasing system throughput. They constructed a GOPG model to find the suboptimal solution for effective UE-AP association and time slot resource allocations under proportional fairness constraints. Given that both research fields are connected to Li-Fi, they are therefore related to one another.[12]

- **Invoking Deep Learning for Joint Estimation of Indoor Li-Fi User Position and Orientation is the title of the research paper.**

Although Wi-Fi and Bluetooth are the most widely used positioning systems, which have already been widely deployed in current smart devices, they cannot satisfy the requirements

(UE position and orientation) of the aforementioned applications because their localization performance suffers. They introduced the idea of user equipment (UE) position and orientation as crucial factors for indoor location-based applications like robotic navigation and autonomous parcel sorting using Li-Fi. Innovative and precise location and orientation estimation techniques are urgently needed as a result of this problem. Here, brand-new ANN models were put forth for the estimation of a randomly situated Li-Fi UE's joint 3D position and orientation, as well as its orientation and emitting power. The suggested method involved creating a measurement-based dataset that includes the instantaneous received SNR and the accompanying 3D location and orientation angles using RSS-based fingerprinting. The SNR feature vectors with the accompanying locations and orientation angles were then efficiently mapped using MLP and CNN models. Given that both research fields are connected to Li-Fi, they are therefore connected to one another.[13]

- **Introduction to Indoor Networking Concepts and Challenges in Li-Fi is the title of the research paper.**

By introducing the idea of indoor networking, they provide justification for why Li-Fi is an extremely opportune technology, particularly for 6th generation (6G) cellular communications. The focus of free-space light communications must be changed from point-to-point link-level data rate improvements in VLC to maximizing data density in a wireless network in order to reach this goal, as was underlined in this research. By offloading data traffic, it has been demonstrated that Li-Fi may considerably enhance Wi-Fi networks. They go through and explain fundamental networking technologies like hybrid Li-Fi/Wi-Fi networking topologies and interference reduction. Finally, they provide the outcomes of a real-world implementation of a hybrid Li-Fi/Wi-Fi network in a testbed for software-defined networking. Results from a Li-Fi deployment in a classroom are also presented, demonstrating how dramatically the performance of the Wi-Fi network can be improved by offloading traffic to the Li-Fi.[14]

- **Title of Research Article: Terminal Orientation in an OFDM-Based Li-Fi System Based on data observations, this article proposes a random process model for changes in the UE orientation.**

In order to facilitate multiuser access and user mobility, light-fidelity (Li-Fi), a wireless communication system, uses both the infrared and visible light spectrums. Given the short wavelength of light, a user's (UE) random orientation has an impact on the optical channel. Here, 222 data measures were collected throughout a series of tests involving 40 individuals while they watched streaming movies and surfed the Internet. The user's minor hand movements and other actions, such as scrolling or typing, were recorded as the random orientation. They also noticed that the sensors' sample intervals were not uniform. Additionally, it was demonstrated that the ACF first hit 0 at a time lag of 0:13 seconds. Since the random orientation was highly correlated in the order of nanoseconds, the CIR could still be expected to be slowly varying in comparison to the usual delay spread of the optical wireless channel, which was in the nanosecond range. Given that both research fields are connected to Li-Fi, They are therefore related to one another.[15]

- **Name of Research Paper: LIDAR-Assisted Channel Modeling for LI-FI They have demonstrated how to model the LI-FI channel for mobile users in a true distributed MIMO situation with high accuracy and minimal complexity.**

They have demonstrated how to accurately and simply model the LI-FI channel for mobile users in a distributed MIMO environment. Potential link obstructions, in addition to reflections from objects and walls, make LI-FI deployment in complicated environments hard. Here, they used 3D LIDAR geometrical data for the first time as an input for LI-FI channel modeling. They used a LIDAR scan to capture the 3D environment, and they then used those data to create the MIMO channel matrix, which includes all LOS and NLOS reflections. They discovered good agreement between the model and measurements, both on single links and when examining the performance of a distributed multiuser MIMO link with an MSE of less than 5%.[16]

- **Machine Learning for DCO-OFDM-Based LI-FI is the title of the study.**

They used machine learning (ML) techniques to determine the ideal DC-bias value for LI-FI systems based on DCO-OFDM. Different types of orthogonal frequency division multiplexing (OFDM), including DC-biased optical OFDM (DCO-OFDM), are used in light fidelity (Li-Fi). In DCO-OFDM, using a large DC bias results in optical power waste, whereas using a little bias increases clipping noise. Finding the right DC bias level for DCO-OFDM is crucial. Different types of orthogonal frequency division multiplexing (OFDM), including DC biased optical OFDM (DCO-OFDM), are used in light fidelity (Li-Fi). In DCO-OFDM, using a large DC bias results in op-ical power waste, whereas using a little bias increases clipping noise. Finding the right DC bias level for DCO-OFDM is crucial. They used a MATLAB tool to create a dataset for DCO-OFDM. They then used the Python programming language to apply ML techniques. They used ML to identify the key DCO-OFDM characteristics that affect the ideal DC bias. Given that both research fields are connected to Li-Fi, they are therefore related to one another. As both the research field are related with Li-Fi. So, they are related to each other.[17]

- **Implementation and assessment of a full Li-Fi system using Simulink is the title of the research paper.**

The performance of the models was compared with the model of the fundamental Li-Fi system already available in the literature in terms of output signal as they developed and evaluated a comprehensive Li-Fi system using Math-Lab Simulation. The comprehensive model that has been suggested performs extremely well. Here, a thorough model of the Li-Fi system was created. For the Li-Fi system, two Simulink models with mirrors and thin convex lenses, respectively, were used before the suggested comprehensive model.[18]

- **Name of Research Paper: Li-Fi is a paradigm-shifting 5G technology.**

It has been discussed in this paper what light-fidelity (Li-Fi) is and why it is considered a Fifth Generation (5G) technology. The usage of ever-higher frequencies has clearly been on the rise in wireless communications. This is a result of the concomitant exponential growth in wireless data traffic that we have been seeing over the past ten years and the constrained availability of RF spectrum in the lower frequency bands. This expansion will continue. Therefore, using frequencies other than the RF spectrum for future wireless communication systems is inevitable. They predicted a paradigm shift in wireless communications as a result of the switch from mm-wave to nm-wave communication, which necessitates the use of light, or Li-Fi. Fully functional cellular networks based on Li-Fi have been developed, and peak transmission speeds of 8 Gbps from a single light source have been achieved. They addressed many myths and provided examples of the possible effects this technology could have on various established and developing sectors.[19]

- **Li-Fi Positioning for Industry 4.0 is the title of the research paper.**

They presented a networked optical wireless communications system for indoor positioning, or Li-Fi. The suggested positioning system was based on time-of-flight measurements between a mobile device moving inside the overlapped coverage area and numerous optical front-ends installed at the ceiling. The goal was to implement positioning by reusing already implemented Li-Fi communication protocol features that many companies had already accepted. They have shown that, when a 3D positioning algorithm is used to estimate the receiver coordinates, the improved positioning algorithm can achieve precision sub-1 cm with realistic optical frontends.[20]

- **Access Point Assignment in Hybrid Li-Fi and Wi-Fi Networks in Consideration of Li-Fi Channel Blockage is the title of the research paper.**

For hybrid Li-Fi and Wi-Fi networks, a novel APA approach was put forth in this paper, taking Li-Fi channel obstruction into account. Because light waves cannot pass through solid objects like walls, interference between compartments can be avoided. In contrast to Wi-Fi APs, Li-Fi access points (APs) have a much smaller range. A hybrid network can combine Wi-Fi's all-pervasive coverage with Li-Fi's high-speed transmission. The entirely overlapping coverage of many networks makes access point assignment (APA) difficult for such a network. The suggested method divides network access into three categories: "Wi-Fi only," "Li-Fi only," and "Li-Fi/Wi-Fi." Users of the first two types are consistently logged into the same network. For the last type, when a channel is blocked, users are switched from Li-Fi to Wi-Fi, and they are switched back when the channel blockage is removed. The proposed method formulates an optimization problem, including the performance degradation brought on by channel blockage, based on users' statistical data about channel blockage. In contrast to ILB, the suggested solution has less computing complexity because it is not required to run every time a user's CSI changes. The system throughput was increased by up to 90% and 56%, respectively, over ILB and SSS, according to simulation results for the suggested strategy.[21]

- **Li-Fi-Based Positioning for Indoor Scenarios is the title of the research paper.**

In this research, the time-of-flight between a mobile device traveling inside the overlapping coverage zones of these frontends and numerous optical frontends installed at the ceiling is measured using an indoor positioning system for Li-Fi. In accordance with ITU-T G9991 standards, the advanced positioning algorithm made use of the waveform structure that was already in place. This waveform structure included frame synchronization and channel estimation that were originally created for Li-Fi's communication capabilities. Experiments conducted in a conference room are used to validate the suggested method. The findings demonstrate that Li-Fi positioning is a promising option for interior localization applications because the precision of distance measurement was in the range of less than 5 centimeters. Their solution was based on the ITU-T G.9991 standard and supports communication utilizing the current physical layer protocol as well as positioning.[22]

- **The title of the study is "Parallel Transmission Li-Fi."**

In this study, parallel transmission for Li-Fi was examined, and a brand-new RA technique called JRA was suggested. PT-Li-Fi, in contrast to ST-Li-Fi, allows the user to be served by numerous APs at once, effectively using the densely placed Li-Fi APs. PT-Li-Fi can enhance network performance in two ways when compared to ST-Li-Fi: first, by offering a flexible method of load balancing; and second, by minimizing the throughput loss brought on by handovers. User mobility, random receiver orientation, and light-path blockages were all taken into consideration while analyzing how well the suggested system performed in terms of user throughput and fairness. The results demonstrate that PT-Li-Fi can significantly outperform ST-Li-Fi in terms of network performance, even with just two sub-flows.[23]

- **Design and Evaluation of Li-Fi Modules for Audio Applications is the title of the research paper.**

