UNDERWATER TRANSMISSION OF AUDIO AND TEXT USING LI-FI TECHNOLOGY

A project report submitted in partial fulfillment of the requirements for the award of the Degree

of

BACHELOR OF TECHNOLOGY

In

ELECTRONICS AND COMMUNICATION ENGINEERING

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GITAM
(Deemed to be University)
(Estd. u/s 3 of UGC act 1956 & Accredited by NAAC with "A+" Grade)

HYDERABAD-502329

(2019-2023)

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This is to certify that the project work entitled "**UNDERWATER TRANSMISSION OF AUDIO AND TEXT USING LI-FI TECHNOLOGY**" is a bonafide work carried out by **A.Aditya Koushik (221910401001), C.Rishitha Reddy (221910401008), S.Ashish (221910401041), T.Sohith (221910401044)** submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in **Electronics and Communication Engineering**, GITAM School of Technology, GITAM (Deemed to be University), Hyderabad during the academic year 2022-2023.

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We hereby declare that the project work entitled **"UNDERWATER TRANSMISSION OF AUDIO AND TEXT USING LI-FI TECHNOLOGY"** is an original work done in the Department of Electrical, Electronics and Communication Engineering, GITAM School of Technology, GITAM (Deemed to be University) submitted in partial fulfillment of the requirements for the award of the degree of **B.Tech. in Electronics and Communication Engineering**. The work has not been submitted to any other college or university for the award of any degree or diploma.

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ACKNOWLEDGEMENT

We would like to thank our project guide **Mr. S Francis Xavier,** Assistant Professor Dept.of EECE for her/his stimulating guidance and profuse assistance. We shall always cherish our association with him/her for his/her guidance, encouragement, and valuable suggestions throughout the progress of this work. We consider it a great privilege to work under his/her guidance and constant support.

We would like to thank our Project Coordinators **Dr. D. Anitha,** Associate Professor, Dept. of EECE and **Dr.N. Shyam Sunder Sagar,** Assistant Professor Dept. of EECE in helping to complete the project by taking frequent reviews and for their valuable suggestions throughout the progress of this work.

We consider it as a privilege to express our deepest gratitude to **Prof. T Madhavi**, Head of the Department, Department of EECE for her valuable suggestions and constant motivation that greatly helped us to successfully complete the project work.

Our sincere thanks to **Prof. N Seetharamaiah** Associate Director, School of Technology for inspiring us to learn new technologies and tools.

Finally, we deem it a great pleasure to thank one and all who helped us directly and indirectly throughout this project.

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Abstract:

The research in underwater wireless communication is attracting and leading to increased attention due to its numerous applications mainly for military & commercial fields. There exists enormous major challenges in the field of submerged communication or communication underwater namely: Finite bandwidth, delay in propagation, less data rate, more BER (Bit Error Rate), Doppler spreading, High ambient noise etc. Underwater wireless communication is based on three types of waves, these are EM wave, acoustic wave and optical wave

The present underwater communication systems are based on the electromagnetic, acoustic and optical signals. The loss will be huge for Electro-Magnetic (EM) waves, so it is limited to short range communication, optical waves have line of sight issues. To overcome the disadvantages of these systems, the LI-FI-based communication system can be used as light can penetrate deep water and it also minimizes signal loss. Li Fi (Light Fidelity) is an emerging technology that uses the visible light spectrum for communication

This will ensure the maximum transmission rate and it is more efficient and cheaper than the other existing methods, and this will avoid the mistakes which are occurring by the other means of data transmission. The communication will be based on the coding in order to provide data security using different coding languages and protocols. The Li-Fi transmitter and receiver are used to analyze the performance and various conditions such as quality, intensity, and distance.

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INTRODUCTION

1.1 Data transfer

Data switch/transfer refers back to the technique of transmitting or transferring digital statistics from one device, region, or community to another. This system can occur the use of various strategies, consisting of stressed out or wireless conversation channels, inclusive of the net, neighborhood location networks (LANs), or different types of laptop networks.Data switch can involve the switch of different varieties of virtual data, which include files, documents, photos, audio, video, and different sorts of digital content. The speed and efficiency of records switches rely upon factors which include the dimensions of the data being transferred, the rate of the relationship or network, and the capabilities of the gadgets concerned.

Data transfer is a vital component of modern-day computing, because it enables users to percentage data and collaborate remotely, access online services, and shop and retrieve facts from cloud garage answers. It is utilized in various industries, together with finance, healthcare, training, and amusement, to name a few.Data transfer can occur in specific ways, relying on the kind of statistics and the gadgets involved. Some of the maximum not unusual strategies of data switch encompass Wired communique channels: Data can be transferred through the use of physical connections, which include Ethernet cables, USB cables, or serial cables. This method is commonly used for transferring statistics between gadgets which can be in near proximity to each other, along with between a computer and a printer or between computer systems linked on a neighborhood community.

Wireless conversation channels: Data may be transferred to the use of wireless communication technologies, together with Wi-Fi, Bluetooth, or mobile networks. This method is usually used for transferring data among mobile gadgets, along with smartphones, tablets, and laptops, or for connecting devices that aren't physically related, together with a wireless printer.

Cloud-based totally storage answers: Data may be stored and accessed from cloud-based totally storage answers, along with Dropbox, Google Drive, or iCloud. This method enables users to get the right of entry to their records from any tool with an internet connection, and it is able to be used for sharing documents with different users.

Data switches can also be categorized based on the path of the transfer. For instance, records transfer can be:

Upload: Data is transferred from a local tool to a faraway server or storage region.

Download: Data is transferred from a faraway server or storage region to a neighborhood device.

Peer-to-peer: Data is transferred among or greater gadgets without the want for a centralized server

Data switch velocity is another important aspect that can impact the efficiency of facts transfer. Data switch speed is measured in bits according to second (bps), bytes per 2d (Bps), or megabits in line with 2d (Mbps), and it relies upon on factors including the community bandwidth, the distance between the devices, and the type of data being transferred.

In summary, facts transfer is an essential procedure in present day computing, enabling customers to proportion, get right of entry to, and store digital data the use of exclusive strategies and technology.

1. Wired transfer: This approach is usually used for transferring massive quantities of information, consisting of backups or device migrations, for the reason that it's typically quicker and greater dependable than wi-fi transfer. However, stressed out transfer can be confined by means of the space between the devices and the form of cable used. For example, USB cables are commonly constrained to 3 meters, while Ethernet cables can be used to connect gadgets over longer distances.

2. Wireless switch: This approach is commonly used for transferring smaller quantities of statistics, which includes pics, movies, or documents, among devices which are in close proximity to each other. Wireless transfer may be slower and less dependable than a stressed switch, but it offers more convenience because it doesn't require bodily connections. Bluetooth and NFC are examples of wi-fi switch strategies which are typically used for shifting statistics among cellular gadgets, consisting of smartphones and capsules.

3. Cloud-primarily based switch: This method is usually used for storing and having access to information from extraordinary gadgets, and for sharing files with others. Cloud-based transfer can be convenient for customers who need to get admission to their facts from a couple of locations or devices, and it may be more relaxed than different methods for the reason that information is stored on a far off server; it really is included with the aid of safety features. However, cloud-based total transfer can be confined via the person's internet connection speed, and it could no longer be suitable for users who want to switch large amounts of data.

4. Peer-to-peer transfer: This method is typically used for sharing documents between two or greater gadgets which can be in close proximity to each other, including among two smartphones or laptops. Peer-to-peer transfer may be quicker than cloud-based totally switching because it doesn't depend on an internet connection, but it may be much less relaxed because the records are transferred without delay among the gadgets.

5. Email transfer: This method is generally used for sharing small documents, including documents or images, with different users. Email transfer is convenient since it doesn't require any extra software or hardware, but it's no longer appropriate for moving huge files or touchy facts, considering email attachments may be intercepted or lost in transit.

The choice of facts transfer method depends on the consumer's needs and the kind of facts being transferred. Wired transfer is typically faster and greater reliable than wireless switch, even as cloud-

Based total transfer is convenient for getting access to records from exclusive gadgets. Peer-to-peer switch and electronic mail transfer are appropriate for moving small amounts of information, at the same time as cloud-based switch is more appropriate for massive amounts of records or for sharing files with others.

1.2. History of data transfer

1898
The paper report folder, a protective covering for papers, and a vertical filing machine are inventions by Edwin G. Siebels, a man who is truly preoccupied with agency.

1898 – Early Seventies – Office Filing Systems
Agencies used to put papers in envelopes and store them in the little cubbies on pigeonhole shelves. Since workplaces in the 1960s and 1970s featured filing cabinets, employees may have been more mindful of important details like smoking breaks and selecting a quality bourbon to accompany a hard day at the office.

Documents are currently having their moment. Files are the most popular choice for essential file and photo garages at workplaces, hospitals, universities, clubs, and government facilities. They come in patterns including tri-tab, multi-colored, indoor pockets, and accordion. The drawback is that report folders tended to accumulate on desks as filing clerks waited, or sometimes they would stray between automobile seats.

At one point during this period, the act of "sharing" a file involved physically handing another person a record folder that was likely stained with the morning's coffee. This developed into a fantastic way to interact with employees in person.

The 1970s – Computer Hobbyists Party Down
A member of the Chicago Area Computer Hobbyists' Exchange (CACHE), Ward Christensen, develops software that mimics the operation of a cork bulletin board. The CBBS, or

Computerized Bulletin Board System, is the name he gives to this programme. Randy Seuss, a fellow laptop aficionado and member, creates the hardware.

This system, which served as a message tool for the small group of people who owned and utilized computers in the 1970s, employed an early file transfer protocol to deliver binary files using a modem, which was accessible by a single smartphone model. The gadget could only be accessed by users in turn.

Figure 1: floppy disc

Tim Truscott and Jim Ellis founded Usenet just one year later. Usenet was one of the earliest online communities that enabled users to post messages or other content to newsgroups. Although it was never intended to be used as a document sharing system, users were able to transmit files over the network thanks to the capabilities.

Back in the real world, IBM makes available to the public 5.25-inch and later 8.25-inch floppy disks, allowing users to store tiny data and software on drives that may be shared with other computer hobbyists.

The Mid-Eighties – Finally, There's Progress

In order to transfer documents over a BBS or telnet, new protocols called Kermit and Fidonet are developed. The File Transfer Protocol (FTP), which was established in 1985, enables users to connect to the same universal community protocol to securely transfer data between computers. It sets down a number of objectives, including selling document sharing, whether it be information or laptop applications, encouraging the use of remote computers, safeguarding users from variations in hosts' report storage structures, and transferring information "reliably and effectively."

The Nineties – The Wild West of Internet & File Sharing

The idea of the global enormous net is born, launching global communications and computers. Customers who are not computer enthusiasts may exchange messages and share documents through an easily comprehensible interface for the first time. The development of MP3, AAC, and MPEG file formats for music and video files is made possible by advancements in compression technology.

Virtual and physical files are frequently exchanged. Software and computer companies are concerned about the negative implications of file sharing, particularly the willingness of users to share computer programmes, games, and music files online with strangers as well as friends.

In the early ‘90s, Sharing software over 3.5-inch floppy discs has gotten to the point where the Software Publishers Association (SPA), the Educational Section Anti-Piracy Committee, and the Copyright Protection Fund are left scratching their heads and wondering what they can do to stop the young people from rampantly copying laptop software.

They make the decision to speak in adolescent slang and produce the amazing rap video "Don't Copy that Floppy," which features MC Double Def DP. While Mr. Double Def DP cautions that cloning floppies may result in the end of computers as we know them(!), in reality, this does not yet happen. It does, however, serve as a fantastic forecast of the internet piracy that would occur in the following decades.

Figure 2: multi floppy discs

1.3. wi-fi (wireless fidelity,a modern data transfer method)

Australian researchers from the Radio Physics Division of the CSIRO (Commonwealth Scientific and Industrial Research Organization) created a test bed prototype for a wireless local area network (WLAN) in 1992.

Instead of using cables, a wireless or wi-fi network connects your devices, such as computers, printers, and cellphones, to the Internet and one another. Within a specific range in all directions, any wirelessly enabled device, such as a laptop or tablet, may pick up the wi-fi signal. Technically speaking, the IEEE 802.11 standard provides the communication protocols for Wi-Fi-enabled wireless devices now in use, such as wireless routers and wireless access points. Several IEEE standards are supported by wireless access points.

The internal router firmware application of wireless routers integrates a Wireless Access Point, an Ethernet switch, and a WAN-interface to provide IP routing, NAT, and DNS forwarding. In order to connect to a cable modem, DSL modem, or optical modem—which is typically the only WAN device—wired and wireless Ethernet LAN devices need a wireless router. With a wireless router, it is possible to configure all three components, namely the access point and router, using a single central tool. The majority of the time, this utility is an integrated web server that is available to LAN customers on wired and wireless networks as well as, occasionally, WAN clients.This utility may also be an application that is run on a computer, as is the case with as Apple's AirPort, which is managed with the AirPort Utility on macOS and iOS

Devices that are within the Wi-Fi range of one or more routers that are online may utilize Wi-Fi technology to access the local network and the Internet. One or more linked access points' (hotspots') coverage can encompass anything from a few rooms to many square kilometers (miles). A collection of access points with overlapping coverage may be necessary to provide coverage for the broader region.

Embedded Wi-Fi modules with real-time operating systems have increased in popularity over the past several years (especially as of 2007), offering a convenient way to wirelessly enable any device that can interact via a serial port. This enables the creation of straightforward monitoring devices. A portable ECG gadget monitoring a patient at home is one example. This Wi-Fi-capable gadget can converse online.

Wi-Fi, also known as wireless connectivity, has become an essential aspect of modern life, allowing digital devices to connect to a wireless local area network (WLAN) and access the internet without the need for physical cables. The story of Wi-Fi is a fascinating one, marked by innovation, competition, and collaboration.

Wi-Fi can be traced back to the 1980s, when the Federal Communications Commission (FCC) allocated a significant amount of radio frequency spectrum in the 900 MHz and 2.4 GHz bands for unlicensed use, which would later be used for Wi-Fi. In 1991, NCR Corporation/AT&T developed a precursor to Wi-Fi known as WaveLAN, which was the first wireless networking standard to use the 900 MHz frequency band. However, it did not become widely adopted.

In 1997, the Institute of Electrical and Electronics Engineers (IEEE) established the 802.11 standard for wireless local area networks (WLANs), which would later serve as the basis for Wi-Fi. This standard established a set of protocols for wireless networking, allowing devices to communicate with each other over a wireless network.

In 1999, the first commercial Wi-Fi products were introduced, such as the Apple iBook and Lucent Orinoco PC Card, based on the 802.11b standard with a maximum data rate of 11 megabits per second (Mbps). While initially used in corporate environments, Wi-Fi quickly spread to homes and public spaces.

As Wi-Fi became more popular, the need for a standard certification program became apparent, leading to the formation of the Wi-Fi Alliance in 2000. This association promoted and certified Wi- Fi products based on the 802.11 standard, ensuring compatibility and quality across different manufacturers.

Throughout the early 2000s, Wi-Fi continued to evolve with the introduction of new standards and technologies, such as the 802.11g standard in 2002, which increased the maximum data rate to 54 Mbps, and the 802.11n standard in 2004, which increased the maximum data rate to 600 Mbps and introduced multiple-input and multiple-output (MIMO) technology.

Additional features were introduced to Wi-Fi over the years, including the Wi-Fi Protected Setup (WPS) feature in 2007, which simplifies the process of setting up and securing Wi-Fi networks, and the Wi-Fi CERTIFIED ac Wave 2 certification program in 2016, which includes new features such as MU-MIMO technology and support for four spatial streams.

The Wi-Fi 6 certification program was introduced in 2019, which is based on the IEEE 802.11ax standard and includes new features such as orthogonal frequency division multiple access (OFDMA) and target wake time (TWT) to improve network efficiency and device battery life.

The ongoing evolution of Wi-Fi technology has enabled new applications and use cases, including the Internet of Things (IoT), smart homes, and autonomous vehicles. Wi-Fi has also played a critical role in enabling telemedicine and remote education during the COVID-19 pandemic.

The future of Wi-Fi is expected to bring even faster data rates, increased reliability and security, and greater support for IoT and emerging technologies.

1.4. Wi-Fi drawbacks

1. Security Concerns

As you don't know the kind of people using that network, most open Wi-Fi networks are risky to connect to. Just so you know, public WiFi networks are most susceptible to hackers. Hackers may use their Id to pretend to be the network Id, which might cost you or your company money. It is therefore preferable to only do business via a private or corporate network.

2. Limited Range – Disadvantages of Wi-Fi

Range problems are the second most frequent drawback of Wireless LAN. Considering that the building has many stories. In a building, the typical Wi-Fi range is between 100 and 150 feet. When you travel away from the access point location, a Wi-Fi device's range and strength would deteriorate. You won't be able to connect to your network if you are not completely within the network range, which might disrupt your operation.

3. Signal Interference

When there are other electromagnetic devices or barriers between you and the Wi-Fi source, the 2.4 GHz frequency that Wi-Fi devices typically operate on may be affected or hampered. This signal issue might affect connectivity or slow down your speed due to a poor signal. During such instances, sending huge files across the network becomes dangerous. In such cases, the likelihood of data corruption during transmission is higher.

4. Bandwidth Usage

The bandwidth is negatively correlated with the number of connected devices. This implies that the bandwidth becomes weaker the more devices there are linked to a single Wi-Fi network. Another well-known drawback of Wi-Fi in the office is this. More users equate to a slower process and a speed restriction that is more restrictive.

5. Slower in contrast to LAN

At the office or at home, wireless LAN is slower than a wired network. Due to interference from other devices or other EMF sources, the majority of the wireless signal is either dispersed or diffused. In the case of wired networks, that is not the case, though. According to a 2011 research titled "Wi-Fi in the House," wireless internet connections might be up to 30% slower than connected ones.

