SECURE DATA TRANSMISSION WITH LIFI TECHNOLOGY USING ARDUINO

PROJECT-21ECP302L

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MAY 2025

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Under Section 3 of UGC Act, 1956)

BONAFIDE CERTIFICATE

Certified that this activity report for the course **21ECP302L PROJECT** is the bonafide work of **S. Nafisa Begam (RA2211004010582), R. John Christopher (RA2211004010589), S. P. Anush Roob (RA2211004010590),** who carried out the work under my supervision.

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ABSTRACT

This project delves into the design and implementation of a secure data transmission system leveraging the principles of Li-Fi (Light Fidelity) technology, employing cost-effective and readily available Arduino Uno microcontrollers as the core processing units. The fundamental communication channel is established through the modulation and transmission of data via an infrared (IR) Light Emitting Diode (LED). The encoded data, represented as variations in the emitted IR light, is then captured and interpreted by an IR sensor positioned at the receiving end. To manage the complexities of data encoding, transmission protocols, reception, and subsequent decoding, the system utilizes two distinct Arduino Uno boards, each programmed with specific functionalities. Demonstrating a practical application of this secure communication link, a relay module is integrated into the system. This relay, acting as a remotely controlled switch, is activated or deactivated based on the securely transmitted data, highlighting the potential for secure control mechanisms in various applications. The inclusion of a USB female port in the project design suggests a provision for user interaction, data input, or output functionalities, potentially enabling the system to interface with other devices or for configuration purposes. This investigation underscores the viability of utilizing Li-Fi technology, coupled with the versatility of Arduino platforms, to establish a low-cost yet potentially more secure alternative to traditional radio frequency-based communication for short-range data transfer and control. The inherent directionality and confinement of light-based communication offer an added layer of security, particularly relevant in environments where electromagnetic interference is a concern or where eavesdropping on radio waves poses a risk. This project serves as a proof-of-concept for secure, light-based communication and control using accessible hardware, paving the way for further exploration and optimization in diverse application scenarios.

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LIST OF ABBREVIATIONS

- **RF:** Radio Frequency
- **EMI:** Electromagnetic Interference
- **Li-Fi:** Light Fidelity
- **VLC:** Visible Light Communication
- **IR:** Infrared
- **LED:** Light Emitting Diode
- **PMS:** Patient Monitoring System
- **OOK:** On-Off Keying
- **WHO:** World Health Organization
- **ETAs:** Electronic Travel Aids
- **Wi-Fi:** Wireless Fidelity (though it appears in the literature survey, not your project description)
- **BC 547:** This refers to a specific type of transistor (likely used in one of the surveyed projects). It's not a general abbreviation.
- **5v:** 5 volts (electrical unit)
- **12v:** 12 volts (electrical unit)
- **GPS:** Global Positioning System (appears in the literature survey, not your project description)
- **RF:** Radio Frequency (repeated)

- **ICSP:** In-Circuit Serial Programming
- **PWM:** Pulse Width Modulation
- **USB:** Universal Serial Bus
- **IDE:** Integrated Development Environment
- **C/C++:** Programming languages
- **I/O:** Input/Output
- **I2C:** Inter-Integrated Circuit (a communication protocol)
- **SPI:** Serial Peripheral Interface (a communication protocol)
- **AES:** Advanced Encryption Standard (mentioned in potential future works)
- **RSA:** Rivest–Shamir–Adleman (mentioned in potential future works)
- **FSK:** Frequency Shift Keying (mentioned in potential future works)
- **CRC:** Cyclic Redundancy Check (mentioned in potential future works)
- **LCD:** Liquid Crystal Display (mentioned in potential future works)