A Li-Fi dongle that may be attached to an audio port on a laptop, tablet, or mobile phone to create Li-Fi communication with a Li-Fi-compatible speaker was designed, developed, and evaluated in this work. They suggested this idea with the intention of employing visible light communication to play audio and music files; it can be compared to a Bluetooth module. The prototype, which comprises a Li-Fi dongle and speaker and is intended to transmit audio signals across a distance of up to 2.62 meters, offers a wide range of potential uses. Readers could also learn how to create their own Li-Fi dongle and speaker for visible light communication with the aid of the suggested work.[24]

- **Understanding the Li-Fi Effect on LED Light Quality is the title of the research paper.**

Here, they looked into how various Li-Fi modulation approaches affected the brightness of an LED's output. Since it is a useful tool for creating Li-Fi systems that address the needs for lighting and data transfer. They took this action. An opportunity to evaluate the anticipated changes in light quality owing to any type of Li-Fi modulation technology is provided by the interrelationship between the driving current and the emitted light quality of an LED that was presented. Given that both research fields are connected to Li-Fi, they are therefore connected to one another.[25]

- **Name of Research Paper: Li-Fi Experiments in a Hospital.**

In this paper they reported the first experimental study of Li-Fi system in a medical scenario. The connected or smart hospital is widely considered as the future of healthcare, where all medical devices are connected to a wireless infrastructure and provide accurate and timely information. Aiming at safe and secure wireless communication, the use of wireless local area networks such as Wi-Fi in surgery environments is limited Due to possible electromagnetic interference (EMI). Hence, the deployment of a networked optical wireless technology (Li-Fi), based on the light has the potential to be employed in hospital environments. The frequency response of the Li-Fi channels was measured in a neurosurgical operating room and corresponding channel parameters were calculated. By considering all measured channels as a virtual distributed MUMIMO system, multiplexing schemes such as i) TDMA; ii) TDMA-SDMA and iii) TDMA-SDMA with ZF were considered and the achievable throughputs were estimated. As both the research field are related with Li-Fi. So, they are related to each other.[26]

- **Efficiency of Opportunistic Cellular/Li-Fi Traffic Offloading is the name of the study.**

They looked into the effectiveness of the cellular/Li-Fi HetNet in offloading traffic. A framework for opportunistic cellular/Li-Fi offloading and timing diagrams for several disconnected scenarios have been shown. The ratio of traffic carried by light-fidelity (Li-Fi) networks to the total traffic carried by both Li-Fi and cellular networks is known as "data offloading efficiency. Li-Fi signal blocking's impact and channel characteristics were taken into account. There was discussion of various Li-Fi offloading timing scenarios. The performance of an opportunistic cellular/Li-Fi traffic offloading scenario was investigated through simulation. Given that both research fields are

- **Analysis of Li-Fi System Performance Considering Different Bit Rates and Link Ranges is the title of the research paper.**

They suggested conducting research on Li-Fi for LEDs with 450 nm wavelengths and LOS channels with various link lengths. People's lives were altered by the internet's revolution. Technology and the internet have mostly taken over our lives. Because it makes life easier and more enjoyable, the internet has become a part of all of our lives, and we cannot imagine not having it. We employ radio waves, which are extremely damaging and only a small portion of the electromagnetic spectrum is available for data transmission, to provide the internet for this enormous population. The proposed study, which considers the effects of electron carrier lifetime and RC time constant, can aid in improving communication using Li-Fi technology. A 50 Mbps bit rate is supported by the simulated system up to a connection distance of 3.4 meters, with a Q factor value of 10.71 and a log BER value of -6.46. With a Q factor of 14.67 and 5.01 and a log of BER values of -47.69 and -6.40 at link ranges of 1 m and 5 m, respectively, this system performs best at lower bitrates.[28]

- **Bias Point Optimization in Li-Fi for Capacity Enhancement is the name of the research paper.**

In this study, scientists looked at ways to increase an LED's bias point so that its bandwidth can increase at higher driving currents while reducing the resulting signal distortion. The methods relied on allowing for a little amount of nonlinear distortion or lowering the signal swing or signal-to-noise ratio while gaining a larger bandwidth at higher driving currents. A framework for calculating the achievable capacity under both circumstances was offered. They use a PAM-4-based VLC system to experimentally validate the optimization.[29]

- **Mobility Management in Multi-Tier Li-Fi Networks is the title of the research paper**.

The main performance indicators in ultra-dense Li-Fi networks are examined in this research for handover to the secondary tier from the primary tier. The research community is looking forward to next-generation technologies as a result of the constantly growing need for wireless communication. The average traffic per smartphone would climb to around 25 GB per month in 2025 as a result of the mobile traffic growth predicted to increase by 31% annually between 2019 and 2025. Future wireless technologies would greatly benefit from meeting these requirements. Due to its large unlicensed spectrum, physical layer security, low cost, and high data rate, Li-Fi, a wireless technology based on the light spectrum, is a feasible alternative to the present radio frequency (RF)-based systems. They offered analytical models for the SAPs' coverage regions based on three different situations for semi-angle at half illumination. As functions of the system parameters, they deduced closed-form formulas for the P2S cross-tier handover and ping-pong rate.[30]

- **Optimal Discrete Constellation Inputs for Aggregated Li-Fi-Wi-Fi Networks is the title of the research paper.**

The performance of a practical aggregated Li-Fi-Wi-Fi system with discrete constellation inputs was examined from a practical standpoint in this paper. Light-emitting diodes (LEDs) and photodiodes (PDs), which can be included in IoT devices, are used as transceivers by Li-Fi. Even though Li-Fi is a strong contender for next-generation wireless technology, its obstruction susceptibility and limited signal coverage provide numerous difficulties for a variety of indoor applications. Therefore, combining the Li-Fi and Wi-Fi systems and taking advantage of their distinct benefits in specific situations is a more workable approach. First of all, they arrived at the system's feasible rate expression using the discrete constellation input signals while taking into account the bandwidths of both Li-Fi and Wi-Fi links. They then carried out additional research on the best input and power distribution for the system under consideration. Additionally, they examined the ideal input distribution and power allocation for the system under consideration and calculated the upper and lower bounds of the attainable rate expression of the system with the discrete constellation input signals. Finally, the effects of important Li-Fi-Wi-Fi system aggregate parameters, threshold, optical power, and bandwidth, on the highest feasible rate.[31]

2.2 Li-Fi

Li-Fi is a form of wireless technology that transmits data using light waves. It is a sort of optical wireless communication (OWC) technology that uses visible, ultraviolet, and infrared light for data transfer. The term "light fidelity" refers to this. Li-Fi technology transmits data to a receiver, often a photodiode, by altering the brightness of light. Li-Fi transmits data to a receiver, often a photodiode, by altering the brightness of light. It delivers better signal dependability for IoT devices and is less vulnerable to electromagnetic interference. Smart homes, medical facilities, and industrial settings are just a few of the potential uses for Li-Fi technology. Overall, Li-Fi technology is a promising advancement in wireless communication and could play a significant role in the future of the IoT ecosystem.

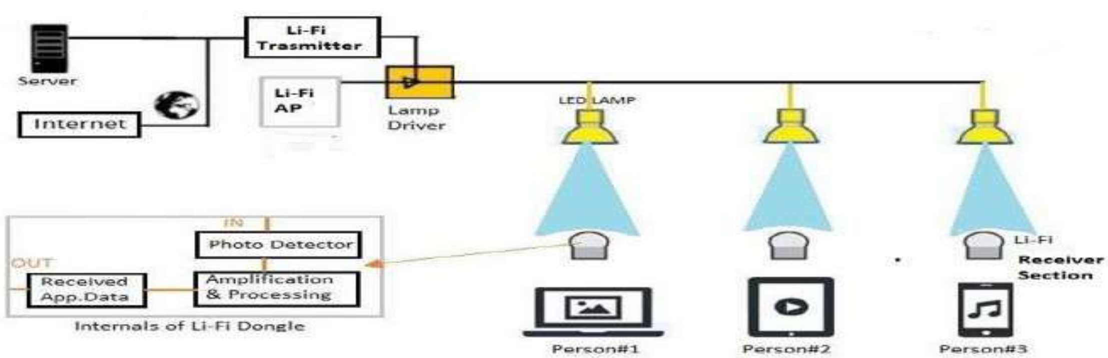

Figure 2.1: Working Principle of Li-Fi

2.3 IoT devices

IoT (Internet of Things) devices refers to physical devices which are embedded with sensors, software, and connectivity that enable them to exchange data with other devices and systems over the internet. These devices can be anything from small consumer devices like smart home appliances (e.g., thermostats, lighting systems, and security cameras) to large industrial machinery used in manufacturing devices that have the capability to collect and analyze real-time data, enabling data-driven decision-making and the ability to automate tasks. This makes them useful for a range of applications, including healthcare monitoring, logistics tracking, and environmental monitoring. However, the use of IoT devices also poses significant security risks. These devices can be hacked or compromised, leading to data breaches or even physical harm in certain cases. Ensuring the security of IoT devices is therefore crucial to prevent unauthorized access and protect sensitive data. Li-Fi's enhanced security features, such as signal confinement and resistance to electromagnetic interference, make it a suitable choice for secure communication between IoT devices. This can help prevent unauthorized access and protect sensitive data, ensuring that IoT devices are used safely and securely.

2.4 Li-Fi Application

- **Li-Fi and live streaming**

  According to a Go-Globe survey, live videos are seen three times longer than videos that are no longer live, and 80% of brand audiences prefer to watch live video from an organization than read a blog. 82% of shoppers concur. Due to the rapid rates, it can reach, Li-Fi can be made available in huge shopping malls, sporting arenas, street lights, airplanes, trains, including underground, train stations, airports, and so on. Any user that comes into contact with Li-Fi-connected LEDs will be able to access rich content media from their smartphones or other mobile devices practically anywhere, including movies and live streaming. This covers buses, railroads, and aircraft. The following events could also profit from Li-Fi live streaming: For conferences, seminars, meetings, team-building exercises, trade shows, business dinners, press conferences, networking events, opening ceremonies, product launches, theme parties, and award ceremonies, Li-Fi live streaming holds out a lot of promise in the years to come.