6. Effects of Wi-Fi on Health

Wi-Fi negatively impacts human health by causing oxidative stress and neuropsychiatric consequences, according to current research findings published in. Apoptosis, cellular DNA damage, endocrine alterations, and calcium excess are further health risks associated with Wi-Fi. These outcomes mirror those brought on by EMFs (Microwave Frequency).Interference:

One of the most frequent problems experienced by Wi-Fi users is interference. Other wi-fi devices running at the same frequency, such as Bluetooth devices, cordless phones, and various Wi-Fi networks, might interfere with Wi-Fi notifications. Obstacles like walls and floors that might degrade or obstruct Wi-Fi signals can also create interference. Slower facts speeds, broken connections, and lost notifications can all be results of this interference.

Security dangers:

The risks to capacity safety that come with Wi-Fi are still another significant drawback. Hackers may get access to unsecured Wi-Fi networks and steal sensitive information including passwords, credit card numbers, and private records. Wi-Fi networks may also be used by hackers to spread malware, spyware, and other harmful software to unwary users. Hackers can employ brute-force attacks or exploit holes in the Wi-Fi protocol to obtain unwanted access, thus even protected Wi-Fi networks are not immune to attacks.

Range barriers:

Wi-Fi networks won't function effectively in large homes, residences, or outdoor places since Wi-Fi signals have a limited range. Wi-Fi signals can be reduced or obstructed by obstructions like walls, floors, and ceilings, lowering the community's effective range. When users move further away from the access point, they may have decreased reported speeds and failed connections. This might result in dead zones where Wi-Fi signals are too susceptible to connect with.

Bandwidth obstacles:
Wi-Fi networks have a limited amount of bandwidth, thus the more devices that are connected to the network, the slower the data rates will be. This can be an issue in crowded places where several users are attempting to connect to the same network at once, such as airports, cafés, and conference centers. This may lead to slow information speeds, dropped connections, and decreased user satisfaction for everyone connected to the network.

In conclusion, although Wi-Fi has transformed our internet connectivity and social interactions, it is not free from shortcomings. Wi-Fi users may encounter issues such as interference, safety hazards, range limitations, and bandwidth obstacles. It is crucial to acknowledge these drawbacks and take measures to address them, including securing your network, optimizing the location of your access point, and reducing the number of devices connected to your network.

Furthermore, there is no consensus among the medical community regarding the potential health effects of Wi-Fi. While some studies have suggested that prolonged exposure to Wi-Fi radiation could have negative health consequences, particularly in schools where children are exposed to Wi-Fi radiation for extended periods of time.

Reliability: Wi-Fi networks aren't always reliable, especially in areas with poor connectivity. For instance, Wi-Fi warnings may be weak or nonexistent in rural regions, making it challenging or impossible to connect to the internet. Wi-Fi networks may potentially experience interruptions as a result of power outages, hardware issues, or other issues.

Complexity: Particularly for non-technical users, setting up and configuring a Wi-Fi network may be a difficult and time-consuming process. In addition, network managers might wish to upgrade firmware, configure routers, and fix connectivity issues. This might be a difficult process that demands technological expertise for the typical individual.

Cost: Setting up and maintaining Wi-Fi networks can be a costly endeavor, especially in larger homes or outdoor areas. The hardware required, such as routers and access points, can quickly add up, as can the expenses associated with installation and maintenance. In addition, some internet service providers may charge extra fees for Wi-Fi connectivity, which can be burdensome for budget-conscious consumers.

Despite its convenience, Wi-Fi technology has several drawbacks, including interference, security risks, range limitations, bandwidth constraints, health concerns, reliability issues, complexity, and cost. Although these drawbacks may not deter users from utilizing Wi-Fi, it is crucial to be aware of them and take necessary measures to mitigate their impact. Through proactive and informed actions, users can ensure a safer, more reliable, and more enjoyable Wi-Fi experience.

1.5. Li-Fi Technology

Professor Harald Haas introduced Li-Fi, or light fidelity, at a TED Global Talk in July 2011. Li-Fi is a wireless networking technology that is based on Visual Light Communication (VLC), which uses LEDs, or light emitting diodes, to enable fully networked wireless systems. Unlike traditional networking technologies, Li-Fi does not require wires to connect electronic devices to the internet. Instead, a transceiver is needed to transmit and receive data between nodes. The LED's modulation technique enables it to carry data through light. Li-Fi was developed to address the limitations of current technologies, as the growing use of internet-based devices has reduced the capacity of Wi- Fi due to a shortage of radio frequency resources.

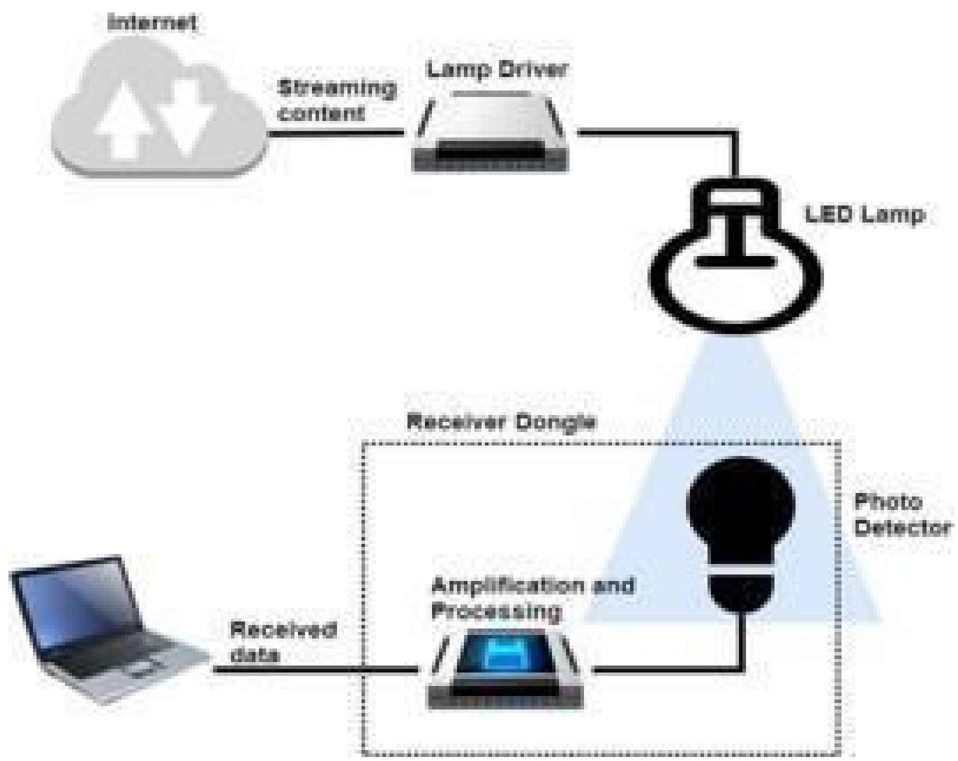

Figure 3: Basic Concept Diagram of Li-Fi

According to figure 3, Li-Fi technology involves using LED lamps for transmitting data, while a photo-detector receives the transmitted data. To ensure that the LED works correctly, a lamp driver is required. The signal that is received by the photo-detector is managed through amplification and processing.

The basic working principle of Li-Fi technology is based on two main concepts: the use of transceivers and light as a medium of transmission. This concept enables duplex communication. Li-Fi has a data transfer rate of 14 GBPS, which can be achieved using three laser diodes (red, green, and blue) that are readily available in the market. The rate can increase to 100 GBPS if the whole visible spectrum is used.

Li-Fi and VLC share a common medium for data communication, which is light. However, the key difference between the two is that VLC uses unidirectional, point-to-point light communication at low data rates.

One of the earliest pioneers of light-primarily based verbal exchange was Alexander Graham Bell, who experimented with the use of light to transmit audio indicators inside the 19th century. Bell's invention, known as the Photophone, used a modulated light beam to transmit speech over a distance of numerous hundred ft.

While Bell's invention was groundbreaking, it was no longer until the 21st century that the idea of the usage of seen light for wi-fi communique commenced to take form. The concept of the use of mild for wi-fi communique was first proposed via Harald Haas, a professor at the University of Edinburgh, in a TED talk in 2011.

Haas's TED speech generated loads of interest inside the concept of Li-Fi, and he went directly to observe an organization called PureLiFi to commercialize the generation. PureLiFi's first Li-Fi merchandise were delivered in 2013, and the employer has persisted to develop and improve the generation ever for the reason that.

The fundamental principle in the back of Li-Fi is easy: modulate the depth of an LED bulb to transmit records. This is performed using a system known as OOK, or On-Off Keying, which turns the LED on and off at a totally high frequency to transmit virtual facts. This technique is just like the manner that Morse code works, with the LED appearing as the transmitter and the receiver detecting the on-off sample to decode the message.

One of the main blessings of Li-Fi technology is its excessive statistics switch speeds. Since seen light has a better frequency than radio waves, Li-Fi can potentially transmit facts at much higher speeds than conventional Wi-Fi networks. In truth, laboratory tests have demonstrated Li-Fi speeds of as much as 224 Gbps, although real-world speeds are probably to be decreased.

Another benefit of the Li-Fi era is its security. Since visible light can't pass through walls, Li-Fi indicators are constrained to the room in which they are transmitted. This means that Li-Fi networks are inherently more comfy than Wi-Fi networks, which can be intercepted by using unauthorized users out of doors of the community.

Li-Fi generation additionally has some potential negative aspects. One of the main drawbacks of Li-Fi is its constrained variety. Since visible mild cannot skip through partitions, Li-Fi indicators are restricted to the room in which they may be transmitted. This means that Li-Fi networks may additionally require greater get admission to points than traditional Wi-Fi networks to offer the identical coverage.

Another potential drawback of Li-Fi is its susceptibility to interference from ambient mild sources. Since Li-Fi signals transmit the usage of visible mild, they can be disrupted by different mild sources within the room, consisting of sunlight or fluorescent bulbs. This can result in slower statistics, switch speeds or dropped connections.

Despite its capacity drawbacks, the Li-Fi era has the capacity to revolutionize the way we consider wi-fi communication. The Li-Fi era has already been utilized in a few packages, such as in hospitals, where Wi-Fi alerts can intrude with clinical systems. Li-Fi has also been used in some clever domestic packages, where it may provide faster and greater comfy switches than traditional Wi-Fi networks.

In recent years, the Li-Fi generation has persevered to conform and enhance. Researchers have evolved new modulation strategies, together with PPM, or Pulse Position Modulation, that allow Li-Fi to transmit records at even higher speeds. Other researchers have explored using Li-Fi in underwater conversation and space verbal exchange programs.

Li-Fi technology is still within the early levels of development, and there are many challenges to be triumph over before it may emerge as a mainstream technology. However, as the demand for faster and greater cozy wireless verbal exchange maintains to grow, Li-Fi generation

The Li-Fi era continues to be in the early ranges of improvement and studies, and there are many areas in which it is able to be applied. One of the most promising applications of Li-Fi is within the field of indoor positioning systems. Since Li-Fi indicators are restricted to the room wherein they may be transmitted, they may be used to precisely locate gadgets inside a building or room. This should have crucial implications for indoor navigation, asset tracking, and other place-based offerings.

Another potential utility of Li-Fi technology is in the discipline of smart towns. Li-Fi could be used to create wireless networks which are faster, more comfy, and more reliable.

Wi-Fi networks. This could have critical implications for the development of smart homes, smart buildings, and different Internet of Things (IoT) packages.

The Li-Fi era may also have critical implications for the sector of augmented reality (AR). AR packages require rapid and reliable information switching so as to provide a seamless consumer experience. Li-Fi technology ought to potentially offer the excessive-speed, low-latency statistics transfer required for AR programs, that may open up new possibilities for gaming, schooling, and other packages.

Despite its potential benefits, there are nonetheless many demanding situations that need to be conquered before Li-Fi can turn out to be a mainstream generation. One of the main demanding situations is the fee of the Li-Fi system. Li-Fi transmitters and receivers are nevertheless noticeably costly, which could restrict the adoption of the era inside the quick term.

Another assignment is the want for line-of-sight conversation. Since Li-Fi signals are constrained to the room in which they may be transmitted, they require an instantaneous line of sight among the transmitter and the receiver. This means that Li-Fi won't be appropriate for programs in which mobility is needed, which include in cars.

Overall, the Li-Fi generation has the ability to revolutionize the way we think about wireless communication. While it is nonetheless inside the early degrees of development, researchers and organizations are persevering to explore new applications and upgrades to the era. In the coming years, it is probable that we can see Li-Fi come to be an increasingly crucial era in the subject of wi-fi verbal exchange.

In addition to the ability packages and challenges noted above, there are numerous different elements of Li-Fi technology which are well worth thinking about.

One benefit of Li-Fi over Wi-Fi is its security. Since Li-Fi signals are confined to a room and can't be bypassed via partitions, they may be less liable to interception or hacking. This may want to make Li-Fi an extra relaxed choice for applications that require a sensitive statistics switch, including in healthcare or finance.

Another gain of Li-Fi is its ability for electricity performance. Li-Fi uses mild as its medium for statistics transfer, which means that it may potentially be powered by means of strength-efficient LED light bulbs. This could make Li-Fi a more sustainable and eco-friendly option for wireless communication.

Li-Fi additionally has the capacity to alleviate congestion on Wi-Fi networks. As increasingly more gadgets turn out to be connected to Wi-Fi networks, these networks can become congested and slow. The Li-Fi era could offer an alternative wi-fi community that is faster and less congested, that may enhance general network overall performance.

Finally, the Li-Fi era has the capacity to provide high-pace records transfer in areas in which radio frequency (RF) verbal exchange is constrained or prohibited. For instance, Li-Fi will be utilized in hospitals or aircraft cabins wherein RF conversation isn't always allowed because of safety worries.

Overall, Li-Fi technology is an exciting improvement inside the subject of wireless communication. While there are nonetheless challenges to be triumphed over and lots of research to be completed, it has the ability to provide faster, greater secure, and more power-efficient wi-fi conversation. As researchers and organizations continue to explore the opportunities of Li-Fi, we're probably looking at new packages and innovations inside the future years.

1.6. Li-Fi principle

Every year, the number of smart devices increases tremendously, and to support a huge diversity of devices and packages, there is an unavoidable need for ultra-rapid facts. Due to frequency, bandwidth, and safety concerns, the use of radio waves in our existing wireless technology has significant limitations. What is Li-Fi technology, how does it work, and what programmes are there?

Professor Harald Haas originally developed Light Fidelity, an excessively fast record transmission generation, in 2011 at a TED talk. Visible light is the transmission channel used by Li-Fi for data communication between devices.

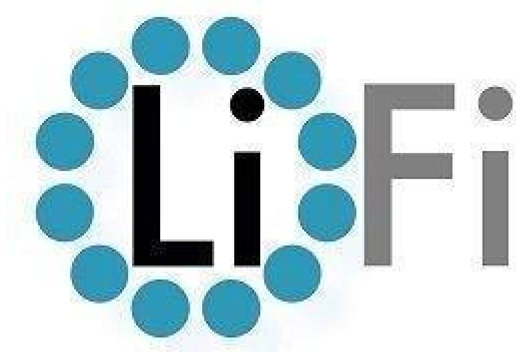

Figure 4: Li-fi representation

Information may be translated into binary bits in the form of zeros and ones, which stand for "on" and "off" states, in a digital transmission device. Visible light is an electromagnetic wave that travels at a very high speed and has an infinite bandwidth. Human eyes cannot detect light switching at high speeds, however relatively sensitive photodiodes can successfully detect light modulation through interaction with detectors.

Sighted light has a thousand times more bandwidth than the radio waves used in traditional wi-fi systems. It is one of the greenest options for apps requiring a lot of statistics because it has unlimited bandwidth. Li-Fi technology is a quick, fully duplex, and bidirectional communication tool with a data throughput of up to 224 gigabits per second.

Li-Fi (Light Fidelity) works by using light-emitting diodes (LEDs) to transmit facts. The LEDs are switched on and stale unexpectedly, a method called modulation, which is invisible to the human eye. This creates a binary code of 1s and 0s, which may be interpreted as records.

To get hold of the facts, a photodetector, which includes a photodiode, is used to discover the changes in mild intensity. The photodetector converts the mild signal into an electrical sign that can be processed by means of a computer or different tool.

The statistics may be modulated onto the light sign in numerous ways. One common method is known as on-off keying (OOK), wherein the statistics is transmitted through switching the LED on and rancid at a high frequency. Another method is called intensity modulation (IM), wherein the depth of the light is numerous to represent the records.

To set up a Li-Fi connection, the transmitter and receiver ought to be inside the identical room, with a clean line of sight between them. Li-Fi indicators can't pass via strong objects, so the signal is confined to the room in which it's miles being transmitted. This can offer improved protection, as it's miles greater hard for hackers to intercept the statistics.

Overall, the Li-Fi era is based on the ideas of visible mild conversation (VLC), which makes use of seen light to transmit records. While Li-Fi is still in the early stages of improvement, it has the capacity to revolutionize wi-fi verbal exchange by way of imparting faster information switch charges, elevated protection, and improved reliability.

The Li-Fi enabled data transmission system is connected to the internet via a high-speed router and transfers through a data access point. This access point functions as a smart hub, facilitating connectivity between Li-Fi enabled devices and the internet. Advanced modulation schemes and encryption techniques are employed to ensure secure communication.

Despite the fact that Li-Fi is a fast, efficient, and cost-effective technology, further research and development is needed before it becomes a versatile solution. With the increasing demand for high-speed data, many wireless technologies are evolving and emerging.