CHAPTER 1

INTRODUCTION

1.1 Introduction

In an increasingly interconnected world, the secure and reliable transmission of data is paramount across various applications, ranging from personal communication to industrial control systems. Traditional wireless communication methods, predominantly relying on radio frequency (RF) signals, are susceptible to eavesdropping and electromagnetic interference (EMI). This necessitates the exploration and development of alternative communication technologies that offer enhanced security and robustness in specific environments. Li-Fi (Light Fidelity), a Visible Light Communication (VLC) technology, has emerged as a promising alternative, utilizing the visible light spectrum to transmit data. By rapidly modulating the intensity of light sources, data can be encoded and transmitted at high speeds, offering potential advantages in terms of security, bandwidth availability, and immunity to EMI. Given that light is inherently confined within a line of sight, Li-Fi offers a physical layer security advantage compared to the omnidirectional nature of RF signals. This report details the design and implementation of a secure data transmission system employing Li-Fi technology, utilizing the widely accessible and versatile Arduino Uno microcontroller platform. The project focuses on establishing a fundamental communication link using infrared (IR) light, a spectrum adjacent to visible light and commonly used in short-range communication. By leveraging the simplicity and affordability of IR LEDs and sensors, coupled with the programmability of Arduino, this project aims to demonstrate the feasibility of secure data transfer and control. The system incorporates two Arduino Uno boards, each responsible for the encoding and transmission, and the reception and decoding of data, respectively. The inclusion of a USB female port provides a potential interface for data input, output, or system configuration. This exploration into Li-Fi-based secure data transmission with Arduino offers insights into the potential of light-based communication for short-range, secure applications, particularly in environments where RF communication may be undesirable or less secure. The project highlights the accessibility of this technology through readily available components and serves as a foundation for further investigation and development in the field of secure and alternative communication methods, potentially finding relevance in diverse scenarios.

1.2 Objective

- Establish a Functional Li-Fi Communication Link using Infrared Light: To successfully transmit digital data wirelessly between two Arduino Uno microcontrollers by encoding information onto the intensity of an infrared (IR) LED and receiving it with an IR sensor.

- Implement a Basic Data Encoding and Decoding Scheme: To develop and implement a simple yet effective algorithm on the Arduino platforms for encoding digital data into a transmittable format via the IR LED and decoding the received signals back into the original data.

- Demonstrate Secure Data Transmission through Directional Light: To showcase the inherent physical layer security aspect of Li-Fi by utilizing the directional nature of IR light for short-range data transfer, limiting the potential for eavesdropping compared to omnidirectional RF signals.

- Integrate a Relay Module for Secure Remote Switching: To demonstrate a practical application of the secure data transmission by controlling a relay module based on the received and decoded data, enabling secure remote activation or deactivation of an external circuit.

- Incorporate a USB Interface for Potential Data Input/Output or Configuration: To provide a user interface or a point of connection for external devices, allowing for potential data input into the transmission system or output of received data, as well as possible system configuration.

CHAPTER 2

LITERATURE SURVEY

- According to a 2022 survey by the World Health Organization (WHO), nearly 2.2 billion people across the globe are living with visual impairments, and this number is poised to grow, especially as the global population ages. When these individuals visit unfamiliar indoor locations, they face many difficulties. While navigation indoors is convenient for sighted individuals, it is essential for the visually Page 3 | 9 impaired to have aiding tools for their daily activities. Electronic Travel Aids (ETAs) were developed to detect obstacles and guide users through acoustic signals for simple navigation. To address these challenges, an indoor navigation system utilizing Li-Fi technology was developed by Srinithi, P., S. Kalpanadevi, P. Rekha, N. Divya, M. Rajkumar, and D. Aathiba. This technology uses LED light bulbs for data transmission and operates on a free, unlicensed spectrum that is unaffected by RF noise. Li-Fi provides high-speed, low-cost wireless communication, is highly secure, and cannot be easily intercepted. Additionally, it offers a larger bandwidth compared to Wi-Fi. To enhance user convenience, the system is integrated with an ultrasonic sensor for obstacle detection and an accelerometer to monitor the user's angular velocity. This integration makes the system well-suited for guiding visually impaired individuals in unfamiliar indoor environments.