- **The Pharma Industry and Li-Fi in Pharmacies**

Some pharmacists in hospital pharmacies use Li-Fi to immediately receive and screen electronically authorized prescriptions in the unit, particularly in aseptic manufacturing facilities. Without having to call or go directly to the aseptic unit, nurses and other healthcare workers from the ward can verify the status of prescription aseptic pharmaceuticals such as cytotoxic drugs, parenteral drugs, and centralized intravenous additive services (CIVAS) in real-time. Automation, including automated packing and inspection, is being used more and more in the pharmaceutical manufacturing process. One of the numerous benefits of automation is its efficiency. Other benefits include minimizing training costs, preventing human error, improving repeatability and reproducibility, and removing the chance of human contamination in cleanrooms. Li-Fi will make it quick, simple, and incredibly secure to exchange medical records. Patients at pharmacy dispensaries may use Li-Fi to check the status of their prescriptions on their cellphones or drugstore terminals while waiting to pick up their medications.

- **Using Li-Fi at Work**

Li-Fi will provide safe wireless connectivity in workspaces rather than lights. In addition to networking, Skype will enable users to join video conference calls and switch between rooms without the call being interrupted. Both employees and guests will have constant access to the internet through the Wi-Fi networks in the workspace. Light can also control network access more efficiently. The CEO of the company's commercial property investment division, Emmanuelle Baboulin, stated: "Li-Fi has the potential to revolutionize the game in offices. In addition to reliable connectivity, the light quality is essential to us since we intend to demonstrate the technology in our smart workplace in La Defense, he continued.

- **Li-Fi in classrooms**

By enabling learning applications on any mobile device and connecting students and teachers to smart technology, the correct wireless network can help create new learning experiences. From the classroom to the university dorms, Li-Fi can also offer seamless network connectivity and security throughout the entire institution. Even now, some schools are implementing Wi-Fi technology in the classroom. Scotland's Kyle Academy has begun implementing Wi-Fi in the classroom. The University of Edinburgh and PureLiFi worked together on the Li-Fi project. Eight LED light bulbs with Li-Fi capabilities have been installed in the ceiling, and students have access to Li-Fi-XC stations that they may plug into their computers to enable high-speed connectivity through the lights.

- **Aircraft and Li-Fi**

Passengers will have access to far more bandwidth with Li-Fi than they do with Wi-Fi at the moment. The internet connection will be faster, and passengers can download and stream entertainment from the comfort of their seats. "This technology is ideal for airplanes because it doesn't interfere with radio signals in the same way that Wi-Fi, which uses radio waves, does," said Professor Haas. Li-Fi, on the other hand, makes use of visible light. Li-Fi is revolutionary for three reasons. It first eliminates a "congestion" problem. We are rapidly running out of wireless spectrum in our data-driven world. This is a challenge in congested areas like airports and airplane interiors since the current bandwidth cannot accommodate the large number of users who wish to access the internet and data-intensive applications simultaneously. By employing almost 1,000 times the bandwidth in comparison to the full radio frequency spectrum, Li-Fi addresses this problem. This additional visible light spectrum bandwidth is unrestricted and free. It makes it possible for local-area networks to be built, allowing passengers to utilize the internet, make calls, and access in-flight entertainment systems more conveniently. Information security is crucial in a world where big data is quickly taking over. Although Li-Fi signals can penetrate through windows in the cabin, the technology provides more security than a Wi-Fi connection. However, OEMs will reap the greatest benefits. They frequently have a lot of LED lighting and few windows in their manufacturing halls, which will improve data security in their facilities.

- **Li-Fi underwater applications**

The vast majority of remotely operated underwater vehicles (ROVs) use wired connections to function. The length of their cabling places a strict limit on their operational range, and the weight and brittleness of the cable may impose further restrictions. Since water quickly absorbs radio waves, underwater radio transmissions are not possible. Because light can cross water, Li-Fi-based communications enable significantly greater mobility. The usefulness of Li-Fi is constrained by how far light can travel through water. More than 200 meters is the maximum distance that significant light may travel. Beyond 1000 meters, no light can be seen.

- **Industry 4.0 and Li-Fi**

Industry 4.0, often known as the "Fourth Industrial Revolution," is a fresh approach to combining conventional production techniques with cutting-edge technology, such as the Internet of Things (IOT) and artificial intelligence (AI), to enhance automation, connectivity, and the use of real-time data. It guarantees enhanced compatibility between machines and the people who operate them, and it will hasten innovation among producers. Li-Fi provides adequate performance for closed-loop control applications that demand real-time and reliability for industrial robots. In Bamberg, Wieland Electric looked into the technological advantages of Li-Fi technology in commercial settings. To collect experience and incorporate it into the creation of Li-Fi for industrial communication, the electronics manufacturer uses the new data transfer standard in its internal manufacturing.

2.5 Different types of wireless technology

Wi-Fi:

- Uses radio frequency technology to transmit data wirelessly.
- Provides access to the internet and other networks.
- Offers fast data transfer speeds and greater range with each iteration.
- Uses encryption to provide security for wireless communication.

Bluetooth:

- Used for short-range communication between devices.
- Enables wireless connections between devices like smartphones, headphones, and speakers.
- Offers low power consumption and low data transfer speeds compared to Wi-Fi.

Wireless medical devices:

- Used in healthcare to monitor patient health remotely.
- Can provide more efficient healthcare services and reduce the need for in-person visits.
- May use Wi-Fi, Bluetooth, or cellular networks to transmit data.
- Requires strong security measures to protect patient data.

Cellular networks:

- Uses radio frequency technology to enable wireless communication over longer distances.
- Provides access to the internet and other networks on mobile devices.
- Offers fast data transfer speeds, but may be limited by signal strength in some areas.

Radio Frequency Identification (RFID):

- Enables wireless communication between a reader and an RFID tag.
- Used for tracking and identifying objects, such as in inventory management and supply chain management.
- Offers low data transfer speeds, but provides a high level of accuracy and automation in tracking and identification processes.

Near Field Communication (NFC):

- Enables wireless communication between devices when they are in close proximity.
- Offers low data transfer speeds, but provides a high level of security since the devices need to be close together to communicate.
- Used for contactless payments, electronic ticketing, and data sharing between devices.

Zigbee:

- A wireless protocol designed for low-power devices and home automation systems.
- Used in smart home devices, such as smart lighting and security systems.
- Offers low data transfer speeds, but provides low power consumption and a range of up to 100 meters.

Z-Wave:

- A wireless protocol designed for home automation systems.
- Offers low data transfer speeds, but provides low power consumption and a range of up to 100 meters.
- Offers strong encryption for secure communication between devices.

Infrared (IR):

- Uses light waves to transmit data wirelessly
- Offers a short

Overall, every wireless technology has its own advantages and disadvantages, and the best one to utilize will rely on the particular requirements of the application. Longer-distance connectivity to the internet and other networks is made possible via Wi-Fi and cellular networks, while short-distance communication between devices is best served by Bluetooth and Li-Fi. By enabling remote monitoring and minimizing the need for in-person visits, wireless medical devices have the potential to transform healthcare. However, effective security measures are needed to protect patient data.

2.6 Security measures of other wireless technology

Bluetooth:

Bluetooth devices use encryption to secure communication between devices, and Bluetooth 5.0 has improved security features such as long-range and low-energy encryption.

NFC:

NFC devices have a range of security measures such as encryption and authentication protocols, and most modern smartphones have security features built-in to protect NFC transactions.

RFID:

RFID tags can use various security measures such as encryption and access control protocols to prevent unauthorized access to the data they hold.

Zigbee:

Zigbee devices use AES-128 encryption for secure communication, and Zigbee networks have several security features such as network and device authentication, secure key management, and secure communication channels.

Z-Wave:

Z-Wave devices use AES-128 encryption for secure communication, and Z-Wave networks have several security features such as network and device authentication, secure key management, and secure communication channels.

Infrared:

Infrared signals are typically used for short-range communication and do not have encryption or authentication features, making them less secure than other wireless technologies.[32][33]

Wi-Fi

Wi-Fi networks have several security measures to protect against unauthorized access and ensure the privacy and security of data being transmitted over the network. Some of the key security measures for Wi-Fi networks include:

1. Encryption: Wi-Fi networks can use various encryption protocols such as WEP, WPA, and WPA2 to secure communication between devices. WPA2 is currently the most secure encryption protocol and is recommended for use on Wi-Fi networks.

2. Authentication: Wi-Fi networks can use various authentication methods such as pre-shared keys, certificates, or 802.1X authentication to ensure that only authorized users can connect to the network.

3. Network Segmentation: Wi-Fi networks can be segmented to create separate networks for different devices or users, with each network having its own security policies and controls.

4. Firewall: Wi-Fi networks can use firewalls to control traffic and prevent unauthorized access to the network.

5. Password Policies: Wi-Fi networks can enforce password policies such as strong passwords and regular password changes to prevent unauthorized access to the network.

6. Intrusion Detection and Prevention: Wi-Fi networks can use intrusion detection and prevention systems to identify and block unauthorized access attempts and protect against network attacks.[34][35][36][37][38]

2.7 Li-Fi vs Wi-Fi

Figure 2.2: The above figure is about an unauthorize person trying to access a signal.

From the figure, we can say that Wi-Fi signal can easily be accessed by an unauthorize person but on the other hand other person is not be able to access Li-Fi signal, as light cannot be penetrated through walls. Hence, he is not getting access to the connections.3.4.1 Block diagram of li-Fi channel.