However, the potential of Li-Fi technology is significant due to its efficiency and cost-effectiveness. LED bulbs, which are semiconductors, serve as the light source for Li-Fi technology, and can be used to transmit data with rapid switching of LED light according to high-end modulation schemes.

Sophisticated transceivers function as both light sources (for visible light) and data transmission nodes, capable of securely sending and receiving high-speed data.

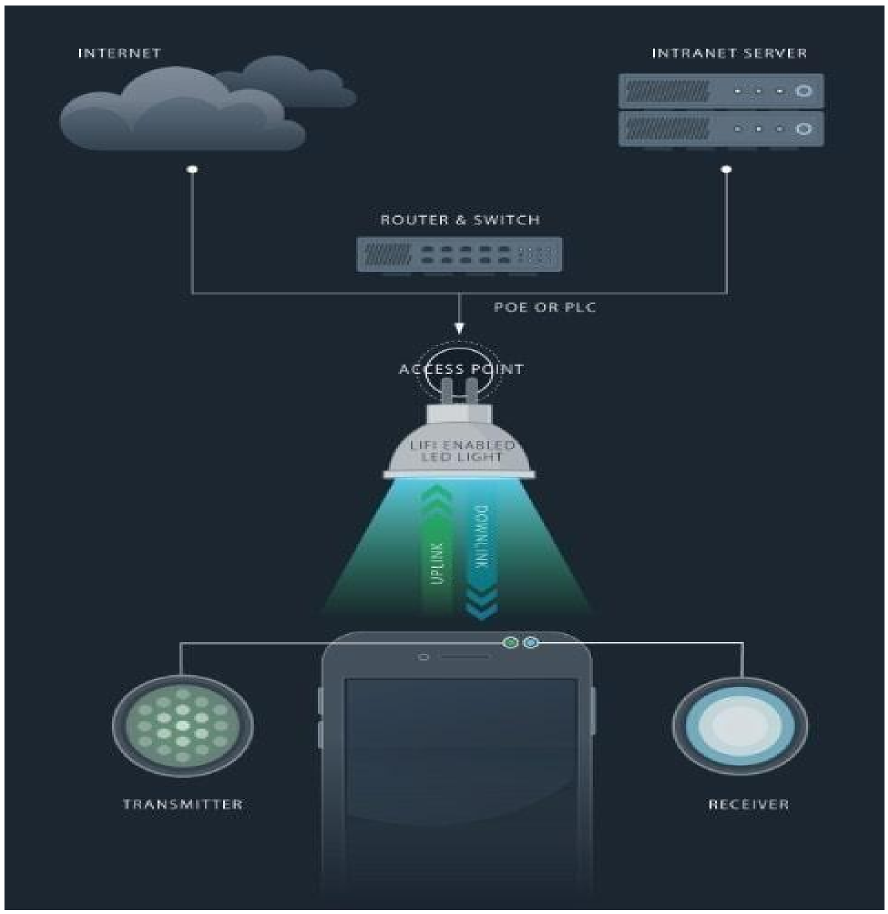

Figure 5: Lifi application

1.6.1 Detailed analysis of LI-FI

Li-Fi technology uses visible light as a medium for high-speed uplink and downlink transmission. Smart devices equipped with Li-Fi technology have a light emitter (transmitter) and a photo detector (receiver) for communication. When the device moves from one light source to another, the connectivity is re- established. However, currently, our smart devices do not have light detection sensors and transmitters. With the latest semiconductor technology, Li-Fi can be easily integrated into a chip that can be uploaded to future smart devices. Companies like PureLiFi and Philips are actively researching and developing Li- Fi technology.

Over the years, the evolution of technology has brought us from large and heavy devices used for voice communication to small and compact smart devices capable of multitasking and high-speed internet browsing. The rate of data transmission has increased dramatically, and if we want to expand our capabilities, we must continue to increase the data rate exponentially. This thesis focuses on a heterogeneous network that combines Li-Fi and Wi-Fi technology for indoor communication.

The network uses two stages of miniature attocells of Li-Fi that operate in the visible light spectrum, resulting in a significant boost in wireless network data transmission. The Li-Fi and Wi-Fi frequency bands do not overlap and belong to different spectrums. Li-Fi access points cover a smaller area than Wi- Fi access points, which can result in multiple handoffs between Li-Fi attocells when there is even minor customer movement, thereby impairing system performance. However, as the span of handover decreases, the Li-Fi data rate increases due to the increased bandwidth of the Li-Fi access point serving the customer. The thesis provides a comprehensive comparison between Li-Fi and Wi-Fi technology.

The developers discovered the millimeter wave frequency range for more than one gigabit wireless communication as a result of the excessively painful expansion of multimedia wi-fi devices in recent years. It is feasible to use millimeter wave wireless communication in the future thanks to recent advancements in antenna generation, RF CMOS technology, and relatively cell baseband signal processing methods. The multi gigabit per second high data rate of millimeter wave wireless communication devices has resulted in a number of projects in many crucial sectors, such as WPAN, WLAN, and backhaul for mobile devices. The frequency range includes 28 GHz, 38 GHz, 45 GHz, 60 GHz, and even frequencies above 100 GHz. A few crucial research and advancements in gigabit millimeter wave wireless communication will be provided by the ZTE communications special issue.

The main justification is that Li-Fi is an environmentally friendly form of communication because it makes use of the existing lighting infrastructure for communication. This results in radiation-free communication, which may be useful for our government's Digital India initiative as well as communication that uses renewable, readily available energy. Records can be sent in quick, dispersed changes in light depth that are invisible to the human eye. An important factor for promoting optical wireless communication with hybrid heterogeneous network technology across the entire globe is that many nations are focusing their funding on this radiation-free and license-free provision of internet service providers for removing the traffic buffer because RF electromagnetic spectrum is restricted and to avoid the congestion of the traffic.

Due to radio spectral band congestion, the book of facts requiring multimedia mobile devices has surpassed its saturation capacity. Li-Fi technology, which uses a 300 THz frequency range that is unlicensed and unspoiled for wireless communication, may provide a solution to this issue. 1. Li-ability Fi's to avoid interfering with RF since it uses a particular frequency is a plus. 2. It enables the blending of HetNet setup in a diverse community.

A heterogeneous community develops the system facts, pricing, and QoS in an indoor setting 3.

As RF equipment is unaffected by Li-Fi, heterogeneous communities perform better overall than separate Li-Fi and RF machines.

Due to the length of the Li-Fi service area, green and equitable load balancing in hybrid diverse communities is difficult. Current research assumes that the aid distribution is steady for four, but in reality, customers may be moving around. Customers thereby experience changeover between Li-Fi attocells while consumer mobility is taken into account.

There are types of handover entering image:

i. Flat handover- This handover taking area between Li-Fi attocells.

ii. Vertical handover- This handover taking area between Li-Fi and Wi-Fi service region.

Handover in a wireless network involves exchanging data between clients and relevant units (CU), which can result in delays depending on the complexity of the algorithm used. During handover, there may also be transmission losses. In traditional RF systems, handover occurs in lower signal to noise ratios (SNR), but in a hybrid heterogeneous network, the issue of stability is considered as a handover can trigger further handover.

Optical Wireless Communication (OWC) uses LEDs to transmit data at high speeds through visible light communication. The Li-Fi enabled smart devices have a photo detector (receiver) and light emitter (transmitter) for uplink and downlink transmission, and can re-establish connectivity when moving between different light sources. Unlike traditional Wi-Fi, Li-Fi is limited to a shorter range due to its inability to penetrate walls, making it more secure against hacking. Li-Fi attocells enhance wireless capacity by supporting Internet-of-Things (IoT) and contributing to the future of wireless technology beyond 5G. This presents all the major areas of research for hybrid Li-Fi/Wi-Fi components, and real- world implementation is currently underway.

The method of Visible Light Communication (VLC) utilizes LEDs to transmit information via intensity modulation (IM) which is detected by a photodiode (PD) using direct detection (DD). This creates a point- to-point communication system, similar to a wired cable transfer. As a result, the IEEE802.15.7 6 standard has been updated to incorporate Li-Fi which offers a complete wireless communication system that supports multi-client communication and bi-directional data transfer. Li-Fi also employs multiple access points to create a network of small attocells that are used for transmission. This allows Li-Fi to move and establish a new layer within a wireless network. Since LEDs are not natural beam formers, Li-Fi signals can be easily localized and channel interference can be effectively controlled, leading to increased physical layer security.

As the demand for data continues to grow, the availability of RF spectrum bands is reaching its saturation point, leading to congestion and traffic. Therefore, the use of visible light spectrum bands is becoming increasingly important in the field of optical wireless communication. The visible light spectrum has a bandwidth capacity of 300THz and is also license-free, making it an excellent alternative to meet the demand for data.

To address the growing demand for data, it is important to utilize a hybrid heterogeneous network. The visible light spectrum should be utilized to establish a Li-Fi network, as it does not cause interference to RF and is abundant and free of licensing requirements. This network should be distributed into attocells using LED-based space light devices for indoor LAN communication. This system offers advantages over traditional RF systems, including improved isolation, smaller size and cost of receivers and transmitters, and no RF licensing laws. By combining visible light and RF spectrum, the system can effectively utilize both.

Indoor visible light-based networks can be connected to an outdoor RF-based network or can be standalone, depending on the application, location, and availability of access points. In areas where RF access is difficult or dangerous, light-based access points can be used. While this curbs security concerns, proper system optimization is necessary for handover and load balancing when mobility is a factor.

The advantages of visible light include its lack of interference to RF systems and its high data rate and capacity. Li-Fi uses light to transmit data in small attocells with several benefits, including operating across high bandwidth and in areas prone to radiation and interference, and providing high transmission speeds. The technology is being actively developed by companies worldwide, and research in optical wireless communication and visible light communication has been beneficial in developing a hybrid heterogeneous network that can provide high capacity and data rates.

As daily internet users continue to grow in number in every country, the use of a hybrid network can serve billions of clients in the future. The network can be configured with a core Wi-Fi interconnected with all the access points of the attocells. However, due to the high installation cost and low power of LED-based Li-Fi machines, the network may not be competitive as a primary internet source for multimedia data demand.

Scientists are working to improve Li-Fi devices to increase their data capacity, making them more useful and widespread. Hybrid heterogeneous networks can serve multiple coverage areas, preventing data congestion.

1.6.2. Li-Fi and Wi-Fi coupled connected devices

To create a communication network among connected devices, a reliable source of low-energy consumption is necessary. However, 5G has limitations, and 6G brings its own complexities. LiFi is a promising solution that can bridge the gap for various devices and applications.

As the amount of data continues to increase, the current model of Wi-Fi network may not be able to handle the strain, resulting in interferences and errors. To meet the demands of connected devices, a hybrid network of Wi-Fi and LiFi can be established, with LiFi acting as a complement to Wi-Fi. For IoT and IoE devices, low-powered smart sensors are required, and reliability is more important than speed for transmitting smaller data packets. However, as the industry grows, we will need to combine reliability and speed.

To create a communication network based on a real-time basis for the "Things in IoT," a matrix array of sensors, actuators, and other peripheral equipment should be used to establish the ecosystem.

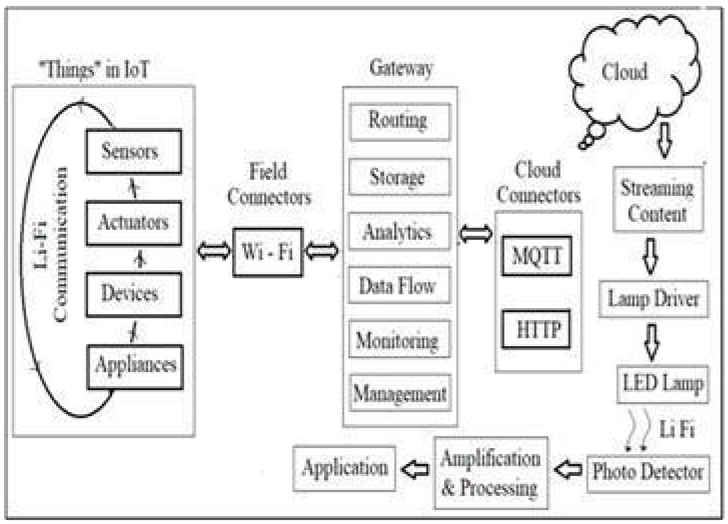

Figure 6: Lifi in IOT

The sensors can measure environmental factors including temperature, humidity, and sun/light intensity in the real-world setting and provide star ratings as comments based on those readings. The entry is often provided most effectively by physical parameters, but we may also convert non-physically readable filesfor specific data that cannot be physically quantified to specific facts and may be just as well handled as an enter signal for the sensor. In a discipline connection gateway with WiFi enabled, these peripherals are connected. The main role of the gate-way is to establish verbal communication and connect the functions utilizing a designated cloud-based overall service.

To illustrate, let's take the example of an actuator used in industrial applications that may have multiple data points to establish from the device. However, we can compare this analogy with a sensor, which is used to switch states from ON to OFF or 0 to 1, either through electromagnetic or logical operations.

The foundational components of the device consist of smart devices such as smartphones, computers, portable devices, and new AI-enabled high-end chip-based systems. These applications and tools are employed to handle complex situations where humans cannot multitask with such a vast amount of data that require simultaneous real-time processing. The primary objective of the IoT gateway is to convert physical area protocols to cloud protocols by establishing communication between sensors and the distributed network used.

Message Queue Telemetry Transport (MQTT) allows for the integration of connectivity between programs and interface middlewares, as well as networks and communications to facilitate the subscribe/post architecture, in which a publisher, a broker, and an end-user (subscriber) are the three pillars. In addition to MQTT, we have Hypertext Transfer Protocol (HTTP), which is preferred in IoT-based applications where reliability, latency, and bandwidth are not the primary concerns. LiFi can be used in the downlink side of the device.

To achieve the downlink of the data flow, a light source driver (such as an LED bulb) is used. The data is converted into readable binary format using the OFDM or PWM modulation method. The required data input is channeled into the light source driver, which controls the supply. The light signal undulations are recorded by the photo-detector and the signal is transferred to the signal conditioning unit. Here, the signal is read, amplified, and fed into the end application after being processed.

1.7. Block diagram of Li-Fi

The transmitter and receiver are the two essential components of the Li-Fi system. The input signal during the transmitter phase may be modulated with a specific term before data is sent using LED bulbs in the shape of 0s and 1s. Here, 0s and 1s are used to represent the LED lights' flashes. A photodiode is used to capture the LED flashes at the receiver's end, enhance the signal, and provide the output.

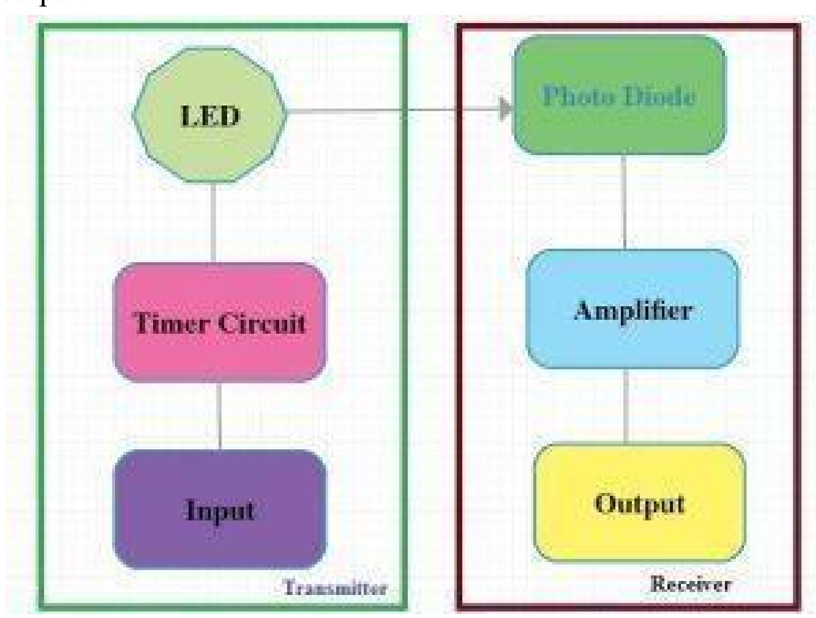

Figure 7: Block diagram of Li Fi

The entry, timer circuit, and LED bulb are included in the transmitter phase of the Li-Fi system's block diagram, which is depicted below. Any type of fact, such as text, audio, etc., can serve as the transmitter's central component. The necessary time intervals between each bit are provided by the timer circuit on this section, and they are conveyed to the receiver in the form of LED flashes. Amplifiers and photodiodes make up the receiver phase. Here, the photodiode receives flashes from an LED light and converts them into electrical impulses. The amplifier then boosts the output after receiving the photodiode's warnings.

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Li-Fi is a VLC (visible light communications) system and the velocity of this device is very excessive. Li- Fi makes use of normal LEDs to allow the facts to transfer and boom the speed up to 224 Gigabits/sec. The statistics transmission of this technology can be executed via illumination. The essential devices of this system are the bright light emitting diodes.

The ON/Off interest of LEDs lets in a kind of data transmission inside the shape of binary codes but the human eye can not apprehend this rework & the bulbs seem with a stable depth.Light Fidelity relies upon on novel potential of solid-nation lighting structures to create 1s and 0s binary code with human- imperceptible LED illumination.

Information can be obtained in place of the mild by using digital gadgets with picture-diodes. This means that mild bulbs can no longer carry only light however wireless connection at same time anywhere wherein LEDs are used. Generally speaking, Wi-Fi plays an efficient position in wireless data coverage within buildings, whilst the use of Li-Fi will offer splendid density records coverage especially in places with no radio interference issues. Li-Fi provides better latency, overall performance, accessibility and protection than Wi-Fi, and underneath laboratory conditions has even reached severe speeds extra than 1 Gbps.