2.7.1 Block diagram of Li-Fi transmission

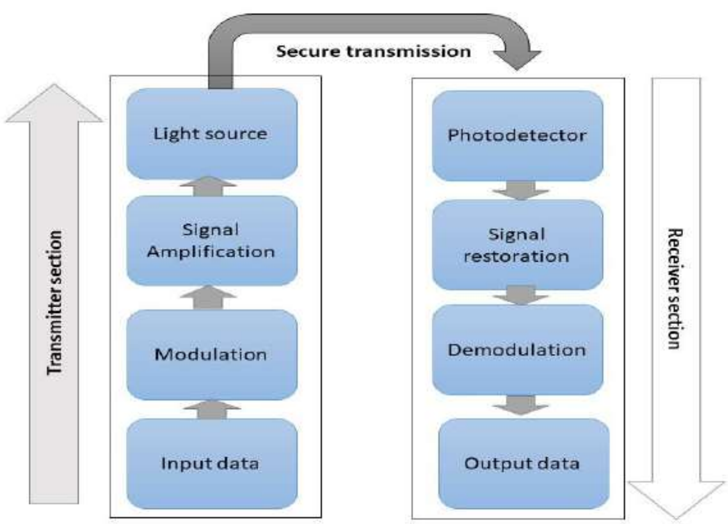

Figure 2.3: Block diagram of Li-Fi transmission

2.8 Comparison between Li-Fi and Wi-Fi

Comparison between Li-Fi and Wi-Fi are given below:[39-42]

Feature	**Wi-Fi**	**Li-Fi**
Technology	Radio frequency	Visible light
Bandwidth	Up to 160 MHz	Multiple Terahertz
Interference	Affected by RF	Immune to RF
Data transfer speed	Up to 10 Gbps	Up to 224 Gbps
Range	Several hundred feet	Up to 33 feet
Security	Standard encryption	More secure
Power consumption	High	Low
Availability	Widely available	Emerging technology
Line of sight	Not required	Required
Multi-path interference	Common	Negligible
Compatibility	Works with most devices	Requires specialized hardware
Light source	N/A	Requires light source such as LED or laser
Fiber optic connectivity	No	Yes
Mobility	Portable	but limited by range and coverage Limited by range and line of sight
Health concerns	May cause health issues in some people	No known health concerns

Table 01: comparison between Li-Fi and Wi-Fi

2.9 Limitation to study

Issues regarding Indoor building

2.9.1 FOV alignment

FOV (Field of View) alignment is a crucial aspect of Li-Fi technology as it ensures the receiver can accurately detect the signal from the transmitter. FOV alignment in Li-Fi involves adjusting the receiver's field of view to match the transmitter's field of view. [43] This is necessary because light waves are directional, and the receiver must be pointed in the same direction as the transmitter to detect the signal accurately[44]. FOV alignment is essential in Li-Fi because it ensures that the signal is correctly detected and prevents interference from other light sources in the environment. It also allows for the use of directional antennas, which can increase the signal-to-noise ratio and improve the reliability of the communication. [45]

2.9.2 Shadowing

Shadowing in Li-Fi refers to the attenuation or blocking of the signal when there is an obstruction between the transmitter and receiver. Shadowing can occur due to various reasons such as the presence of an object, human body, or even movement of the receiver. This can result in reduced signal strength and data transfer rate. To mitigate the impact of shadowing, Li-Fi systems use various techniques such as multiple input multiple output (MIMO) and beamforming. MIMO involves the use of multiple transmitters and receivers to improve signal strength and reduce the impact of shadowing. Beamforming, on the other hand, involves the use of directional antennas to focus the signal towards the receiver, reducing the impact of shadowing.[46]

2.9.3 Interference

Interference in Li-Fi refers to the presence of other signals that can cause interference with the Li-Fi signal, leading to errors and reduced data transfer rates. Interference can come from various sources, including other Li-Fi systems, Wi-Fi networks, and other wireless signals. To mitigate the impact of interference, Li-Fi systems use various techniques, such as frequency hopping and spread spectrum modulation. Frequency hopping involves rapidly switching between different frequencies to avoid interference from other signals. Spread spectrum modulation involves spreading the signal over a wide range of frequencies, making it less susceptible to interference from other signals.[47]

2.10 Modulation technique used in Li-Fi

Orthogonal Frequency Division Multiplexing (OFDM) is the modulation method employed in Li-Fi. By dividing the data into numerous sub-carriers and sending them all at once over the available bandwidth, OFDM is a digital modulation technology. This method is frequently employed in wireless communication systems, such as 4G LTE and Wi-Fi[48]. When using Li-Fi, the light source is rapidly turned on and off in a binary pattern, modulating the data onto the light waves. On-off keying, often known as OOK, is this procedure. The digital information is then encoded into the light waves using OFDM modulation by varying the frequency of the OOK signal. OFDM is used in Li-Fi because it offers several advantages, including high spectral efficiency, resistance to multi-path fading, and the ability to support high data rates. These features make it ideal for transmitting large amounts of data over the visible light spectrum.[49][50]

2.11 Enhancing secure Li-Fi transmission.

In order to achieve secure Li-Fi transmission, we have to consider a few factor. We know Li-Fi uses light as medium for transmission. light itself cannot be hacked, as it is an electromagnetic wave. However, the systems that use light for communication, such as optical networks or wireless optical communication, can still be vulnerable to security breaches. Enhancing security in Li-Fi (light-based communication) systems involves considering several factors. Here are a few key considerations to improve Li-Fi security:

- **Physical Security:** Ensure that the room or environment where the Li-Fi system operates is physically secure. Limit access to authorized personnel and implement measures to prevent unauthorized physical tampering with devices or infrastructure.

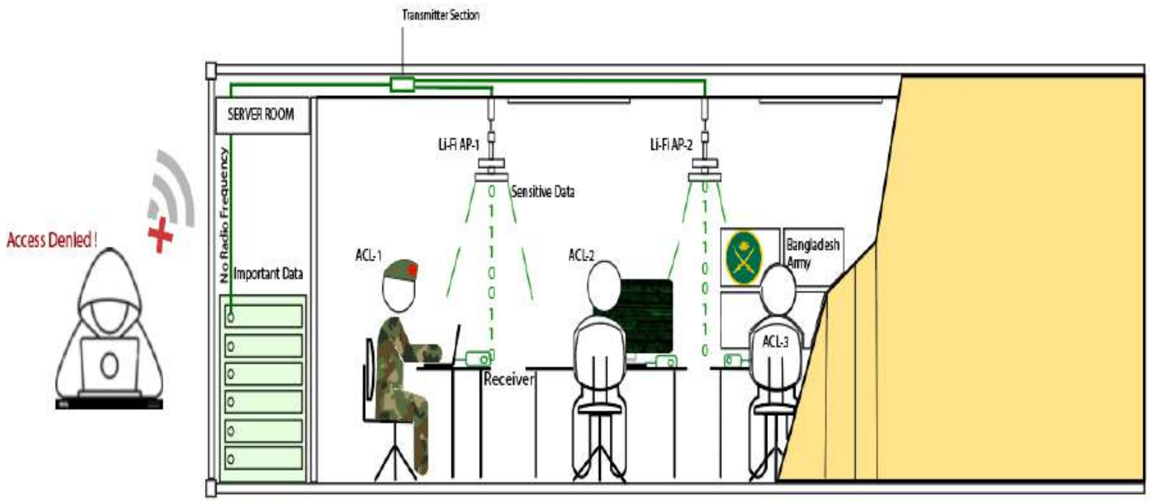

Figure 2.4: Li-Fi based security framework for sensitive data transmission.

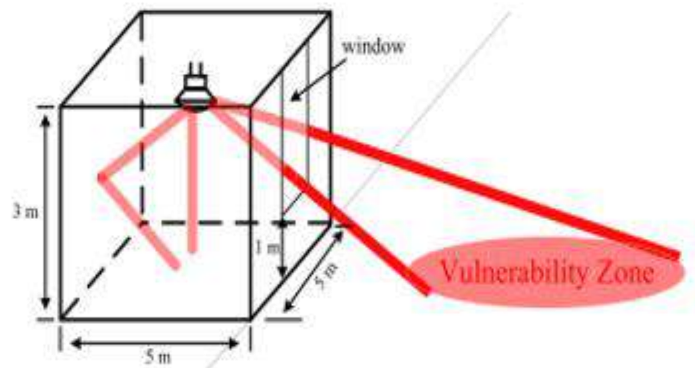

Figure 2.5: Vulnerability due to open window

- **Authentication:** Implement strong authentication mechanisms to verify the identity of users or devices before granting access to the Li-Fi network. This may include username/password combinations, digital certificates, biometric authentication, or other secure authentication protocols.
- **Access Control list**: Use access control lists (ACLs) to control and restrict access to the Li-Fi network. Define rules and permissions that determine which users or devices are allowed to transmit or receive data through the network.

Let three predefine Access control list user be with authentication pass is given.

Client name	password
Faculty	Password1
ETE	Password2
STUDENTS	password3

Table-02: ACL with Authentication

- ❑ When a person from user (ACL) tries to enter using proper authentication. The interface looks following.

```
Enter username: faculty
Enter password: password1
Transmitting light signal: -..----...Transmitting data from transmitter section to receiver section
Transmitted data: 1001111000
Received data: 1001111000
Access granted! user is connected
Welcome, faculty!
```

Figure 2.6: User among ACL

- ❑ When a unauthorize person outside user (ACL) tries to enter using proper authentication. The interface looks like the following:

```
Enter username: BBA
Enter password: password9
Access denied!! Unauthorized person trying to access information.
```

Figure 2.7: User outside ACL

2.12 Objective

1.To design and develop a Li-Fi based security framework that can secure IoT devices from various security threats in indoor environments.

2.To design Li-Fi transceiver.

3.To compare SNR distribution of Indoor li-Fi for different size room.

CHAPTER 3

METHODOLOGY

Methodology refers to the systematic approach and set of principles used in a particular field of study or research to gather data, analyze information, and draw conclusions. It provides a structured framework to ensure that the research is conducted in a rigorous and reliable manner. The methodology chosen for a study depends on the nature of the research question, the available resources, and the desired outcomes.

In academic and scientific research, methodology typically includes the following components:

Research Design: This involves selecting the overall plan or strategy for conducting the study, such as experimental, observational, case study, survey, or qualitative research design.

Data Collection: The process of gathering relevant data using various methods such as surveys, interviews, experiments, observations, or secondary data sources.

Data Analysis: The techniques used to analyze the collected data, such as statistical analysis, content analysis, or thematic analysis.

Sampling: The process of selecting a subset of the population being studied that represents the larger group (the population) from which it is drawn.

Ethical Considerations: Addressing ethical issues related to the treatment of participants, data privacy, informed consent, and potential conflicts of interest.

Limitations: Identifying and discussing the potential weaknesses or constraints of the study that could affect the reliability or generalizability of the findings.

Interpretation: Interpreting the results and drawing conclusions based on the data analysis.

Validity and Reliability: Ensuring that the study's findings are valid and reliable, meaning they accurately represent the phenomenon being studied and are consistent over time and across different conditions.

Academic Citations: Properly citing and referencing previous research and sources that inform the study.

3.1 RESEARCH METHODOLOGY

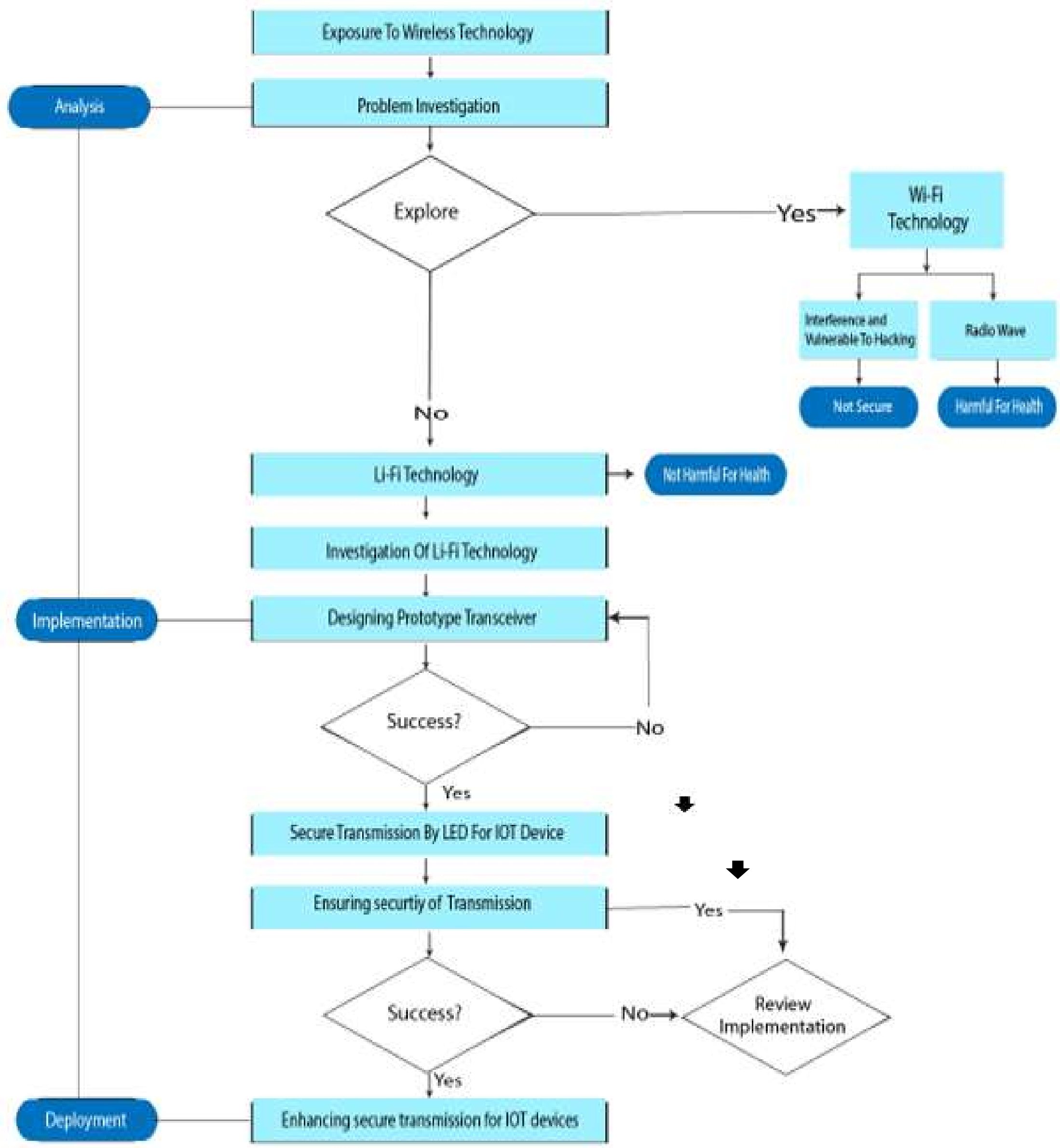

Figure 3.1: Methodology of research

Different fields of study have their own specific methodologies, such as the scientific method in natural sciences, case study approach in social sciences, or grounded theory in qualitative research. The chosen methodology is appropriate for the research objectives and contribute to the advancement of knowledge in this respective field.

CHAPTER 4

Design and Simulation

4.1.1 Network gateway:

A network gateway is a hardware or software component that connects various networks and makes communication possible between them. It provides routing and other network services to facilitate communication between devices on various networks and acts as a point of entry and departure for data flow between networks

4.1.1 Li-Fi Architecture

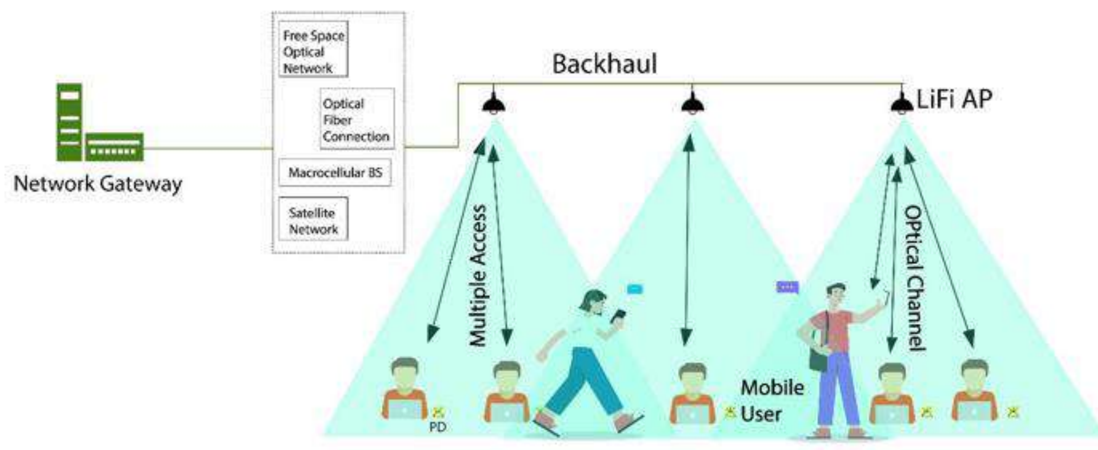

Figure 4.1: Li-Fi system architecture

4.1.2 Li-FI AP:

Devices that enable wireless communication using Li-Fi technology are known as Li-Fi APs (Access Points). It serves as a bridge to connect Li-Fi-enabled devices to a wired network so they can communicate and exchange data. An LED bulb or LED array that can be modulated to transmit data at high speeds using visible light is typically included in a Li-Fi AP. A photodetector that receives the modulated light signal and changes it back into an electrical signal is also part of the AP. The AP then decodes the signal it has just received and sends the information to the wired network or to other Li-Fi devices it has connected. Smart lighting, indoor positioning, and high-speed wireless data transfer are just a few uses for Li-Fi APs. Compared to conventional radio-frequency (RF) wireless technologies, they have a number of benefits, including faster data rates, increased security, and resistance to interference from other wireless devices. Only a few commercial Li-Fi AP products are currently on the market because Li-Fi technology is still in its infancy. However, there is still work to be done in this area, and Li-Fi technology is anticipated to spread more widely in the future.

4.1.3 Optical channel in Li-Fi System

In Li-Fi transmission, the optical channel refers to the medium through which data is transmitted using visible light. The optical channel plays a crucial role in establishing communication between the Li-Fi transmitter (e.g., Li-Fi access point) and the receiver (e.g., Li-Fi-enabled device).

Light Source: The optical channel begins with a light source, typically an LED (Light Emitting Diode) or laser diode. These light sources emit visible light that carries the data to be transmitted.

Modulation: The data to be transmitted is modulated onto the light source. Various modulation techniques can be used, such as intensity modulation, frequency modulation, or phase modulation. Modulation allows the data to be encoded onto the light signal.

Transmission Medium: The light emitted by the light source propagates through the transmission medium, which can be the air in the case of free-space Li-Fi or a waveguide in indoor environments. The transmission medium affects factors such as signal attenuation, dispersion, and reflection. It’s important to note that the optical channel in Li-Fi transmission is limited to the coverage area where the visible light can reach. This makes Li-Fi suitable for indoor applications or specific controlled environments where the light can be effectively directed.