In this block diagram, there are three foremost components: the transmitter, the verbal exchange medium, and the receiver.

The transmitter includes a sign processing unit that encodes the information to be transmitted, and a mild source, that's generally an LED or laser, that modulates the information onto the seen mild.

The verbal exchange medium is the seen light itself, that is used to transmit the modulated data from the transmitter to the receiver.

The receiver includes a light detector, that is usually a photodiode, and a information processing unit that decodes the data received from the modulated mild, the statistics is transmitted from the transmitter to the receiver by means of encoding it onto the seen mild, which is then detected and decoded by way of the receiver, and the information is processed for further use.

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1.8. Comparison with other Technologies

1.8.1. Li-Fi vs BLUETOOTH

1. Bluetooth :

Bluetooth is a wireless communication technology that uses radio waves to transfer data over short distances. It allows for high-speed and low-power wireless connectivity between devices, eliminating the need for cables. It is mainly used for exchanging information between mobile and stationary devices over short distances. While it works well for keeping devices connected at close range, it loses connectivity when the range extends beyond a certain limit. Bluetooth is commonly found in portable electronic devices such as laptops, PDAs, smartphones, tablets, and audio systems. However, its range and transmission speeds are typically lower than those of Wi-Fi.

Figure 8: Bluetooth representation

2. Light Fidelity (LiFi) :

Light Fidelity is referred to as LiFi. LiFi is a form of wi-fi communication that uses light, not radio frequencies like Bluetooth, to convey data. that it transmits information using gentle vibrations. It also goes by the name "wi-fi optical networking technology" for this reason. Speeds on LiFi are faster than on WiFi. LiFi uses LiFi bulbs, which include a chip inside that invisibly modifies light for optical data transfer. Information from LiFi is delivered through LiFi bulbs and received by photoreceptors. It is a high-speed, bidirectional, fully networked generation of WiFi. LiFi technology provides a bigger area of insurance than a single WiFi router when it is deployed in all the lighting inside and outside of a building.

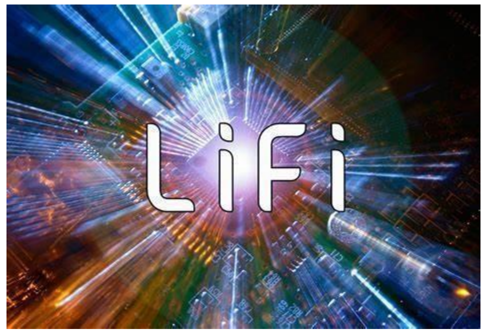


Figure 9: Lifi tech

S.no.	Feature	Li-fi	Bluetooth
1.	source	Light	Radio frequency
2.	**EM Interference**	VLC communication is not affected due to EM sources.	RF communication is affected due to EM sources.
3.	Power Consumption	Less, It is a power efficient system.	High, It is a power inefficient system.
4.	Bandwidth	High	Low
5.	Security concern	It provides secured communication due to LOSS (Line Of Sight) communication within the room.	It does not provide secured communication as RF signal penetrate walls and can be intruded by some one from the other room
6.	Health risk	No health risks involved in VLC based wireless communication.	RF communication is harmful when high power is used for transmission
7.	Coverage distance	Short	Medium
8	Visibility	Yes	No

Table 1: Differences between Lifi and Bluetooth

1.8.1. Li-Fi vs WIFI

S.no.	On the basis of	Wi-fi	Li-fi
1.	**Stands for**	Wi-fi stands for Wireless fidelity.	Li-fi stands for Light fidelity.
2.	**Operation**	It is used to transmit data via radio waves using a wi-fi router.	It is used to transmit data via LED signals using LED bulbs.
3.	**Invented by**	Wi-fi was invented in 1991 by NCR corporation.	Li-fi was invented in 2011 by Prof. Harald Hass.
4.	**Data transfer speed**	The range of data transfer speed of wi-fi is from 150 Mbps to 2 GBPS.	The range of data transfer speed li-fi is about 1 GBPS.
5.	**Area coverage**	The area coverage of wi-fi is up-to 32 meters.	The area coverage of li-fi is about 10 meters.
6.	**Working environment**	Wi-fi works in a less dense environment because of interference related issues.	It works in a high environment
7.	**Privacy**	In wi-fi, the radio frequency signals pass through the walls, so there is a need to use more secure techniques to protect data.	In Li-fi, data is protected and more secure because there is a use of light that is blocked by the walls.
8.	**Components**	The components of wi-fi are routers, modems, and access points.	The components of the Li-fi are the LED bulb, LED driver, and photodetector.

Table 2: Differences between Lifi and Wifi

1.8.2. Infrared light for Transmission

Infrared technology operates within a frequency of light that is not visible to the naked eye and falls between 300 gigacycles and 400 THz. This technology utilizes radiation within the electromagnetic spectrum and is distinct from radio frequencies. Unlike radio waves, infrared waves cannot penetrate walls and are typically confined within a space, making them useful in reducing interference and the risk of reprocessing in adjacent rooms. Infrared waves have a longer wavelength than light but a shorter wavelength than radio waves, ranging from 850 nm to 900 nm.

Infrared is a viable communication medium with a high data rate, but its full potential has yet to be realized. Interference with IR communication may occur as the sun generates radiation in the infrared band. The development of extremely high-speed wireless LANs in the future will use the infrared band extensively.

There are several standards developed for infrared electric circuits, such as IRDA. IRDA-C provides standards for bidirectional communications used in wired devices like mice, keyboards, joysticks, and handheld computers. IRDA-C operates at a rate of 75 Kbits/sec and has a distance range of up to 8 meters. Another standard, IRDA-D, offers data rates from 115 kb/s to 4Mb/s with a distance range up to one meter. IR circuits were designed as a wireless alternative to connecting devices such as computers to a pointer.

Infrared signals can achieve higher data rates with point-to-point transmission, but devices must remain in their locations. In contrast, broadcasting allows for more flexibility, but with lower data rates. Unlike other wireless communication technologies, an independent agency license is not required to use infrared. However, infrared signals cannot penetrate walls or other objects and may be diluted by strong light sources.

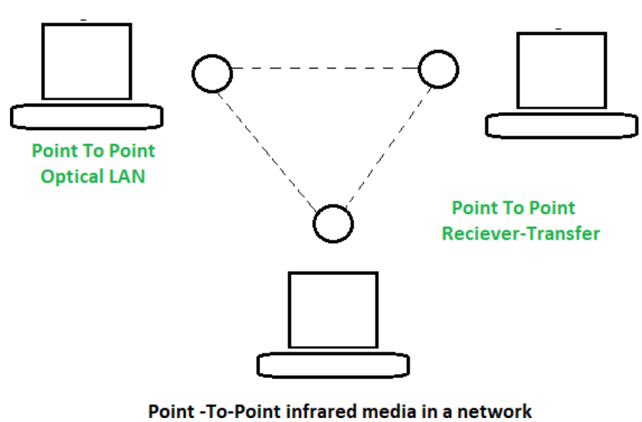
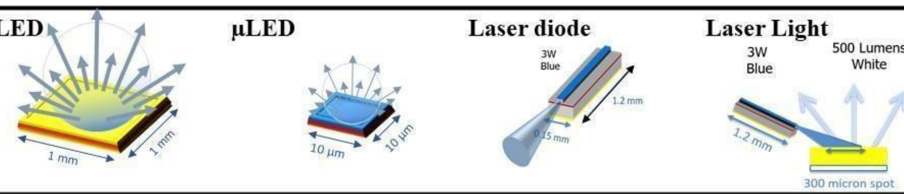


Figure 10: Point-point Infrared media in a network

1.8.3. Advanced LiFi technology: Laser light

This passage discusses a new product platform that uses visible light from a laser-based surface mount device (SMD) for high-speed LiFi data communication. The product platform provides 10- 100 times the brightness of traditional LED sources and uses high-power blue laser diodes that provide over 3.5 GHz of 3 dB bandwidth. The laser-based white light SMD modules exhibit a high signal-to-noise ratio (SNR) above 15 dB up to 1 GHz, which is combined with high order quadrature amplitude modulation (QAM) and orthogonal frequency division multiplexing (OFDM) to maximize bandwidth efficiency.

The authors present a laser-based white light SMD module that includes a single 3W blue laser diode installed on a heat-sink, optically coupled to a collimating optic, and achieves a LiFi data rate of up to 10 Gbit/s. They also demonstrate the use of wavelength division multiplexing (WDM) with a white light SMD module that includes two blue laser diodes separated in height wavelength to enable separate communication channels. Using WDM, the dual laser SMD module enables LiFi data rates of over 20 Gbit/s by simultaneously transmitting data over both channels.



	LED	µLED	Laser diode	Laser Light
Area	0.1~1mm^2	<0.01mm^2	<0.2mm^2	~0.01mm^2
Limiting factor	τ_{RC}(~1 ns)	$\tau_{carrier}$(~0.1 ns)	τ_{Photon}(~ 1ps)	τ_{Photon}(~ 1ps)
Bandwidth	~10 MHz	<1.5 GHz	10~20 GHz	10~20 GHz
Power$_{out}$	>1 W	~ µW	>1 W	>1 W
Eye safe	Yes	Yes	No	Yes

Figure 11:Component Parameters

There are various types of light emitting devices that can be utilized as LiFi transmitters. Traditional LEDs have been extensively studied because they are easily available in full white LED applications. However, as shown in Table 1, the relatively large size of LEDs allows for high optical power, but it also results in a significant RC parasitic effect. This restricts the modulation bandwidth to the order of MHz because of the RC constant, instead of the carrier lifetime.

Micro-sized LEDs (µLEDs) have an area that is at least 1 to 2 orders of magnitude smaller than traditional LEDs. Although the light output is proportionally reduced with a smaller area, the RC parasitic effect is dramatically reduced. Therefore, the modulation bandwidth is limited by the carrier lifetime, which is the theoretical limit of carrier recombination in the active region. The highest recorded bandwidth of µLEDs has been reported to be over 1 GHz in both GaN and GaAs material systems. Arrays of µLEDs have been suggested as a means to recover the output power achievable in LEDs.

In terms of both light output and high-speed performance, LDs are more attractive transmitters. The device area is not as small as µLEDs, and the modulation is governed by stimulated fast photons in the cavity instead of the carriers in the active region. As a result, the modulation bandwidth of LDs can be much higher than that of LEDs, up to around 20 GHz.

However, LD chips are typically single wavelength and need to generate white light for a LiFi transmitter if they are to be widely used for lighting applications. The key requirement of white laser light generation is to maintain the same high-speed performance as a remote laser source while also generating white light. Laser-pumped phosphor material creates an eye-safe white light emission, which provides a significant advantage compared to the non-eye-safe beam from a single wavelength coherent emitting high-power LD chip. Figure 1 illustrates an integrated surface mount device (SMD) package for laser lighting applications.

The laser beam hits the phosphor, and the combination of the photons from the LD and phosphor- converted photons generate a white light spectrum. These laser light SMDs can generate directional beams with 400500 lumens from a 300400 micron spot, to generate luminance levels well in excess of 1,000 cd/mm2 and beyond.

In summary, the generated laser has light effects in a Lambertian white emission similar to LEDs, but with significantly higher luminosity. This higher luminance allows for more efficient collimation of the emitted white light to deliver more photons to a target at a distance. This is highly advantageous for long-distance communication without losing signal intensity through the wireless channel. Additionally, the bandwidth of laser light is not degraded from that inherent to LEDs.

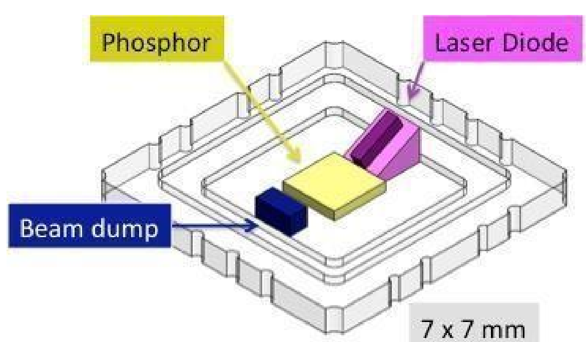


Figure 12: Laser Diode

1.9.1. Visible Light Communication (VLC) and LiFi

Visible Light Communication (VLC) is a form of data communication that uses light as a medium. However, simply turning a light on and off (like Morse code) cannot be considered VLC because the light source is not efficient enough. In order to achieve a constant source of light, the flickering of the light needs to be so brief that it is indistinguishable from a steady light source. Regular bulbs are unable to switch on and off quickly enough, which is why LED bulbs are used instead. Additionally, transmitting information does not require the LEDs to be turned on all the time, and it is possible to transmit data by dimming the light to the point where it is barely emitting light. LEDs are semiconductor diodes, and their light output is directly proportional to the forward current. Therefore, reducing the forward current of LEDs can reduce their brightness. Another method used to reduce the light intensity is Pulse Width

Modulation, which regulates the time and relative duration of the pulses.

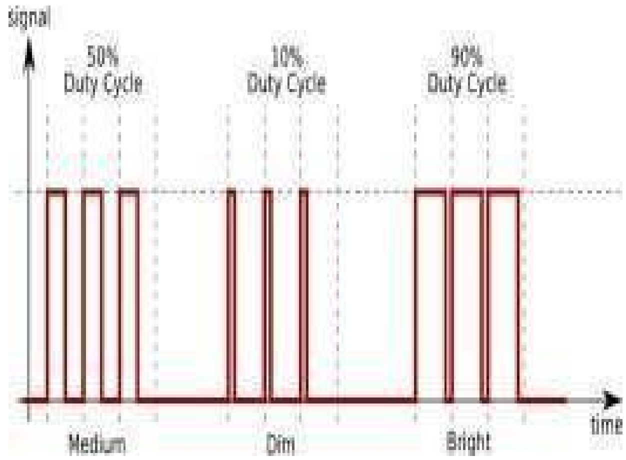


Figure 13: Visible Light Communication

LiFi falls into the Optical Wireless Communication (OWC) category and utilizes high-speed Visible Light Communication (VLC) technology. The term LiFi was coined by Professor Harald Hass, a professor of Mobile Communication at the University of Edinburgh in 2011 during TEDGlobal. The LED bulbs are used for data transmission by flashing light on and off at high speeds. To establish a LiFi network, an LED light source and a light sensor or image detector are required. When the LED light source is turned on, the emitted photons are detected by the image sensor. The intensity of the light falling on the image sensor in a regular dim and bright manner corresponds to binary 1 or binary 0. The data received by the image detector needs to be amplified and then fed to the accessing device.

1.9.2. PHYSICAL IMPLEMENTATION OF VLC circuit

The visible light is utilized to transmit data in the form of binary digits, unlike the prevalent systems that operate in the radio-frequency or microwave band. This enhances the dependability and precision of transmission, with the range of wavelength falling between 400nm to 700nm of Electromagnetic Waves (EMW).

A variant of this model facilitates one-way communication through multiple channels that cover a wide area, allowing numerous customers to access the service simultaneously. This suggests that this model can be utilized when the use of the uplink channel is obsolete. This model is suitable for promoting products where the media server, connected to Wi-Fi, can be accessed for payment methods.

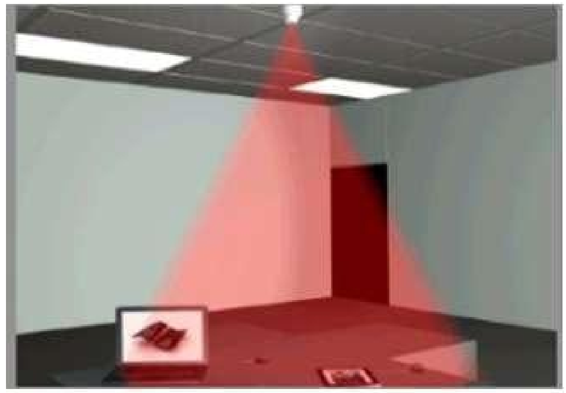


Figure 14: Implementation of VLC

MIMO is an acronym that stands for Multiple Input Multiple Output. As its name implies, this model employs multiple channels to enable bidirectional data transfer, unlike Giga Shower, which only provides unidirectional data transfer capabilities. By providing a bidirectional data transfer service to a large audience through Visible Light Communication, this model has the potential to replace the traditional .

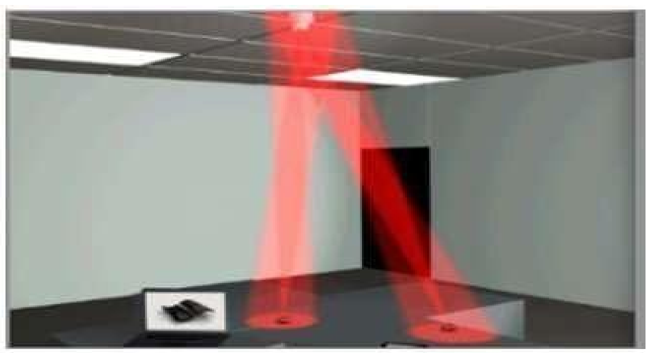


Figure 15: VLC application

CHAPTER 2
LITERATURE SURVEY

LiFi (Light Fidelity) is a wireless communication technology that uses light waves to transmit data. It has the potential to provide high-speed data transmission and can be used for various applications such as audio and data transmission.
Here are some recent research papers that can be useful for a literature survey on LiFi audio and data transmission:

"LiFi-based audio communication system" by M. A. Imran and K. M. Iftekharuddin. In this paper, the authors propose a LiFi-based audio communication system that uses visible light to transmit audio signals. The system consists of a transmitter that converts audio signals into modulated light signals, and a receiver that converts the modulated light signals back into audio signals.

"LiFi technology for audio data transmission" by S. Shreejith and S. Prakash. In this paper, the authors present a LiFi-based audio data transmission system that uses LED lights to transmit audio signals. The system uses pulse width modulation (PWM) to encode the audio signals onto the light signals.

"Audio communication using LiFi: a review" by R. Singh, M. K. Soni, and R. K. Gupta. This paper provides a comprehensive review of the recent advances in LiFi-based audio communication systems. The paper discusses the various techniques used for audio signal modulation and demodulation, and compares the performance of different LiFi-based audio communication systems.

"LiFi technology for high-speed data transmission" by H. Haas. This paper provides an overview of LiFi technology and its potential for high-speed data transmission. The paper discusses the advantages of LiFi over other wireless communication technologies, and presents some of the recent developments in LiFi technology.

"LiFi technology: data transmission through illumination" by R. W. Jafri, S. Bhatnagar, and M. Sharma. This paper provides an overview of LiFi technology and its applications in data transmission. The paper discusses the various modulation techniques used in LiFi-based data transmission systems, and compares the performance of different LiFi-based data transmission systems.
These research papers can provide a good starting point for a literature survey on LiFi audio and data transmission.

CHAPTER 3
SYSTEM DESIGN

3.1 Project Overview
3.1.1 Audio Transmission

Li-Fi technology can be used for audio transmission by modulating the light signal to carry audio signals. This is achieved by varying the intensity of the light signal in a way that corresponds to the audio signal. The modulated light signal is then detected by a receiver and converted back into the audio signal. This technique is known as audio modulation and demodulation.
One of the advantages of using Li-Fi for audio transmission is that it provides high-quality audio with minimal interference. Unlike traditional radio waves, which can be affected by electromagnetic interference, Li-Fi uses visible light, which is less prone to interference. This makes Li-Fi ideal for applications where high-quality audio is required, such as in public address systems, home entertainment systems, and conference systems.

3.1.2 Data Transmission

Li-Fi technology can also be used for data transmission, with data rates of up to several gigabits per second possible. The technology uses the same principle of modulating the light signal to carry data. The data is encoded in the light signal, which is then detected by a receiver and decoded back into its original form.
One of the advantages of using Li-Fi for data transmission is its high speed. With data rates of up to several gigabits per second, Li-Fi is ideal for applications where high-speed data transfer is required, such as in video streaming, file transfer, and internet connectivity. Li-Fi is also more secure than traditional Wi-Fi since the light signal cannot pass through walls, making it difficult for hackers to intercept the data.

3.2 Hardware Requirements
3.2.1 power supply

5V Power Supply using 7805 Voltage Regulator.In most of our electronic products or projects we need a power supply for converting mains AC voltage to a regulated DC voltage. For making a power supply designing of each and every component is essential.

Designing of regulated 5V Power Supply

Component List:

1. Voltage regulator
2. Capacitors
3. 1k Resistor
4. Led diode

Voltage regulator:

As we require a 5V we need LM7805 Voltage Regulator IC.

7805 IC Rating:

- Input voltage range 7V- 35V
- Current rating $I_{c\,=}$ 1A
- Output voltage range $V_{Max=5.2V}$, $V_{Min=4.8V}$

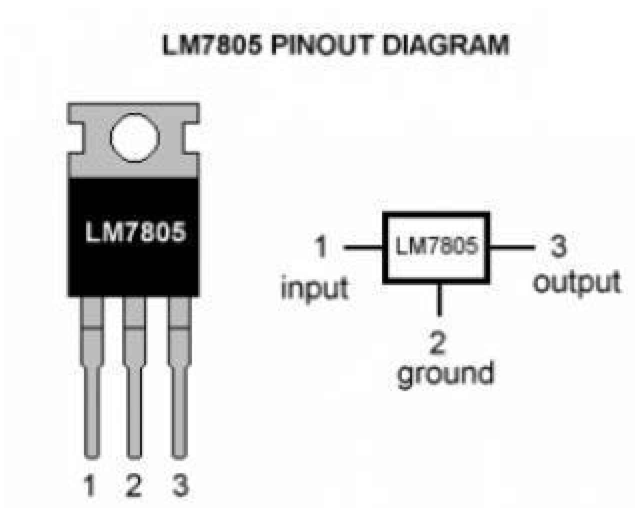


Figure 16: LM7805 PINOUT DIAGRAM

Capacitors:

We are going to build this power supply, with a couple of simple changes. This regulator needs a 1000 uF capacitor on the input side, and a 100 uF capacitor on the output side. The capacitors help filter the input and output from noise created by the power supply, and/or the load. We will add larger capacitors on both sides, to help keep our power supply clean, and noise free. Secondly, there is no way of knowing if our power supply is working, so we will add a little LED as our power indicator.

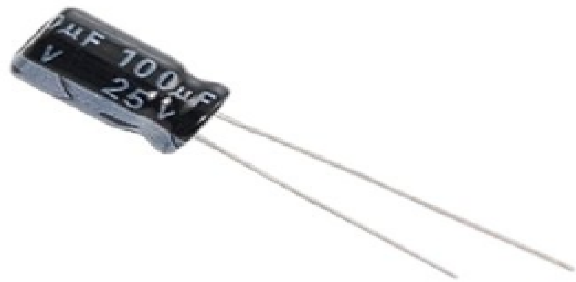


Figure 17 : Capacitor

1k Ohm Resistor with LED:

With the quick calculation above, you can see that for maximum brightness of our red LED, we need a resistor of 100 ohm. Since I don't really care about maximum brightness, I'd rather have a dimmer LED and save my battery; so I decided to use a **1k ohm resistor** instead, which will still give me plenty of brightness and increase my battery life**.**

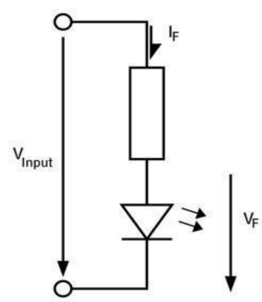


Figure 18 : Resistor diagram

3.2.2 Arduino UNO

The Arduino Uno is a microcontroller board that is open-source and built around the Microchip ATmega328P microcontroller. It was created by Arduino.cc and was first launched in 2010. The board includes sets of digital and analog input/output (I/O) pins that can be connected to various expansion boards (shields) and other circuits. It has 14 digital I/O pins, 6 of which are capable of PWM output, as well as 6 analog I/O pins. It can be programmed using the Arduino IDE (Integrated Development Environment) via a type B USB cable, and can be powered by a USB cable or a barrel connector that accepts voltages between 7 and 20 volts. The board is similar to the Arduino Nano and Leonardo, and the hardware reference design is available on the Arduino website under a Creative Commons Attribution Share-Alike 2.5 license. Production and layout files for some versions of the hardware are also available.

The name "Uno" means "one" in Italian and was chosen to signify a major redesign of both the Arduino hardware and software. The Uno board succeeded the Duemilanove release and was the 9th version of USB-based Arduino boards. Newer releases of version 1.0 of the Arduino IDE for the Arduino Uno board are now available. The ATmega328 on the board comes pre-programmed with a bootloader that allows for the uploading of new code without the need for an external hardware programmer.

The Uno board communicates using the original STK500 protocol, but unlike previous boards, it does not use an FTDI USB-to-UART serial chip. Instead, it utilizes the Atmega16U2 (Atmega8U2 up to version R2), which has been programmed as a USB-to-serial converter.

Technical Specifications

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Input Voltage (limit): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- PWM Digital I/O Pins: 6
- Analog Input Pins: 6
- DC Current per I/O Pin: 20 mA
- DC current for 3.3V Pin: 50 mA
- Flash Memory: 32 KB (ATmega328P) of which 0.5 KB used by bootloader
- SRAM: 2 KB (ATmega328P)
- EEPROM: 1 KB (ATmega328P)
- Clock Speed: 16 MHz
- LED_BUILTIN: 13
- Length: 68.6 mm
- Width: 58.4 mm
- Weight: 25 g

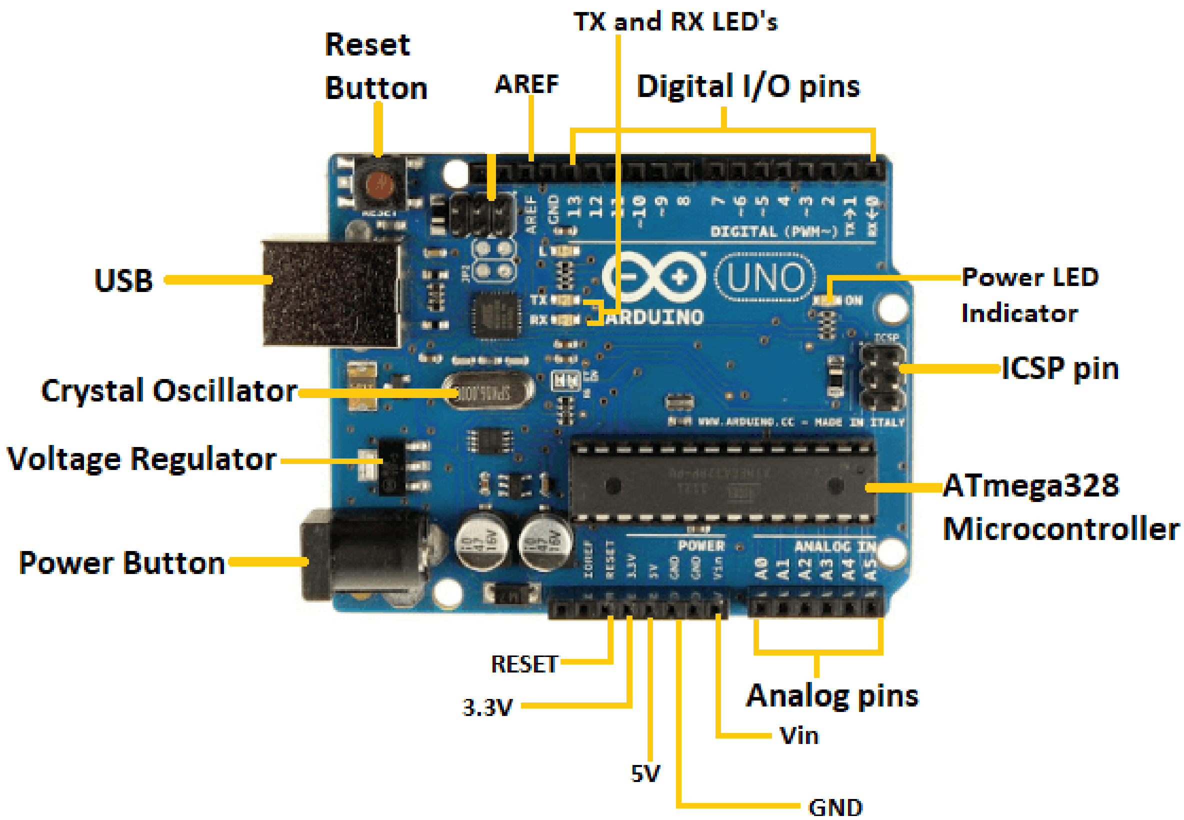


Figure 19: ARDUINO Board

3.2.3 Audio Amplifier

The PAM8403 amplifier board is a dual-channel stereo amplifier that produces 6W (3W+3W) output. To ensure reliable operation, it comes equipped with built-in short circuit protection, a necessary feature in any major amplifier system.

One of the unique features of the PAM8403 amplifier IC is that it does not require a heat sink, making it an ideal choice for custom speaker projects. It can directly drive 4 or 8 speakers, but it is important to use speakers with a maximum output rating of 3W.

Since this is a stereo amplifier board, it has two inputs (L and R) with a common ground. Any audio input can be used and amplified to produce a 3W + 3W audio output.
This amplifier board has a maximum gain of 24 dB with 10 percent THD at 5V DC input and 4 Ohm load output. Additionally, it provides thermal protection, which is a critical feature for a small wattage amplifier module, even without the need for a heat sink. This feature saves additional board space while ensuring reliable performance.

Features:

1. Dual channel stereo, high output power (3 w + 3 w power @ 5V and 4 ohms load).
2. Good sound quality.
3. Double panel wiring solves crosstalk.
4. Super mini design allows it to be easily placed in a variety of digital products.
5. 3W Output at 10% THD with a 4ΩLoad and 5V Power Supply.
6. Filterless, Low Quiescent Current and Low EMI.
7. Superior Low Noise.
8. Short Circuit Protection.
9. Thermal Shutdown

Applications

- Bluetooth Stereo Audio hands-free/headsets
- In robots that speak or generate sounds to indicate activities
- Portable Speakers
- LCD Monitors / TV Projectors
- Arduino or Raspberry Pi Game Machines
- Speaker Phones

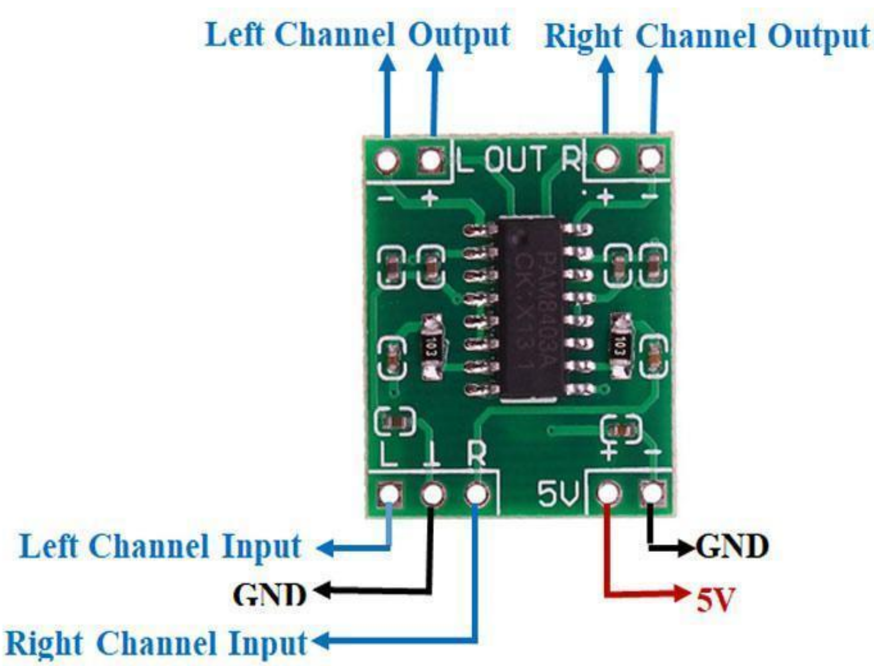


Figure 20 : PinOut Board

Pin No.	Pin Name	Description
1	+OUT_L	Left Channel Positive Output
2	-OUT_L	Left Channel Negative Output
3	INL	Left Channel Input
4	INR	Right Channel Input
5	-OUT_R	Right Channel Negative Output
6	+OUT_R	Right Channel Positive Output
7	5V	Positive Supply
8	GND	Ground Pin

Table 3: **Pinout Configuration**

Specifications

- 2 channel 3 W PAM8403 audio amplifier
- Output Power: 3 W + 3 W (at 4 ohm)
- Working Voltage: 2.5 to 5.5 V
- Board Size: 24 x 15 mm
- High amplification efficiency 85%
- Unique without LC filter class D digital power board
- Can use computer USB power supply directly

3.2.4 Laser

A laser is an apparatus that emits light using stimulated emission of electromagnetic radiation as a result of optical amplification. The term "laser" is derived from "light amplification by stimulated emission of radiation." The first laser was constructed by Theodore H. Maiman in 1960 at Hughes Research Laboratories, based on theoretical work by Charles Hard Townes and Arthur Leonard Schawlow.

The most significant characteristic of a laser is its coherence, which is different from other light sources. The spatial coherence of a laser enables it to be focused into a narrow beam, allowing for applications such as laser cutting and lithography. A laser beam can also maintain its narrowness over great distances (collimation), allowing for laser pointers and lidar applications. A laser can also have high temporal coherence, which allows it to produce light with a narrow spectrum. Alternatively, temporal coherence can be utilized to generate ultrashort pulses of light with a broad spectrum but durations as short as a femtosecond.

Lasers are utilized in optical disc drives, laser printers, barcode scanners, DNA sequencing instruments, fiber-optic, semiconductor chip manufacturing (photolithography), and free-space optical communication, laser surgery and skin treatments, cutting and welding materials, military and law enforcement devices for marking targets and measuring range and speed, and in laser lighting displays for entertainment. In addition, semiconductor lasers in the blue to near-UV range have replaced light-emitting diodes (LEDs) for exciting fluorescence as a white light source. This allows for a much smaller emitting area because of the much greater radiance of a laser and avoids the droop suffered by LEDs. These devices are already used in some car headlights.

Specifications

Housing Material	Copper
Laser Output Type	Dot Facula (continuous output)
Dimensions(Dia.xLen.) mm	6×10
Weight (gm)	2
Operating Voltage (VDC)	5
Operating Temperature (°C)	-10 to 50
Output Power	5mW
Wavelength (nm)	650
Working Current	<40mA
Working Life	more than 2000 hours
Cable Length (cm)	7

Shipment Weight	0.005 kg
Shipment Dimensions	3 × 3 × 2 cm

Table 4 : Specifications of Laser

Figure 21 : Laser

3.2.5 Solar Panel

Sunlight is a source of energy that photovoltaic solar panels use to produce direct current electricity. A packed, linked assembly of photovoltaic solar cells that come in various voltages and wattages is known as a photovoltaic (PV) module.

The photovoltaic array of a photovoltaic system, which produces and supplies solar power for commercial and residential uses, is made up of photovoltaic modules. Solar water heating systems are the most typical use of solar energy collecting outside of agriculture.