4.2 Li-FI transmitter & Li-Fi receiver section

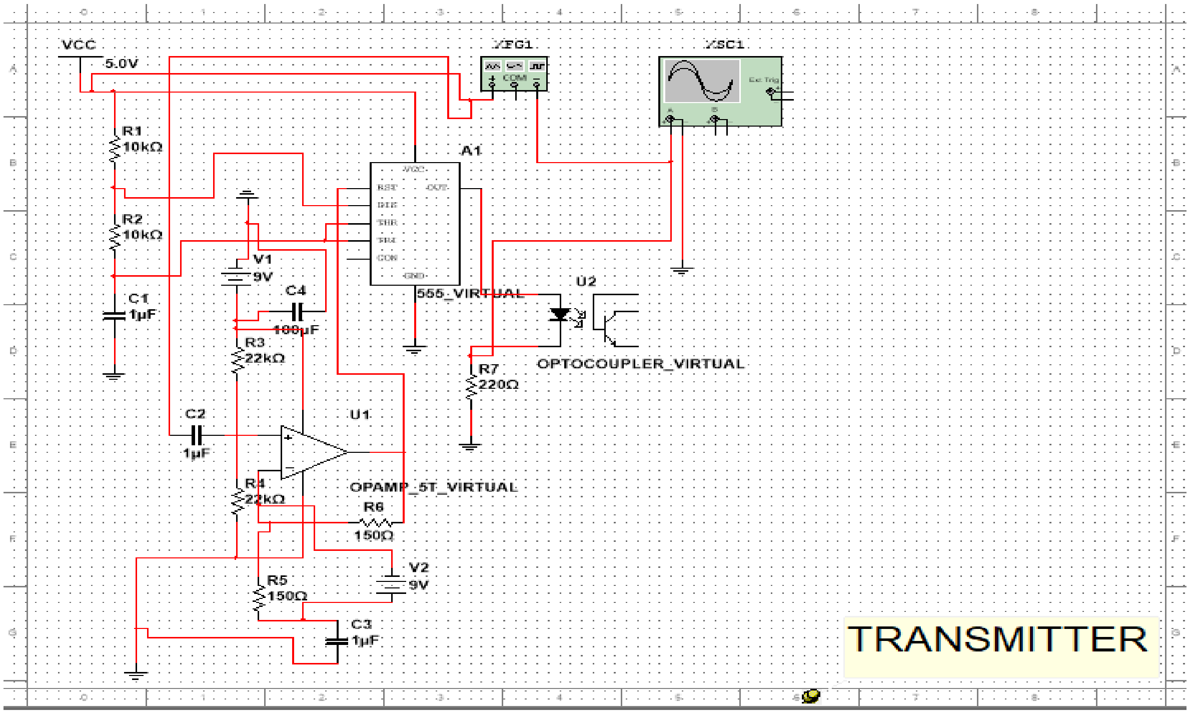

Figure 4.2: Li-Fi Transmitter

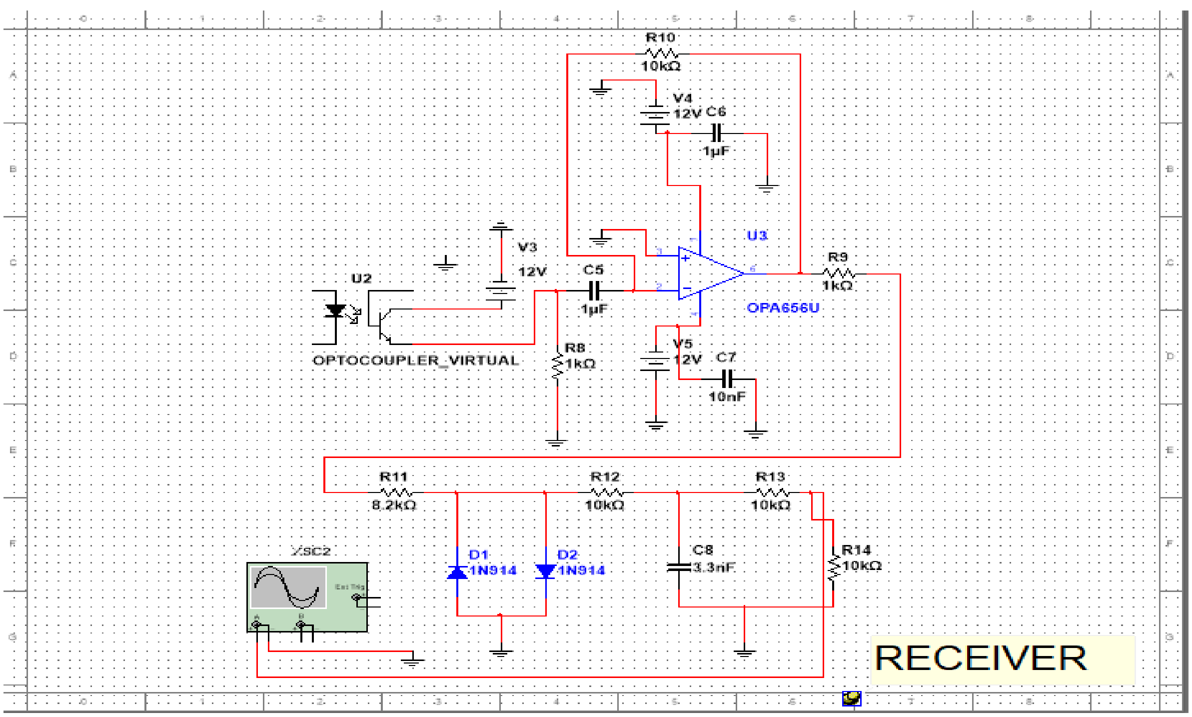

Figure 4.3: Li-Fi Receiver

4.3 Design of a Li-Fi transceiver

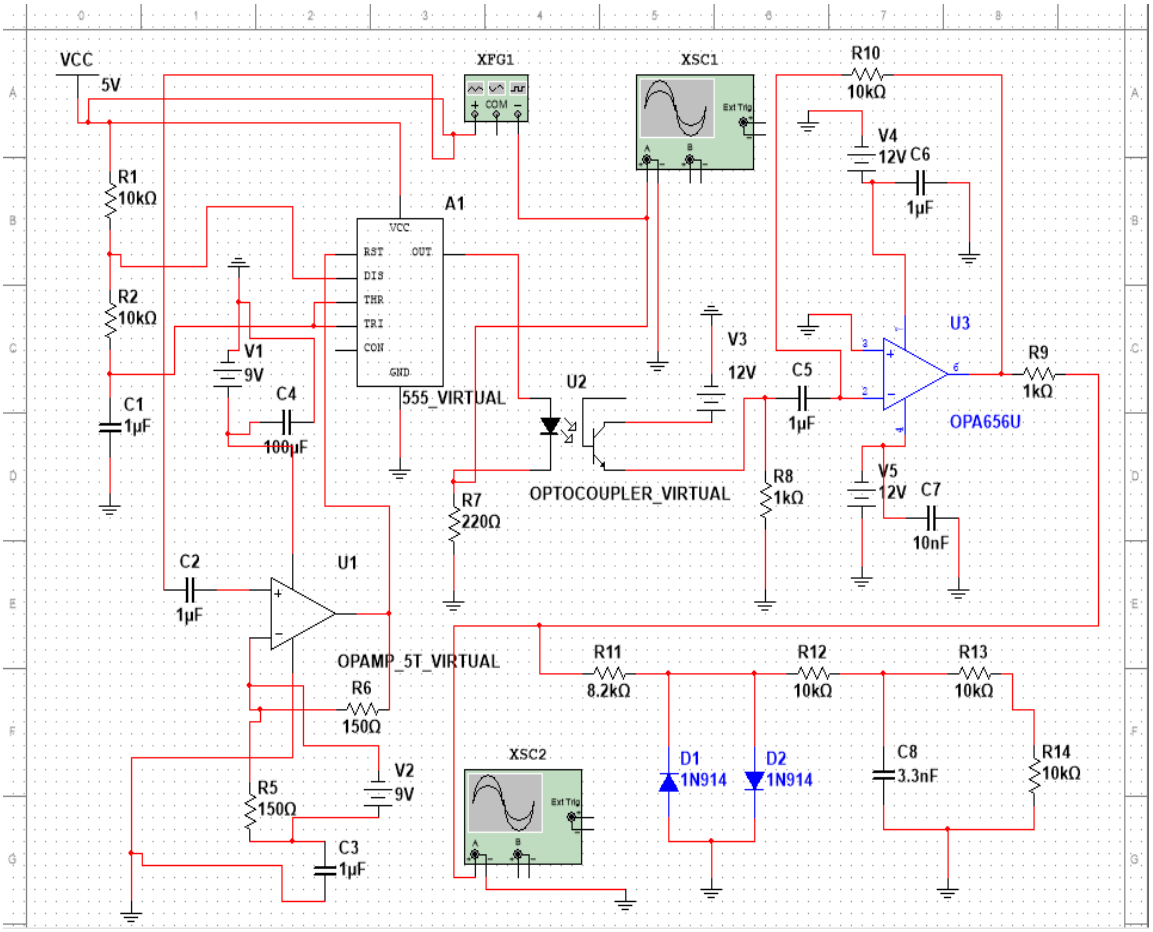

Figure 4.4: Li-Fi transceiver

A Li-Fi transceiver is a device that enables bidirectional communication using visible light. It consists of both a transmitter and a receiver to facilitate data transmission and power amplifier reception. The Transmitter section consists of led and receiver section composed of photodiode. The specific design of a Li-Fi transceiver can vary depending on the desired application, performance requirements, and implementation constraints. A design of Li-Fi transceiver is given below. At the transmitter end, the Li-Fi transceiver system consists of a light source such as an LED (Light-Emitting Diode) or laser diode. These light sources are modulated with data signals to encode the information onto the light waves. The optocoupler acts as a bridge between the 38 electrical domain (transmitter) and the optical domain (light waves). An optocoupler, also known as an optical isolator, is an electronic device that consists of a light-emitting diode (LED) and a photosensitive detector (photodiode or phototransistor) enclosed in a single package. The LED emits light when an electrical signal is applied, while the photosensitive detector senses the intensity of the incoming light. In the Li-Fi transceiver system, the electrical data signals are used to control the intensity of the LED in the optocoupler. The modulated electrical signals are fed into the input side of the optocoupler, causing the LED to emit light with varying intensity corresponding to the data being transmitted. The light waves carry the In the Li-Fi transceiver system, the electrical data signals are used to control the intensity of the LED in the optocoupler. The modulated electrical signals are fed into the input side of the optocoupler, causing the LED to emit light with varying intensity corresponding to the data being transmitted. The light waves carry the encoded data. At the receiver end, photodiode is employed to detect the light signals. The incoming light waves strike the photosensitive detector (photodiode or phototransistor) in the optocoupler, generating a proportional electrical current. This current is then converted back into data signals through appropriate amplification and demodulation techniques. The use of optocouplers in Li-Fi transceiver systems offers several advantages. Firstly, optocouplers provide electrical isolation between the transmitter and receiver circuits. This isolation helps to protect sensitive electronic components from potential electrical noise or voltage spikes. It also ensures the safety of the receiving circuitry by preventing electrical hazards.