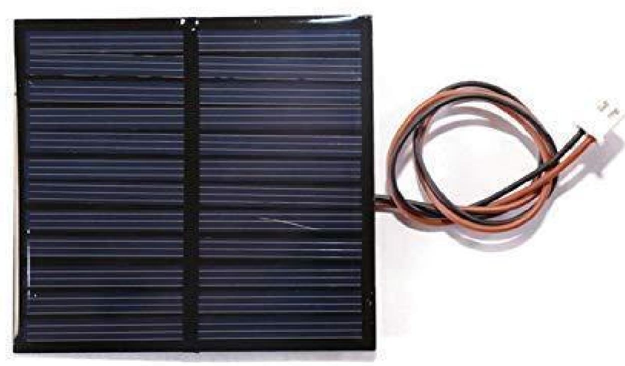


Figure 22: Solar panel

3.2.6 Speaker

A speaker, also referred to as a loudspeaker or loud-speaker, is an electroacoustic transducer that transforms electrical audio signals into corresponding sound waves. Dynamic speakers, invented by Edward W. Kellogg and Chester W. Rice in 1924, are the most widely used type of speaker in the 2010s. Dynamic speakers work on the same principle as dynamic microphones, but in reverse, to create sound from an electrical signal. A circular gap between the poles of a permanent magnet holds a coil of wire, called a voice coil, which moves rapidly back and forth due to Faraday's law of induction when an alternating current electrical audio signal is applied to it. This motion causes a diaphragm, usually conically shaped, attached to the coil to move back and forth and push the air, creating sound waves.

Apart from dynamic speakers, there are various alternative technologies that can be utilized to convert electrical signals into sound. However, regardless of the technology, the sound source (e.g., a sound recording or a microphone) needs to be amplified using an audio power amplifier before being sent to the speaker.

Figure 23: Speaker

3.2.7 Audio Recorder Module

The ISD1820 Recording Module Voice Board offers a simple way to incorporate voice recording and playback capabilities into your project. This module can be used directly through its 3 push buttons or with a microcontroller such as an Arduino. It comes equipped with a built-in microphone and can be connected to any 8 Ohm speaker. Thanks to the non-volatile storage of the ISD1820, your recordings are saved even without power. This module utilizes the ISD1820 voice record and playback IC, capable of recording a single voice message of up to 10 seconds. The message is stored in specialized analog flash memory which retains it even after power is removed. Additionally, the module includes push buttons for recording, partial playback, and full playback of the message. Interface with a microcontroller is made easy with header pins and playback can be controlled using just one digital pin.

Specifications:

- High-quality, natural voice restored
- Can be used as a propaganda module
- With looping, jog playback, single-pass play function
- Available single-chip control
- Record and playback control mode: key control or SCM, control line IO has been led out.
- Main chip: ISD1820
- Dimensions : 43 x 34 x 11 (LxWxH) mm
- Working voltage: DC 3V - 5V
- Loudspeaker: 8 Ohm, 0.5W

Application

- DIY circuits requiring audible message playback/record functionality.
- Message recording Applications.
- Speech Controlled Device.

3.2.8 3.5mm jack

The 3.5mm jack, sometimes referred to as a phone connection, headphone jack, audio jack, or jack plug, is a series of electrical connectors that are frequently used for analogue audio transmissions. The phone connector, which was created in the 19th century for use in telephone switchboards, is still commonly used today.

Figure 24: 3.5mm jack

3.3 Software Requirements

3.3.1 IDE Software

The Arduino Software (IDE), also known as the Arduino Integrated Development Environment, is a software tool that includes a text editor for writing code, a message area, a text console, a toolbar with common function buttons, and various menus. This tool is used to upload programs and communicate with the Arduino hardware. Sketches are programs written using the Arduino Software (IDE) and are saved with the file extension .ino. The text editor contains features for cutting, pasting, searching, and replacing text. The message area provides feedback while saving and exporting files and displays any errors. The console shows text output from the Arduino Software (IDE), including error messages and other relevant information. The bottom right-hand corner of the window shows the configured board and serial port. The toolbar buttons are used to verify and upload programs, create, open, and save sketches, and open the serial monitor.

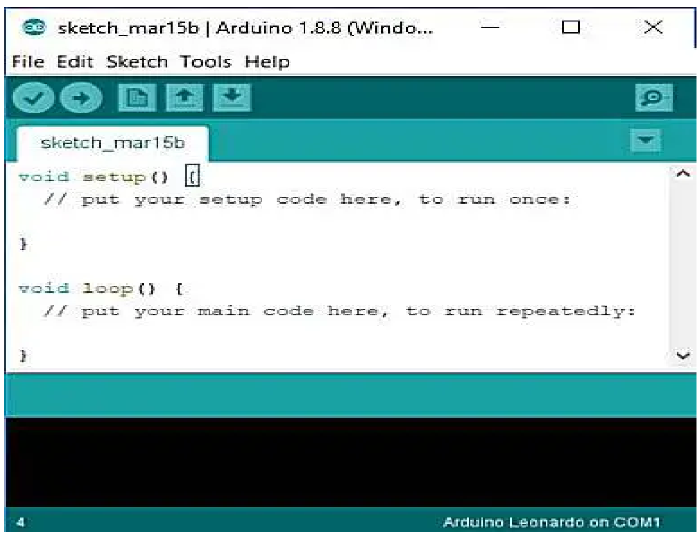


Figure 25: ARDUINO software

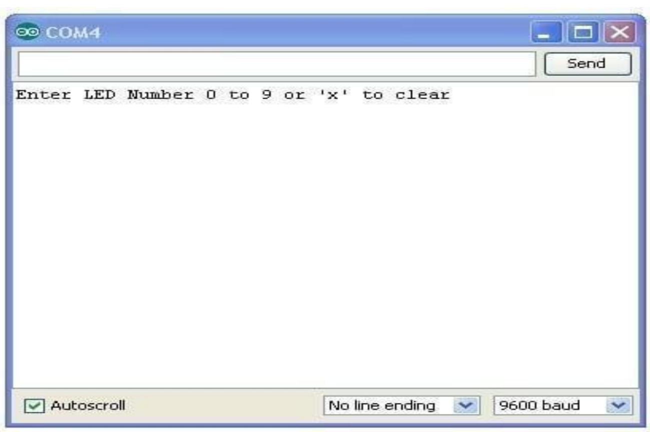


Figure 26: ARDUINO command window

3.4 Transmitter

3.4.1 Block Diagram of Transmitter

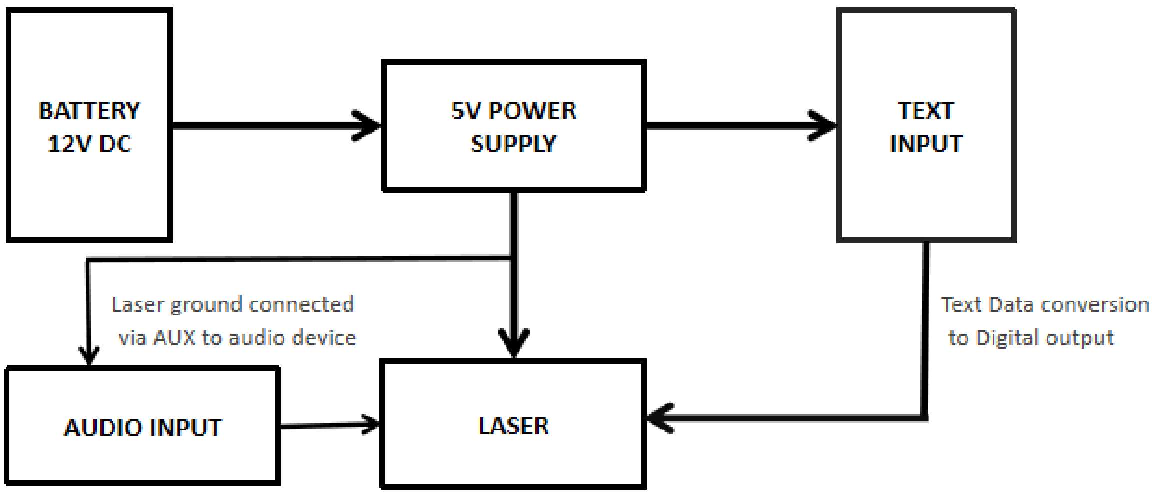


Figure 27: Transmitter block diagram

Audio Input

An audio signal represents sound, often using an electrical voltage level for analog signals or a sequence of binary numbers for digital signals. Audio signals generally have frequencies within the audio frequency range of about 20 to 20,000 Hz, which corresponds to the range of human hearing.

The input for an audio signal usually comes from the audio output of devices like mobile phones, laptops, or musical instruments. However, the signal output from these devices is usually at a low voltage level that is insufficient to drive a laser. To drive the laser, amplifiers are required to amplify the signal.

Text Input

Li-Fi technology can also be used for data transmission, with data rates of up to several gigabits per second possible. The technology uses the same principle of modulating the light signal to carry data. The data is encoded in the light signal, which is then detected by a receiver and decoded back into its original form.
One of the advantages of using Li-Fi for data transmission is its high speed. With data rates of up to several gigabits per second, Li-Fi is ideal for applications where high-speed data transfer is required, such as in video streaming, file transfer, and internet connectivity. Li-Fi is also more secure than traditional Wi-Fi since the light signal cannot pass through walls, making it difficult for hackers to intercept the data.

3.4.2 Integration

Set up the audio source: The audio source can be a microphone, a computer, or a mobile device. The audio signal needs to be converted into a digital signal using an analog-to-digital converter (ADC) before it can be modulated onto the laser beam.
Set up the text source: The text source can be a computer, a mobile device, or any device capable of generating text data. The text data needs to be encoded into binary digits before it can be modulated onto the laser beam.
Set up the LiFi laser system: The LiFi laser system consists of a light source, a modulator, and an optical lens. The audio and text signals are modulated onto the laser beam using the modulator.
Set up the two way switch system : In this project, we are transferring both audio and text . To control the Transmission of input,we use two way switching. One way is for data and one way is for audio
Align the transmitter and receiver: The LiFi laser system requires line-of-sight communication between the transmitter and receiver. Therefore, the transmitter and receiver need to be aligned with each other with no obstacles in between.
Calibrate the system: The LiFi laser system requires calibration to optimize the data transfer rate. Calibration involves adjusting the power of the laser beam and the sensitivity of the solar panel to ensure efficient data transfer.
Connect the audio and text sources to the LiFi laser system: The audio and text sources are connected to the LiFi laser system using cables or wireless connections. The audio signal is modulated onto the laser beam and transmitted to the solar panel receiver, while the text data is encoded into binary digits and modulated onto the laser beam.

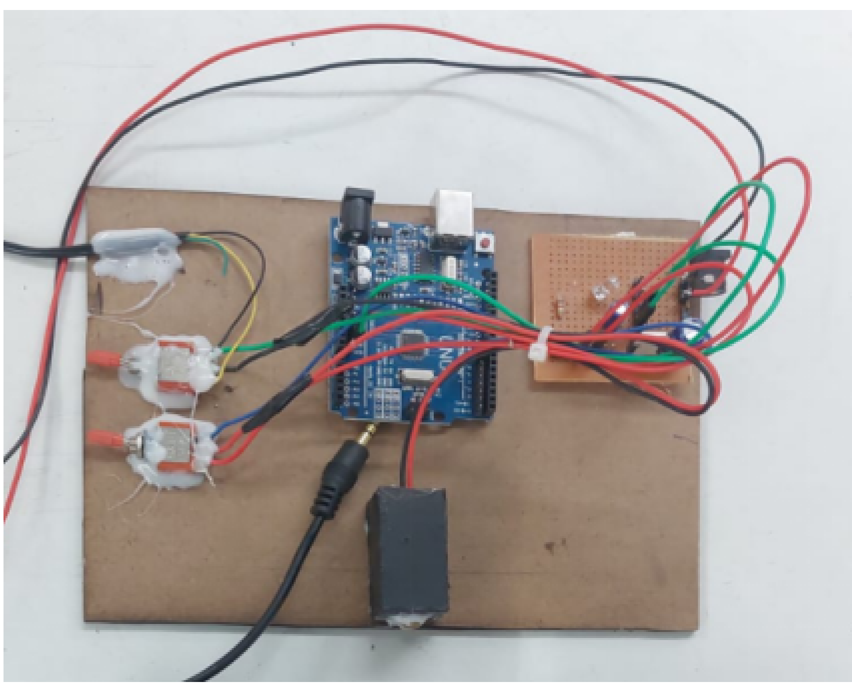


Figure 28: Transmission end of the device

3.5 Receiver

3.5.1 Block diagram

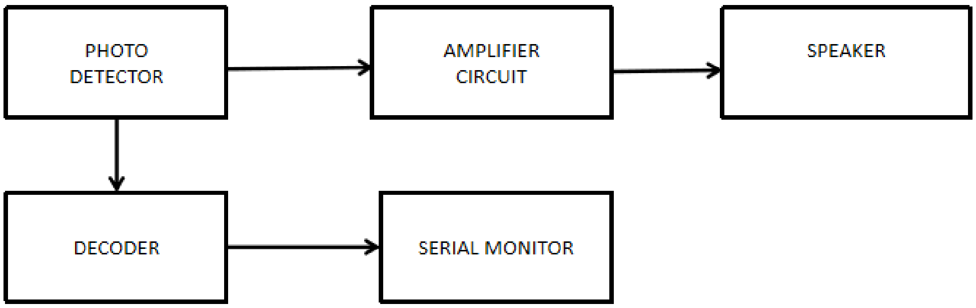


Figure 29: Receiver block diagram

Photo Detector

The Laser's sent signal has to be recognised, demodulated, and detected. so that the message signal from the laser light may be detected. We utilize a solar cell or a photocell (which comprises a large number of photocells connected in series). As blinking may be easily observed and the solar cell's output is an analogue message signal, the solar cell simply detects variations in light. Hence, we were able to identify and demodulate the delivered communication signal utilizing solar energy.

Amplifier Circuit and Speaker

The signal after demodulation will have a modest voltage range. As a result, an amplifier is used to increase it to the desired voltage level. The same kind of amplifier that we used on the transmitter side will be used for this amplifier. This is because any phase mistakes that occurred will be corrected at this point. Using the speaker's internal electromagnets, the speaker will transform the electrical signal into an aural one.

Amplifier Audio output

The speaker sends the demodulated audible signal on to its destination. In order for the audience to hear the audio message that has been amplified and relayed from the source's transmitter.

Text Output

The received text is transmitted from the Arduino board and the results will be displayed on the serial monitor. So that the audience can see the message that has been transmitted from the transmitter at the source.

Decoder

A decoder is a circuit component that decodes an input code. Given a binary code of n-bits, a decoder will tell which code is this out of the 2^n possible codes. Thus, a decoder has n-inputs and 2^n outputs. Each of the 2^n outputs corresponds to one of the possible 2^n input combinations.

3.5.2 Integration

Set up the solar panel receiver: The solar panel receiver consists of a solar panel, an optical filter, and an amplifier. The solar panel receives the modulated light signal and generates an electrical signal that is amplified by the amplifier.
Set up the Amplifier and speaker : The signal after demodulation will have a modest voltage range. As a result, an amplifier is used to increase it to the desired voltage level. The same kind of amplifier that we used on the transmitter side will be used for this amplifier. This is because any phase mistakes that occurred will be corrected at this point. Using the speaker's internal electromagnets, the speaker will transform the electrical signal into an aural one.
Process the signal: The electrical signal generated by the solar panel receiver is processed using Embedded C code. For audio signals, the Amplifier reconstructs the audio signal from the digital signal and plays it back through a speaker. For text signals, the Arduino decodes the binary digits to retrieve the original text data.
Align the transmitter and receiver: The LiFi laser system requires line-of-sight communication between the transmitter and receiver. Therefore, the transmitter and receiver need to be aligned with each other with no obstacles in between.
Calibrate the system: The LiFi laser system requires calibration to optimize the data transfer rate. Calibration involves adjusting the power of the laser beam and the sensitivity of the solar panel to ensure efficient data transfer.
Connect the audio and text sources to the LiFi laser system: The audio and text sources are connected to the LiFi laser system using cables or wireless connections. The audio signal is modulated onto the laser beam and transmitted to the solar panel receiver, while the text data is encoded into binary digits and modulated onto the laser beam.