4.4 Graphical view of both oscilloscope

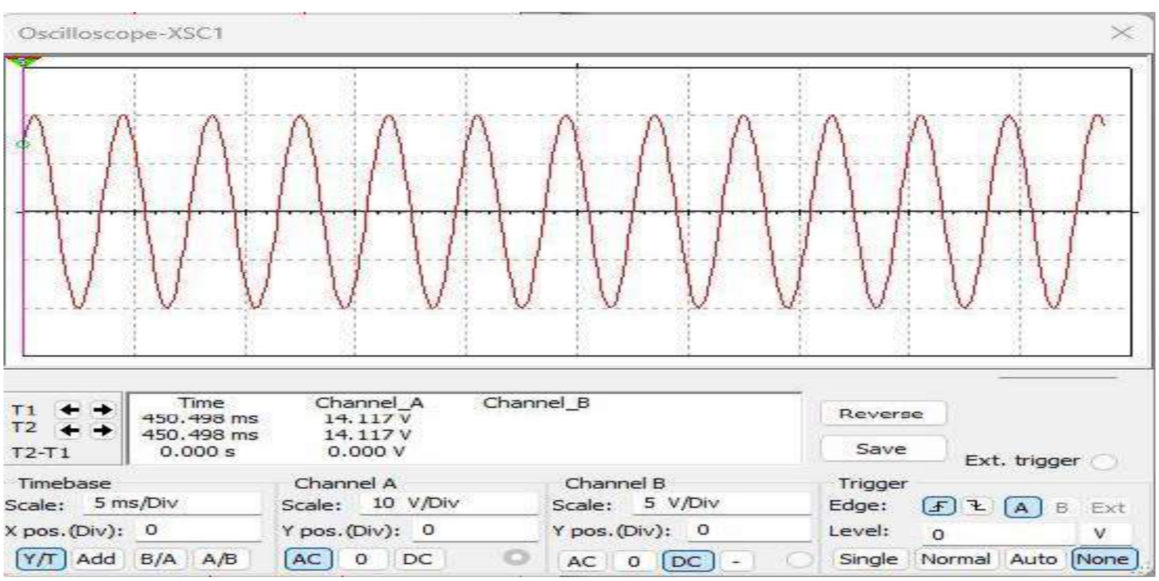

Figure 4.5: Graphical view of oscilloscope XSC1

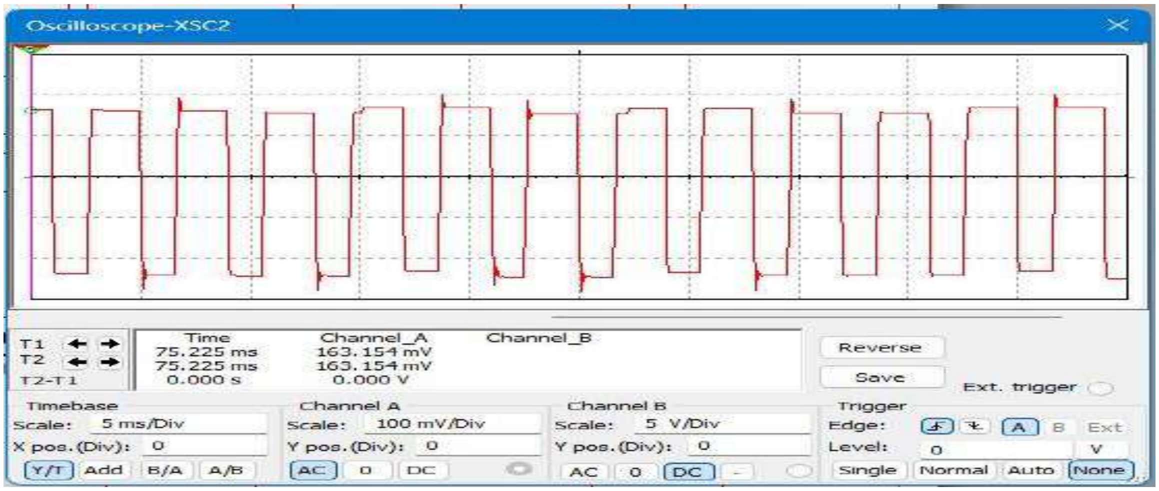

Figure 4.6: Graphical view of oscilloscope XSC2

Here Figure(4.5) indicates the input signal at transmitter section and Figure(4.6) indicates the output signal at receiver section. At transmitter section an electrical signal converted to optical signal through LED and at receiver section a photodiode receive the optical signal and converted it to electrical signal.

4.5 Output parameter

Transmitted Frequency	Frequency Loss(Hz)	SINAD(Signal Noise Distortion) dB	Percentage Frequency Loss	Fundamental Frequency Power (W)
200 Hz	13.4018	6.46	13.4018%	102.79
250 Hz	13.8464	6.59	13.8464%	102.81
300 Hz	13.9617	6.67	13.9617%	102.4
350 Hz	15.1605	6.79	15.1605%	94.19

Table-03: Table of Output parameter

4.6 Li-Fi SNR distribution:

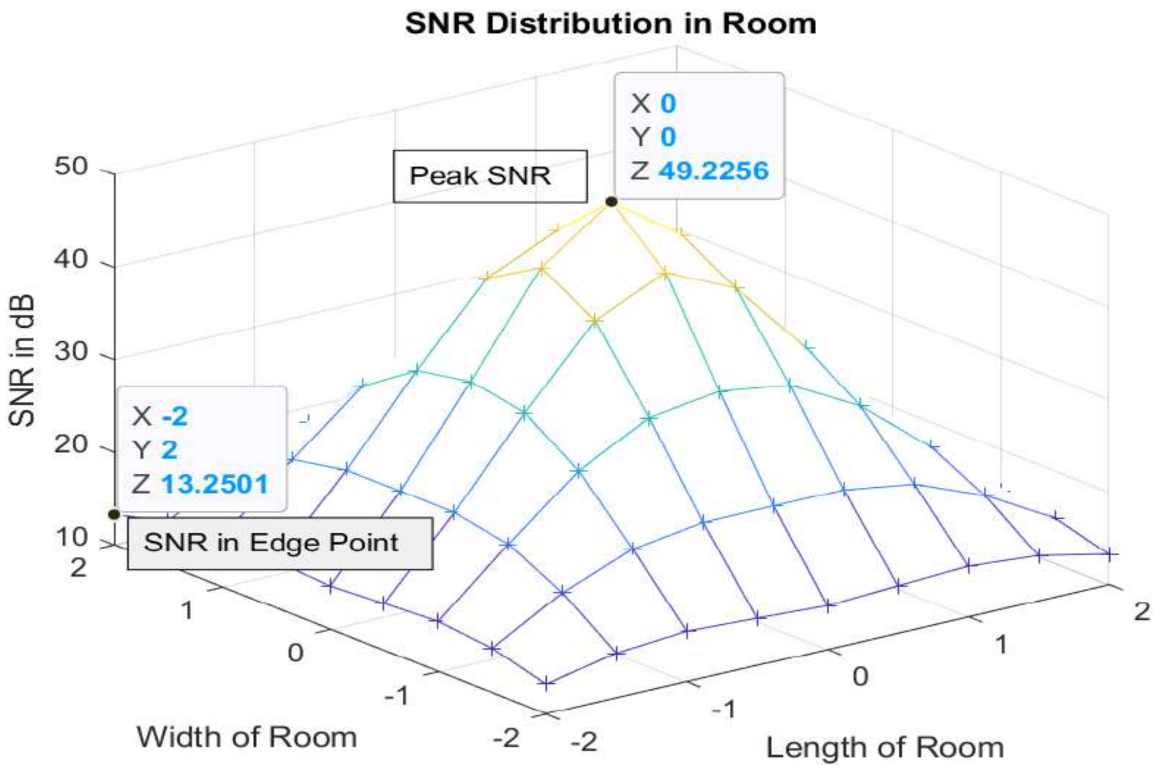

Fig 4.7: SNR Distribution for Li-Fi communication

The Signal-to-Noise Ratio (SNR) distribution in Li-Fi (Light Fidelity) systems represents the variation in SNR values across different locations within the coverage area. SNR is a critical metric indicating the quality of the received signal compared to background noise. Factors like distance between the transmitter (LED) and receiver (photodetector), light intensity, obstructions, interference, and modulation scheme influence the SNR distribution. Changes in the environment and the use of optical components also play a role. Understanding the SNR distribution helps optimize Li-Fi performance and data transfer reliability. To obtain specific SNR distribution data, measurements and simulations tailored to the system's setup and conditions are necessary.

CHAPTER 5
CONCLUSION

5.1 Summary of Research Findings

This thesis has focused on the utilization of Li-Fi technology for enhancing indoor security in the context of IoT devices. Throughout our research, we have indicated the potential advantages offered by Li-Fi, including increased data transfer speeds, enhanced security through line-of-sight requirements, and reduced interference from other wireless signals. Our findings have demonstrated that Li-Fi holds significant promise in strengthening indoor security and overcoming the limitations of conventional wireless communication methods.