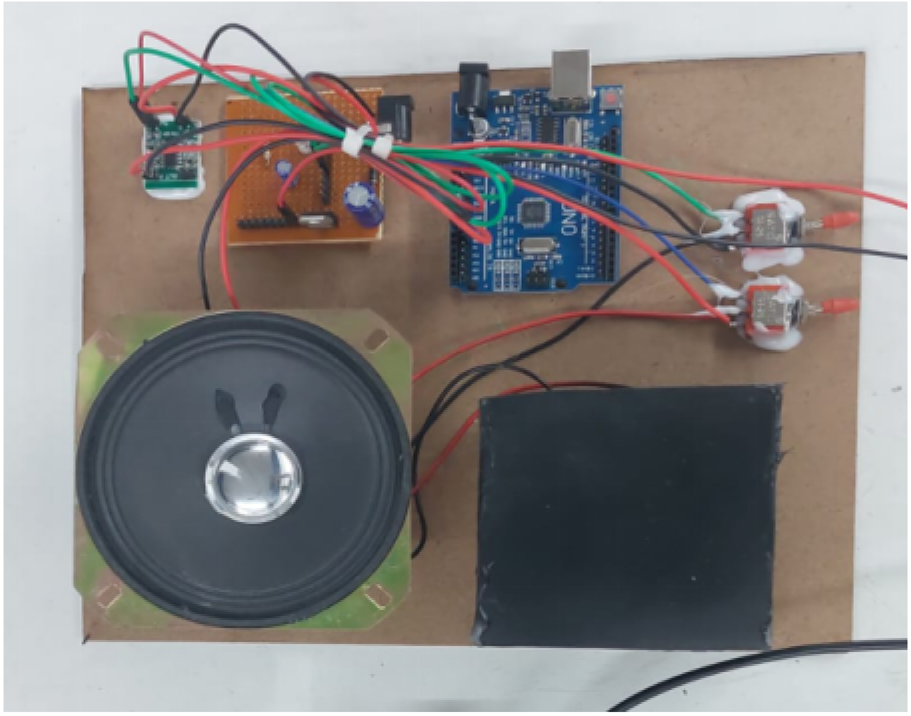


Figure 30: Receiver end of the device

3.6 Transmitter Circuit

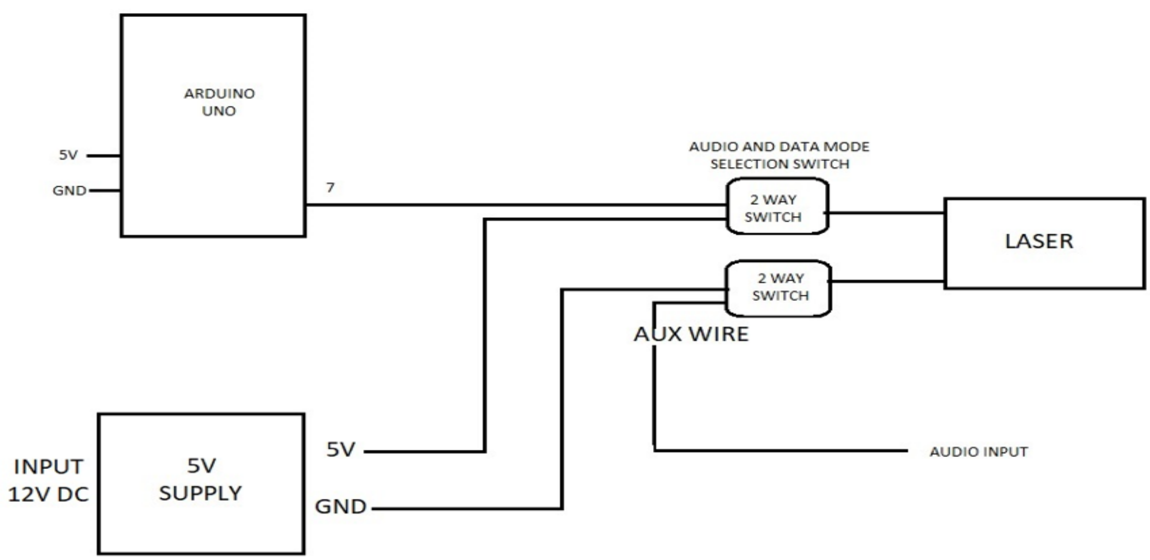


Figure 31: Transmitter circuit diagram

3.7 Receiver Circuit

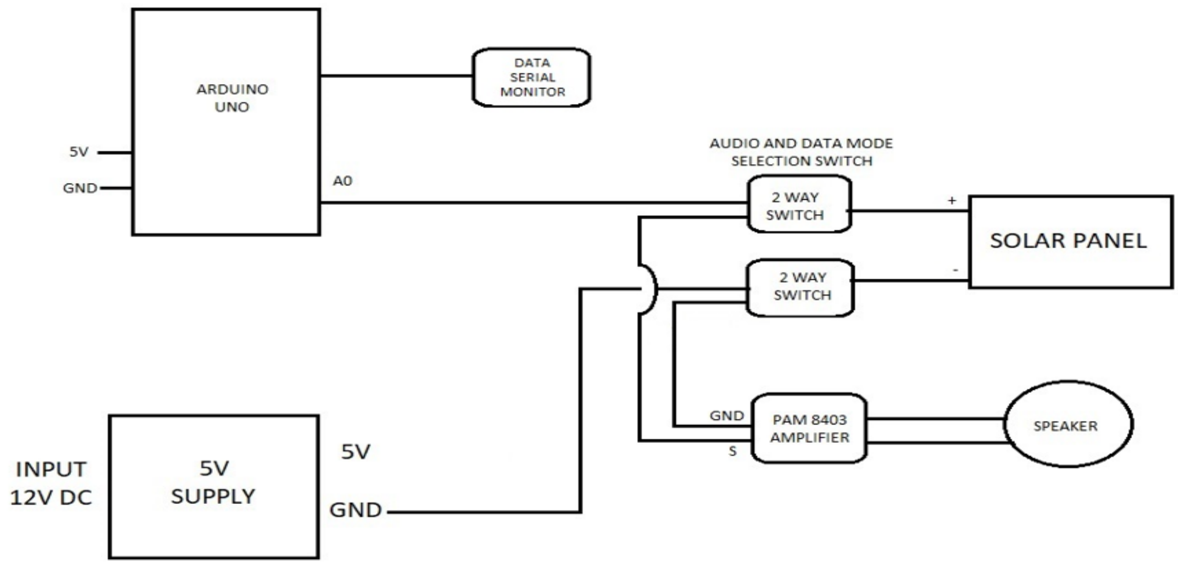


Figure 32: Receiver circuit diagram

CHAPTER 4
WORKING

4.1 Data transferred in Li-Fi Technology

The Li-Fi communication system comprises two main components: the transmitter and the receiver. The transmitter, which can be an LED lamp or flash, is responsible for transmitting data by turning the LED on and off at high speeds. This modulation allows for the transmission of data in binary format, with the LED being turned on representing a binary '1' and the LED being turned off representing a binary '0'. The data is converted into light pulses and directed to the receiver, which consists of an image detector sensor that senses the changes in light intensity and converts the light signal back into its original data format.

A smartphone is a mobile phone with advanced features and capabilities beyond traditional functions such as making phone calls and sending text messages. It is equipped with enhanced hardware, such as sensors for detecting the environment, position, and movement, as well as a built-in camera, wireless internet connection, and powerful software for playing videos, displaying images, checking the weather, sending emails, and much more. This study investigates recording wireless communication using the Li-Fi method, where a mobile phone serves as the transmitter by sending data using its built-in flash. At the receiver end, the phone's built-in ambient light sensor is utilized, leading to the development of a smartphone-to-smartphone communication device based on Li-Fi.

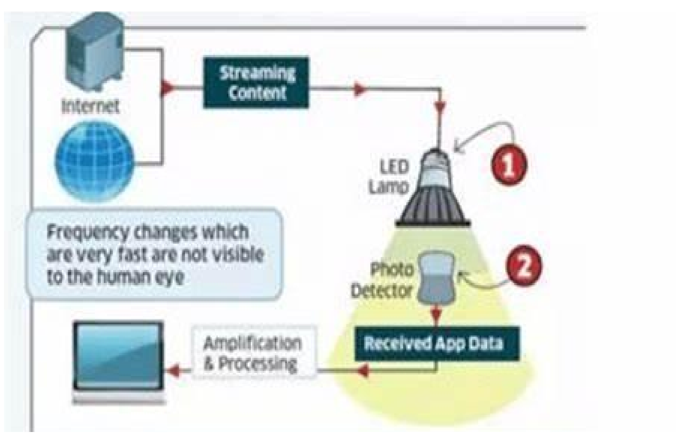


Figure 33 : Procedure of Li-fi Technology

In recent years, there has been significant research conducted on Li-Fi technology, exploring its potential as an alternative medium for wireless data transmission due to its numerous advantages.

The proposed communication system comprises two parts: the transmitter and receiver components. The transmitter unit utilizes a light source to send data, while the receiver component consists of a light detector sensor that detects the light signal and converts it into usable data. Initially, the proposed model explores how the light sensor integrated into smartphones can be utilized to establish a peer-to-peer communication system based on Visible Light Communication (VLC) and assesses whether the achieved data rate is compatible with

Li-Fi's expected throughput. Later, an external light sensor is tested to demonstrate how the data bit rate can be improved. The following section outlines the proposed system structure, including each module that comprises the overall system architecture.

Transmitting statistics through photodiodes has been occurring for a long time through our IR Remotes. Every time we pressed a button on our Television far flung the IR LED inside the Remote pulses very rapidly this would be acquired by using the Television and then decoded for the records. But, this antique technique could be very slow and can not be used to transmit any worthy statistics. Wi-Fi and Bluetooth are the consistent huge range sources utilized by more than one applications these days. However, these techniques use radio frequency spectrum and noise of the sign could be very excessive. Other inconveniences of these strategies are special system requirements, high power consumption, and excessive cost. Secure information transmission isn't available here.WPS key encryption can be provided and hacking can also be achieved without difficulty seeing that it makes use of radio wave transmission it is dangerous to health.

The potential applications of Li-Fi are numerous and warrant further exploration. If this technology can be put into practical use, every light bulb could be used as a Wi-Fi hotspot to transmit wireless data, moving us towards a cleaner, greener, safer, and brighter future. The concept of Li-Fi is currently receiving a lot of attention because it can offer a real and highly efficient alternative to radio-based wireless communication. As more people and their devices access wireless internet, the airwaves are becoming increasingly congested, making it harder to obtain a reliable high-speed signal. Li-Fi could solve problems such as the shortage of radio-frequency bandwidth and enable internet connectivity in places where traditional radio-based wireless is not permitted, such as airplanes or hospitals. However, one of its shortcomings is that it only works in direct line of sight.

Li-Fi technology is focused on transmitting multimedia data among terminals using LED lights. It uses visible light of the electromagnetic spectrum for image transmission between devices. In Li-Fi, data is sent through illumination by varying the intensity of an LED light bulb faster than the human eye can perceive. In this project, underwater communication is achieved using a small 20-micrometer white LED as the light source, and a silicon-based image diode is used for device perception. LASERs can also be used instead of LEDs. The transmitter sends signal pulses, and the light falls on the image diode, which is filtered to eliminate possible radiation interference. Li-Fi is ideal for high-density wireless data coverage in a limited area and for mitigating radio interference issues. Li-Fi offers better bandwidth, efficiency, availability, and security than Wi-Fi. When designing Li-Fi, we should consider the presence of light, line of sight, and the use of fluorescent light and LED for better performance.

4.2 Working analysis

The running principle of the Laser conversation device may be very similar to fiber optic hyperlinks, but the distinction is that the beam is transmitted via an unfastened area. An easy laser communique (LC) gadget transmits serial information via air from a transmitter to a receiver via a laser beam. This paper tells approximately the microcontroller based totally communication machine the use of laser mild as a device to transmit records. Here the microcontroller is attached with a PC wherein the PC acts as an input to the laser which offers input text to transmit with the help of laser medium. After efficiently implementing this mission, we found that the data transmission via laser light has carried out splendid success whilst

comparing with the traditional verbal exchange gadget.
(1) Transmitter End: The transmitter consists of a PC with a keyboard and an Arduino. The enter is given thru the keyboard (instance: AbCdE). The Arduino (1) converts the textual content into an 8 bit binary. On the transmit facet, a UART should create the facts packet appending sync and parity bits and ship that packet out the transmission line with specific timing through a laser beam.
(2) Transmission medium: The transmission medium is nothing but air. After transmitting, the statistics containing laser travels via the air and incident upon the sun panel of the receiver.
(3) Receiver End: The receiver contains a small solar panel, an Arduino and a PC with a screen. When the laser beam is incident on the sun panel, it converts the data containing mild signs into a contemporary and this present day goes with the flow via the Arduino (2). This.Arduino converts the bits into corresponding alphanumeric characters and the pc display indicates them. This is our preferred output.Laser communications systems are wireless connections through the environment. They paint further to fiber optic links, besides the beam is transmitted through loose space.

While the transmitter and receiver have to require line-of-sight situations, they have the benefit of putting off the need for broadcast rights and buried cables. Laser communications structures may be effortlessly deployed when you consider that they're inexpensive, small, low electricity and do not require any radio interference research.

(A)Sending end;

At the sending end, Arduino-1 is used to transform the alphanumeric characters into eight bit ASCII code. For the code, we must do the followings:

i. Take the characters as enter
ii. Convert the characters into ASCII code of which the begin bit is 1
iii. The put off is set 10ms between two consecutive bits
iv. Set the put off of 100ms among consecutive Bytes.
V. Upload the code

(B)Receiving end;

Laser mild is dispatched to the sun panel and solar panel now gets the facts. The solar panel is hooked up with the A0 pin and floor. After checking the price of the sun panel constructed in “AnalogReadSignal” each while there may be no light on the laser, and when there's light on the laser. We then set the THRESHOLD Value for the solar panel by means of analyzing the cost from “AnalogReadSignal”.

Dec	Hex	Binary	Char	Dec	Hex	Binary	Char	Dec	Hex	Binary	Char
32	20	0010 0000	space	64	40	0100 0000	@	96	60	0110 0000	`
33	21	0010 0001	!	65	41	0100 0001	A	97	61	0110 0001	a
34	22	0010 0010	"	66	42	0100 0010	B	98	62	0110 0010	b
35	23	0010 0011	#	67	43	0100 0011	C	99	63	0110 0011	c
36	24	0010 0100	$	68	44	0100 0100	D	100	64	0110 0100	d
37	25	0010 0101	%	69	45	0100 0101	E	101	65	0110 0101	e
38	26	0010 0110	&	70	46	0100 0110	F	102	66	0110 0110	f
39	27	0010 0111	'	71	47	0100 0111	G	103	67	0110 0111	g
40	28	0010 1000	(	72	48	0100 1000	H	104	68	0110 1000	h
41	29	0010 1001	)	73	49	0100 1001	I	105	69	0110 1001	i
42	2A	0010 1010	*	74	4A	0100 1010	J	106	6A	0110 1010	j
43	2B	0010 1011	+	75	4B	0100 1011	K	107	6B	0110 1011	k
44	2C	0010 1100	,	76	4C	0100 1100	L	108	6C	0110 1100	l
45	2D	0010 1101	—	77	4D	0100 1101	M	109	6D	0110 1101	m
46	2E	0010 1110	.	78	4E	0100 1110	N	110	6E	0110 1110	n
47	2F	0010 1111	/	79	4F	0100 1111	O	111	6F	0110 1111	o
48	30	0011 0000	0	80	50	0101 0000	P	112	70	0111 0000	p
49	31	0011 0001	1	81	51	0101 0001	Q	113	71	0111 0001	q
50	32	0011 0010	2	82	52	0101 0010	R	114	72	0111 0010	r
51	33	0011 0011	3	83	53	0101 0011	S	115	73	0111 0011	s
52	34	0011 0100	4	84	54	0101 0100	T	116	74	0111 0100	t
53	35	0011 0101	5	85	55	0101 0101	U	117	75	0111 0101	u
54	36	0011 0110	6	86	56	0101 0110	V	118	76	0111 0110	v
55	37	0011 0111	7	87	57	0101 0111	W	119	77	0111 0111	w
56	38	0011 1000	8	88	58	0101 1000	X	120	78	0111 1000	x
57	39	0011 1001	9	89	59	0101 1001	Y	121	79	0111 1001	y
58	3A	0011 1010	:	90	5A	0101 1010	Z	122	7A	0111 1010	z
59	3B	0011 1011	;	91	5B	0101 1011	[	123	7B	0111 1011	{
60	3C	0011 1100	<	92	5C	0101 1100	\	124	7C	0111 1100	|
61	3D	0011 1101	=	93	5D	0101 1101	]	125	7D	0111 1101	}
62	3E	0011 1110	>	94	5E	0101 1110	^	126	7E	0111 1110	~
63	3F	0011 1111	?	95	5F	0101 1111	_	127	7F	0111 1111	DEL

Figure 34: Binary conversion for threshold values

In setup, we take into account the solar pin A0 as enter and fix the Serial.Begin to 9600. Then we take the studying from the solar pin. If the Reading from the solarpin is more than the brink, then we do not forget it to be ‘1’, in any other case it is considered as ‘zero’. These binary bits are saved in an array.

We set the put off to ‘100’ to match the postponement of the sending side. Anything aside from 50, the interpretation will now not be proper and it can produce fake end results. The binary bits are converted to ASCII value. Then the ASCII values supply us with suitable characters.

Lasers are used nowadays in the home and global community. These optical systems ultimately provide the bandwidth that is in such demand. Laser Torch Based Transmission and Reception are cheaper and simpler in construction than RF transmitter and receiver. Infra-Red and Blue-Tooth can also be used for transmission and Reception reason, however their variety is small compared with their rate.

Taking the business attitude of the enhancements in those regions will lead to better communications at low price, low loss of the alerts, higher overall performance, negligible time put off, better protection, less complex systems, will grow the reliability of the communications, and increasingly application areas.

Visible Light Communication (VLC) refers to the transmission of data through visible light ranging from 400 to 800 THz. Compared to radio frequencies, which have a bandwidth of 3 KHz to 300 GHz, the bandwidth of VLC is much higher. Modulation is used to transmit audio through the optical channel between the LED and the photodiode module.

The Li-Fi system can be used to provide short-range tele-operational control of underwater vehicles by communicating through visible light up to 5m under favorable lighting conditions. We introduce a framework for estimating the expected variations in the emitted light quality of illumination LEDs used in Li-Fi. We propose a novel bidirectional underwater visible light communication (BiUVLC) that transmits and records signals using a single RGB LED through a water tank that represents an underwater environment, and the signal is then received by a VLC receiver through a color filter.

The quality of the system for text transmission is measured by calculating the Character Error Rate (CER), while the quality of image transmission is determined using the Bit Error Rate (BER). The system consists of a transmitter that directs a light beam towards the receiver, thereby converting the electrical data signal into an optical signal.

Here in our project we are sending audio and data over laser light to solar panels .
For Audio signal transmission , the positive end of laser is connected to 5v supply , ground of laser is connected to aux cable to audio device , the signal amplitude fluctuation are transmitted to solar panel , the solar panel output is connected to amplifier circuit i.e connected to speaker.
For Data transmission laser source is connected to Arduino uno microcontroller , the text data is converted to digital output in 1 , 0 forms to the solar panel . At the receiving side solar panel the analog output of Arduino uno , then the output character data is taken out via serial monitor.