5.2 Key Contributions

The research conducted in this thesis has made several important contributions to the field of indoor security and IoT applications:

- we have emphasized the criticality of secure communication within indoor environments, particularly with the proliferation of IoT devices. The interconnected nature of these devices introduces substantial security risks, and our research has shed light on how Li-Fi can effectively mitigate these risks.
- We have provided a comprehensive overview of Li-Fi technology, explaining its principles, operation, and advantages over traditional wireless communication methods. This knowledge serves as a foundation for understanding the potential of Li-Fi in enhancing indoor security.
- We have designed a transceiver using Li-Fi technology for IOT devices. we also conducted experiments and simulations to evaluate the performance of Li-Fi in indoor security scenarios. Our findings indicate that Li-Fi offers low frequency losses, Standard Bit error rate and quality factors.
- we have explored the feasibility and practicality of integrating Li-Fi into existing security systems. By discussing the compatibility of Li-Fi with infrastructure and its potential for retrofitting, we have provided insights into the implementation challenges and opportunities associated with adopting Li-Fi technology.

5.3 Implications and Future Research Directions

The findings presented in this thesis have significant implications for various stakeholders, including researchers and organization that works with sensitive information. The potential of Li-Fi technology in enhancing indoor security opens up new avenues for research and development in the field of IoT security. It encourages further exploration into the integration of Li-Fi with other security mechanisms and protocols to create comprehensive and robust security frameworks. For certain organization, our research offers practical insights into the deployment and utilization of Li-Fi technology in indoor security systems. It highlights the need for careful planning, infrastructure considerations, and collaboration with manufacturers to ensure seamless integration and optimal performance. Cybersecurity engineer can benefit from our research by recognizing the importance of security in the rapidly expanding IoT ecosystem. They can consider the regulatory implications and standards required to govern the use of Li-Fi technology, ensuring the privacy and protection of personal and sensitive data. Future research directions in this field could include investigating the scalability of Li-Fi networks in indoor environments, optimizing the performance of Li-Fi under varying lighting conditions, and exploring the potential for Li-Fi in specific applications such as healthcare, smart homes, or industrial settings. Additionally, further studies could focus on the development of novel security protocols and encryption algorithms tailored specifically for Li-Fi communication.

5.4 Conclusion

In conclusion, the use of Li-Fi technology for enhancing indoor security in IoT devices presents significant opportunities and advantages. Li-Fi offers faster data transfer speeds, increased security through line-of-sight communication, and reduced interference from other wireless signals. These features make Li-Fi a viable solution for strengthening the security of IoT devices within indoor environments. By leveraging Li-Fi technology, indoor security systems can benefit from improved data transmission rates, enabling real-time monitoring and response. The high bandwidth and low latency of Li-Fi facilitate swift and efficient communication, critical for time-sensitive security operations such as intrusion detection and emergency response. Li-Fi's reliance on line-of-sight communication adds an extra layer of security, as data can only be intercepted within the direct range of the light source. This characteristic reduces the risk of unauthorized access or interception, enhancing data integrity and confidentiality. Moreover, the reduced interference from other wireless signals enhances the reliability and stability of indoor security systems. Li-Fi's utilization of light waves for data transmission minimizes the potential for signal jamming or device interference, ensuring uninterrupted and secure communication between IoT devices. The implementation of Li-Fi technology for indoor security requires minimal infrastructure changes and is compatible with existing systems. This makes it a practical and feasible solution for retrofitting security systems without significant investments in hardware or infrastructure modifications. The findings of this research have implications for researchers, practitioners, and policymakers. Researchers can further explore the integration of Li-Fi with other security mechanisms and protocols, paving the way for comprehensive security frameworks. Practitioners can leverage the insights provided to effectively deploy Li-Fi in indoor security systems, considering infrastructure considerations and collaboration with manufacturers. Policymakers can recognize the importance of securing IoT devices within indoor environments and develop regulations and standards to ensure data privacy and protection.

In the future, additional task can focus on scaling Li-Fi networks in larger indoor environments, optimizing Li-Fi performance under diverse lighting conditions, and exploring its applications in specific domains such as healthcare, smart homes, or industrial settings. Developing specialized security protocols and encryption algorithms for Li-Fi communication can also enhance its security capabilities. As the demand for secure and reliable IoT applications continues to grow, the adoption of Li-Fi in indoor security systems can contribute to creating safer and more secure environments.

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APPENDIX

SOURCE CODE- 01

```
import random

class AuthenticationError(Exception):

   pass

class LiFiTransmitter:

   def __init__(self, encryption_key):

      self.encryption_key = encryption_key

      self.transmitted_data = None

   def transmit_data(self, data, username, password):

      if self._authenticate_user(username, password):

         encrypted_data = self._encrypt_data(data)

         light_signal = self._convert_to_light_signal(encrypted_data)

         self._transmit_light_signal(light_signal)

         self.transmitted_data = data

         return True

      else:

         raise AuthenticationError("Authentication failed. Transmission aborted.")

   def _authenticate_user(self, username, password):

      # Simple authentication check (can be replaced with a secure authentication
mechanism)

      valid_users = {"faculty": "password1", "ETE": "password2", "STUDENTS":
"password3"}
```

```
        if username in valid_users and valid_users[username] == password:
            return True
        return False
    def _encrypt_data(self, data):
        # Apply encryption algorithm (e.g., AES)
        # Add implementation for encryption using the encryption key
        encrypted_data = data + self.encryption_key
        return encrypted_data
    def _convert_to_light_signal(self, data):
        # Convert data to a light signal (e.g., modulation techniques)
        light_signal = data.replace('0', '.').replace('1', '-')
        return light_signal
    def _transmit_light_signal(self, light_signal):
        # Transmit the light signal using Li-Fi transmitter hardware
        print("Transmitting light signal:", light_signal)
class LiFiReceiver:
    def __init__(self, encryption_key):
        self.encryption_key = encryption_key
    def receive_data(self, light_signal):
        decrypted_data = self._decrypt_light_signal(light_signal)
        data = self._extract_data(decrypted_data)
        return data
    def _decrypt_light_signal(self, light_signal):
```

```
        # Decrypt the light signal (e.g., decryption algorithm)
        # Add implementation for decryption using the encryption key
        decrypted_data = light_signal.replace('.', '0').replace('-', '1')
        return decrypted_data
    def _extract_data(self, decrypted_data):
        # Extract the original data from the decrypted signal
        data = decrypted_data.replace(self.encryption_key, '')
        return data
# Example usage
encryption_key = "A1B2C3D4E5F6"
transmitter = LiFiTransmitter(encryption_key)
receiver = LiFiReceiver(encryption_key)
# Generate random data to transmit
data = ''.join(random.choices('01', k=10))
# User authentication
username = input("Enter username: ")
password = input("Enter password: ")
try:
    # Transmit and receive data if authentication is successful
    transmitter.transmit_data(data, username, password)
    received_data = receiver.receive_data(data)
    # Verify if the received data matches the transmitted data
    print("Transmitted data:", transmitter.transmitted_data)
```

```
    print("Received data:", received_data)

    if transmitter.transmitted_data == received_data:

        print("\033[92mAccess granted! Transmission of data from the transmitter section to the receiver section is possible.\033[0m")

        print(f"Welcome, {username}!")

    else:

        print("\033[91mTransmitted message and received message do not match. Access denied.\033[0m")

except AuthenticationError as e:

    print("\033[91mAccess denied!! Unauthorized person trying to access information.\033[0m")
```

Source code -02

```
clear all;
clc;
close all;

Incidence = 70*pi/180;
TX_FOV = 70;               % Transmitter Field Of View
RX_FOV = 100;               % Receivers Field Of View
Tx = [2,2,2];             % Transmitter Location
%Rxp = [2,2];              % Receiver Location
W_Room = 4;                % Width of Room
L_Room = 4;                % Length of Room
H_Room = 6;                % Height Between Transmitter and Receiver
R = 1;                   % Responsivity of Photodiode
Apd = 1e-5;               % Area of PhotoDetector
Rb = 1e6;                % Data rate of system
Iamp = 5e-13;              % Amplifier Current
q = 1.6e-19;              % Electron Charge
Bn = 50e6;                % Noise Bandwidth
I2 = 0.562;              % Noise Bandwidth Factor
PLED = 10;                 % Power Emitted by LED
index =1;
HLED = 1;
[W L] = meshgrid(-(W_Room/2) : 0.50 : (W_Room/2));      % Consideer Length of BLock for Room
xydist = sqrt((W).^2 + (L).^2);
hdist = sqrt(xydist.^2 + HLED.^2);
%D = Tx - Rx;
```

```
%d = norm(D);
%Incidence = acos()
A_Irradiance = ((Tx(3)-HLED)./hdist);
%I(index) = Irradiance*180/pi;
%if abs(Incidence <= RX_FOV)
     p = TX_FOV ;
     Tx_FOV = (TX_FOV*pi)/180;
     % BASIC CALCULATION IN VLC SYSTEM %
     % Lambertian Pattern
     m = real(-log(2)/log(cos(Tx_FOV)));
     % Radiation Intensity at particular point
     Ro = real(((m+1)/(2*pi)).*A_Irradiance^m);
     % Transmitted power By LED
     Ptx = PLED .* Ro;
     % Channel Gain ( Channel Coefficient Of LOS Channel )
     %Theta=atand(sqrt(sum((Tx-Rx).^2))/H_Room);
     HLOS = (Apd./hdist.^2).*cos(Incidence).*Ro;
     % Received Power By PhotoDetector
     Prx = HLOS.*Ptx;
     % Calculate Noise in System
     Bs = Rb*I2;
     Pn = Iamp/Rb;
     Ptotal = Prx+Pn;
     new_shot = 2*q*Ptotal*Bs;
     new_amp = Iamp^2*Bn;
     % Calculate SNR
     new_total = new_shot + new_amp;
     SNRl = (R.*Prx).^2./ new_total;
     SNRdb = 10*log10(SNRl);
%          else
%                  SNRl = 0;
%                  SNRdb = 0;
%          end
index = index + 1;
%    Plot Graph %
figure;
mesh(W,L,SNRdb);
%mesh(SNRdb);
%ylim([0 30]);
title('SNR Distribution in Room');
xlabel('Length of Room');
ylabel('Width of Room');
zlabel('SNR in dB');
```

Enhancing Indoor Security by using Li-Fi Transmission for IoT devices (AutoRecovered) (1)

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