4.3 Audio transmission working

Audio Signal Encoding:
The audio signal is first converted into a digital signal using an analog-to-digital converter (ADC). The ADC samples the analog audio signal at regular intervals and converts each sample into a digital value. The digital signal is a sequence of binary digits, where each binary digit represents the amplitude of the audio signal at a particular time.

Modulation:
The digital signal is then modulated onto a laser beam. In modulation, the digital signal is used to vary the amplitude, frequency, or phase of the laser beam. The laser beam is then directed towards the solar panel receiver.

Reception:
At the receiver end, the laser beam is detected by a solar panel that is equipped with a photodiode or photovoltaic cell. The photodiode or photovoltaic cell detects the light signal from the laser beam and converts it into an electrical signal. This electrical signal is then processed to retrieve the original data that was transmitted.

Digital-to-Analog Conversion:
The electrical signal is first converted back into a digital signal using a digital-to-analog converter (DAC). The DAC converts the digital signal back into an analog audio signal.

Audio Signal Decoding:
The analog audio signal is then amplified and played back through a speaker. The listener can hear the original audio signal that was transmitted.

Audio transmission using laser and solar panel Li-Fi has several advantages over traditional RF-based audio transmission, such as higher sound quality, lower latency, and reduced

interference. However, it also has some limitations, such as the requirement for a clear line of sight between the transmitter and the receiver and susceptibility to atmospheric turbulence and weather conditions. Therefore, it is typically used for applications such as indoor audio transmission and short-range communication between fixed points.
Audio transmission using laser and solar panel Li-Fi is a promising technology that offers several advantages over traditional RF-based audio transmission. It has the potential to revolutionize the way we transmit and receive audio signals, especially in indoor environments. However, further research is required to address the technical challenges associated with this technology and to optimize its performance in various environments.

4.4 Text transmission Working

Text Data Encoding:
The text data is first encoded into binary digits using a binary code such as ASCII or Unicode. Each character in the text is represented by a unique sequence of binary digits.

Modulation:
The binary digits are then modulated onto a laser beam. In modulation, the binary digits are used to vary the amplitude, frequency, or phase of the laser beam. The laser beam is then directed towards the solar panel receiver.

Transmission: The modulated laser beam is then transmitted over the air to the receiver. The laser beam is typically directed towards the solar panel using a collimating lens.

Reception:
At the receiver end, the laser beam is detected by a solar panel that is equipped with a photodiode or photovoltaic cell. The photodiode or photovoltaic cell detects the light signal from the laser beam and converts it into an electrical signal. This electrical signal is then processed to retrieve the original data that was transmitted.

Decoding:
The binary digits are then decoded to retrieve the original text data. Each sequence of binary digits is mapped back to its corresponding character in the text.
Text transmission using laser and solar panel Li-Fi has several advantages over traditional RF-based text transmission, such as higher data rates, lower latency, and reduced interference. However, it also has some limitations, such as the requirement for a clear line of sight between the transmitter and the receiver and susceptibility to atmospheric turbulence and weather conditions. Therefore, it is typically used for applications such as indoor text transmission and short-range communication between fixed points.
In addition to the advantages mentioned above, text transmission using laser and solar panel Li-Fi offers improved security as the transmission is limited to the physical space where the laser beam is directed.

Furthermore, since the laser beam is highly directional, it is less interfered with and can be used in crowded environments without affecting other communication channels.

In summary, text transmission using laser and solar panel Li-Fi is a promising technology that offers several advantages over traditional RF-based text transmission. It has the potential to revolutionize the way we transmit and receive text data, especially in indoor environments. However, further research is required to address the technical challenges associated with this technology and to optimize its performance in various environments

4.5 Applications

Home and building automation
Because Li-Fi has the potential for higher speeds and offers security advantages due to the way the technology functions, many experts predict a trend towards it in residential settings. The network may be confined in a single physical room or building since the light conveys the data, lowering the risk of a distant network assault. The advent of home automation, which necessitates significant amounts of data to be sent across the local network, may push home consumption forward, even though this has more ramifications for corporate and other sectors.

Underwater application
Wired connections are used to run the majority of remotely operated underwater vehicles (ROVs). Their working range is strictly constrained by the length of their cabling, and they may also be constrained by other considerations like the weight and fragility of the cable. Light can traverse water, therefore communications based on Li-Fi may provide considerably more mobility. [40] [Source untrustworthy] The range that light can travel through water limits the practicality of Li-Fi. More than 200 meters is the maximum distance that significant light may travel. Beyond 1000 meters, no light can be seen.

Aviation
In airborne situations, such as a commercial passenger airplane, Li-Fi enables effective data connection. The radar and other radio-wave-dependent systems aboard the airplane won't be hampered by using this light-based data transfer.

Hospital
Medical establishments are increasingly employing remote exams and even treatments. A better method for transferring low latency, high volume data across networks may be provided by Li-Fi systems. [Reference required] Light waves offer a faster pace while also having less of an impact on medical equipment. An illustration of this would be the potential usage of wireless gadgets in radiosensitive procedures like MRIs. Localization of resources and employees is another way that LiFi is used in hospitals.

Vehicles
To improve traffic safety, vehicles might communicate with one another using their front and rear lights. Information regarding the state of the roads might also be obtained from traffic lights and street lights.

Industrial automation
Li-Fi is capable of replacing slip rings, sliding contacts, and small cables, like Industrial

Ethernet, everywhere in industrial settings where data must be sent. Li-Fi is also an option to popular industrial Wireless LAN standards because of its real-time nature (which is sometimes necessary for automation operations). German research company Fraunhofer IPMS claims to have created a component that is ideal for industrial applications involving time-sensitive data transfer.

Advertising

As a person passes by, adverts for neighboring establishments or attractions might be shown on street lighting for mobile devices. Current specials and promotions can be shown on a customer's mobile device as they enter a business and pass by the front lights.

Warehousing

Indoor location and navigation is a key component in warehousing. Robots benefit from more realistic and complex visual experiences because of 3D positioning. Visible light from LED bulbs may be used to compute the placement of the items since it is used to communicate with robots and other receivers.

4.6 Objectives and Benefits

(1) Faster facts transfer speeds: Li-Fi has the potential to transmit data at a whole lot faster than traditional Wi-Fi era. Li-Fi can acquire speeds of as much as several gigabits in step with 2nd, that's hundreds of times faster than cutting-edge Wi-Fi requirements.

(2)Higher bandwidth: The Li-Fi era can use a better bandwidth of the electromagnetic spectrum as compared to standard Wi-Fi technology, that's congested due to the increasing range of connected devices.

(3)Increased protection: Li-Fi generation is more relaxed than Wi-Fi because seen light can't bypass strong gadgets like walls, making it hard for hackers to get entry to the records.

(4)Reduced interference: Li-Fi technology makes use of light waves to transmit information, which do not interfere with radio frequencies utilized by other wi-fi technology.

(5)Energy efficiency: Li-Fi technology is greater energy-green than traditional Wi-Fi technology because it makes use of LED lights, which consume less energy than conventional light bulbs.

(6)New applications: Li-Fi era has the capability to create new programs in numerous fields, together with healthcare, transportation, and clever towns, where excessive-velocity and relaxed statistics transmission is important.

(7)The Li-Fi era is to provide faster, extra relaxed, and power-green wireless communication that can aid the developing call for facts switch in a selection of packages.

(8)The major goal of the task is to offer an efficient, low fee, digitally managed and speedy data transfer approach.

(9)Data density may be multiplied and also it offers secure conversation.

(10) In this challenge, we're shifting text, audio and photographs from transmitter to receiver to underwater using LiFi.

4.7 Challenges

(1)The noise in photodiodes: The predominant sources of noise are dark modern noise, shot noise and thermal noise in a photodiode. The dark contemporary noise arises because of the darkish modern-day which flows inside the circuit while the solar panel isn't always in an illuminated environment underneath the bias condition.

(2) Atmospheric Attenuation: In fashionable, attenuation is the relation among transmitted signal energy and obtained signal strength as observe
Attenuation=10log (P-transmitted / P-received)

(3)The hard task is locating a foothold in the market where there is a clear gain over WiFi. WiFi is embedded in society and in maximum cases is perfectly ok. There is likewise WiFi 6 coming alongside in an effort to provide extra ability

(4)Need for Special Hardware: LiFi needs special LED bulbs for transmission and picture-detector for reception. The need for special LED bulbs has made it tough to implement LiFi on a huge scale as these bulbs aren't but mass produced.

(5)Uplink Issues: Every LiFi presentation has always missed out a primary part of its implementation, the uplink. There isn't any era available for mobile devices to transmit LiFi signals.

(6)Limited Range: LiFi is evolved with a purpose to replace the conventional WiFi systems to boost the bandwidth. But one foremost problem with LiFi lies inside its primary principle of the usage of mild for transmission. It limits the range of LiFi. A not unusual household can get along with an unwired WiFi router while the same family would want more than one LiFi bulbs for protecting the complete residence.

(7)Light Intensity: Since LiFi uses light to transmit statistics, we have to remember the ordinary lights in a common family which can interfere with the connection. What I imply with the aid of this is, if the LiFi bulb has an intensity which isn't always easily distinguishable from other sources of mild which include normal bulbs or sunlight, it might cause the complete gadget to fail.

(8)Line-of-sight verbal exchange: One of the most important challenges with Li-Fi generation is that it calls for a direct line of sight between the transmitter (LED light) and the receiver (photodetector). This means that the sign can be blocked through objects like partitions, furniture, or humans. In order to conquer this challenge, a couple of LED lighting fixtures might need to be used to offer coverage throughout a space.

(9) Interference: Bright sunlight can interfere with the signal from LED lighting fixtures,

making it tough to acquire statistics. This is because the photodetector is designed to pick out very small adjustments in light, and vibrant daylight can overwhelm the sensor.

(10)Standardization: There is presently no extensively common popular Li-Fi generation, because of this that unique producers may additionally implement the era in different methods. This ought to make it hard to ensure compatibility between exclusive Li-Fi devices.

CHAPTER 5
RESULTS

In our project, we created and built a wireless communication system called LIGHT FIDELITY, which transmits audio messages wirelessly (Li-Fi). The task is divided into two components. two sections: a transmitter and a receiver. The transmitter component uses LASER to modify the incoming message and audio signal before transmitting it in the form of visible light to the receiver. A message is shown on a serial monitor after the receiver part analyzes the incoming light, which is detected using a solar panel, and transforms it to an audible sound signal using a speaker.

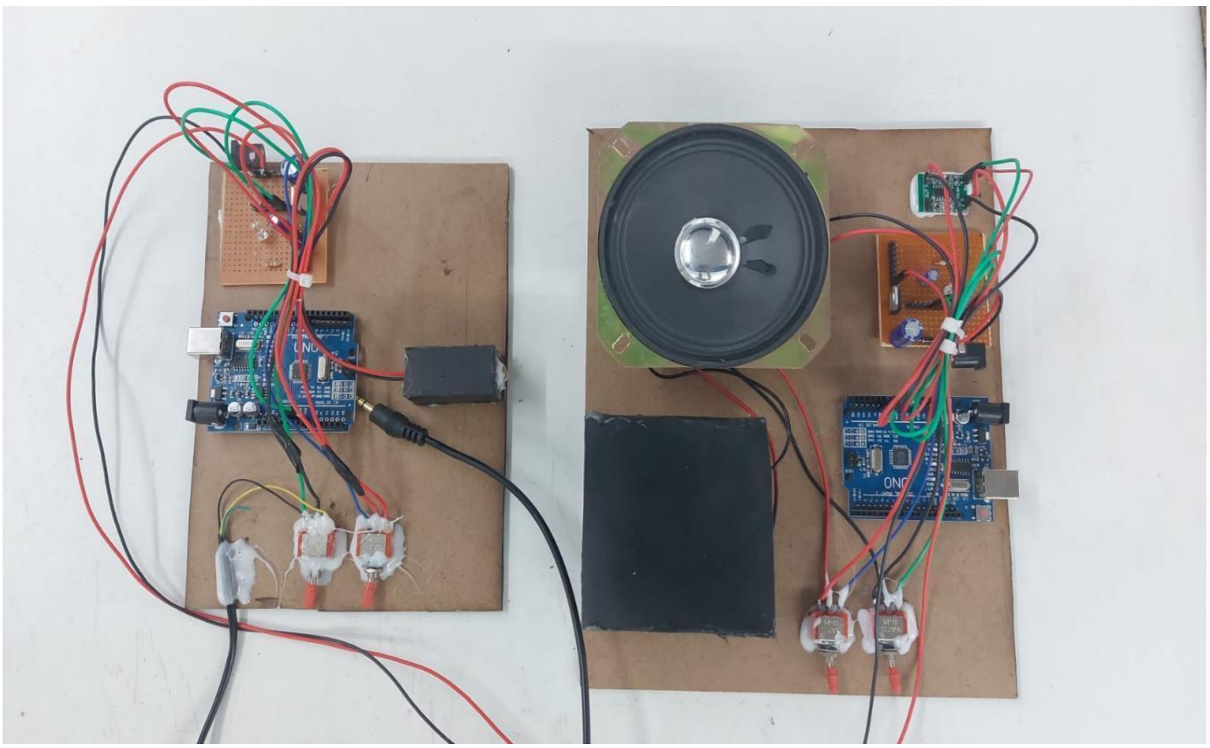


Figure 35 : Final module

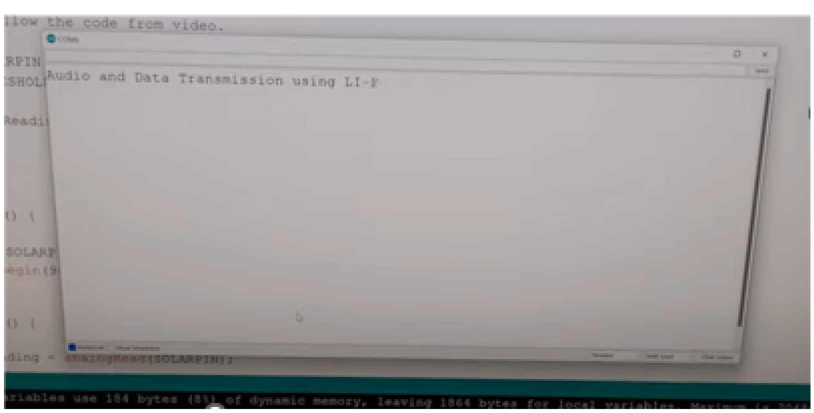


Figure 36 : Text Transmitted Results

CHAPTER 6
CONCLUSION

6.1 Conclusion

The project on audio and text transmission using LiFi has shown that LiFi technology has a lot of potential in the field of communication. The project demonstrated the ability of LiFi to transmit both audio and text data in real-time using visible light as a communication medium.
The rapid growth of wireless communication technologies has revolutionized the way we communicate with each other. WiFi and Bluetooth have become ubiquitous, providing wireless connectivity to billions of devices around the world. However, these technologies have limitations in terms of data transfer rates, security, and interference. LiFi technology has emerged as an alternative to traditional wireless communication systems, providing higher data transfer rates, increased security, and reduced interference. This project aims to demonstrate the ability of LiFi to transmit both audio and text data in real-time using visible light as a communication medium.
However, there are still some limitations to LiFi technology that need to be addressed. For instance, LiFi signals are blocked by physical obstacles, and the technology requires a direct line of sight between the transmitter and receiver. This limitation makes it difficult to deploy LiFi in large-scale communication systems.
Overall, the project has provided valuable insights into the potential of LiFi technology and has opened up new avenues for research and development in this area. With further advancements in the technology, LiFi could become a mainstream communication technology that offers high-speed data transfer, improved security, and reduced interference, transforming the way we communicate in the future. The project has shown that LiFi technology has a lot of potential, and it will be exciting to see how it develops in the coming years.

6.2 Future Scope

There are several areas of future work that researchers and developers are focusing on to further develop and improve Li-Fi technology. Here are some of the potential areas of future work:
Standardization: Currently, there is no standardized protocol for Li-Fi technology. Developing standardized protocols for Li-Fi could improve interoperability between devices and make it easier for manufacturers to develop Li-Fi-enabled products.
Security: Li-Fi technology is considered more secure than Wi-Fi, but there is still room for improvement. Researchers are working on developing more secure Li-Fi protocols that can protect against hacking and eavesdropping.
Range and Coverage: Li-Fi technology currently has limited range and coverage compared to Wi-Fi. Researchers are working on developing Li-Fi transmitters that can cover larger areas and transmit signals over longer distances.
Power Efficiency: Li-Fi technology currently requires a lot of power to transmit data.

Developing more power-efficient Li-Fi systems could make it more energy-efficient and sustainable.
Integration with other technologies: Researchers are exploring ways to integrate Li-Fi with other technologies such as Wi-Fi, 5G, and IoT. This could improve the efficiency of data transmission and enable more seamless communication between devices.
Commercialization: Li-Fi technology is still in its early stages, and more work needs to be done to commercialize it.

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Senior Secondary	MPC	Narayana junior college	2019	87.4%
High School	SSC	Bhashyam public school	2017	9.0

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Senior Secondary	MPC	Nano Junior college	2019	80%
High School	SSC	Narayana e-Techno School	2017	8.7

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B.Tech	ECE	GITAM University	2023	7.45
Senior Secondary	MPC	Narayana junior college	2019	616
High School	SSC	St. Patrick's high school	2017	8.5

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B.Tech	ECE	GITAM University	2023	7.81
Senior Secondary	MPC	Narayana Junior college	2019	82%
High School	CBSE	Vignan Bo Tree School	2017	8.6