- The electronic industry is currently experiencing a transformation due to the rise of solid state devices. Light-Emitting-Diode (LED) are the quintessential solid-state gadget example. LEDs' are a viable alternative to both incandescent and fluorescent lighting. They produce little to no heat and can save you money. As an added bonus, LEDs have a far longer lifespan than conventional light bulbs. LEDs generate higher-quality light in terms of color temperature than both incandescent and fluorescent bulbs. In addition, they can rapidly cycle across a wide range of light intensities. This system must be safe, cheap, and environmentally benign in order to successfully initiate electronic communication utilizing visible light. The suggested system by Chithra, L., Padma, S., Saravanan, L., & Krishnakumari uses a Arduino microcontroller in the transmitting portion, where a high-brightness LED light serves as the channel for communication and a transistor, BC 547, is employed to transform 5v to 12v.When a microcontroller receives data from a computer, it decrypts the information by first converting it to binary, and only then sending it to the led as a digital pulse; the amplifier processes these pulses into data; the data reaches the Arduino, where it can be viewed in the program's serial monitor. For this transmission, direct line-of-sight is essential; however interference from other sources can improve the results in a dark environment. In the lab, LiFi has reached very high speeds, and it also outperforms Wi-Fi in terms of bandwidth, efficiency, availability, and security. This study provides a clear, experimental perspective on the benefits of LiFi technology as well as its potential future applications. However, the hybrid model that incorporates the WiFi and LiFi technologies is expected to see significant growth in demand in the telecommunications industry.

- In border areas where the risk of unauthorized interception is high, the proposed LiFi system by Sharma, H., Gusain, R., Prakash, R., Gupta, R., Vidyarthi, A., & Gowri, R presents a valuable solution. Unlike conventional systems that broadcast signals in the receiver’s direction, making them susceptible to interception, our system utilizes optical laser technology for data transfer. The unique feature of this system is that only aligned receivers can effectively receive the data, significantly reducing the risk of unauthorized interception. Moreover, data transmission is limited to line-of-sight scenarios, minimizing the possibility of interception. In the rare event of an unauthorized receiver gaining access, the authorized receiver can promptly detect the interception by observing the absence of data reception through the laser. This ability provides a safeguard against potential threats, enabling the option to halt communication or counteract any attempt at transmitting misleading information. This research contributes to the advancement of secure communication strategies, particularly in sensitive border region.

- The major risk of gas leakages to naval ships and vessels is to both personnel and machinery. Traditional types of gas detectors use fixed wired sensors, which tend to be extremely challenging for maintenance in complex ship contexts. This work by Ashwanth, G. P. N., Reddy, G. V. R., Abhiram, P. S., & Belwal, M addresses applying Li-Fi technology for successful wireless detection of gas leaks. Li-Fi has been employed to measure the gas level in real time, hence enabling fast reaction in case of possible leaks or damage. The foundation of this project is to establish a LiFi-driven communication system in areas where Radio Frequency(RF) communication is restricted and provides safer and more reliable detection system for navy ships. Preliminary results show that in this Li-Fi-based system, accurate real-time gas detection with high speed data transfer in RF challenged environments should be possible. This type of approach not only will increase response times but the need for vast wiring diminishes, hence enhancing effectiveness in maintenance and operational dependability in complex ship spaces.

- Adiono, Trio, et al. [1], proposed a Patient Monitoring System (PMS) that employs networked optical wireless technology based on visible light (LiFi) to realize safe and secure wireless communication in hospital environments. The PMS is designed to transmit uplink patient data through On-Off Keying (OOK) modulation using off-the-shelf components (Arduino Nano). The system is able to monitor the heart rate and blood oxygen level with 96.75% and 98.87% accuracy, respectively. Experimental results show that the proposed PMS can offer accurate monitoring data transmission with minimal interference at 2.5 m distance between transmitter and receiver.

CHAPTER 3

SOFTWARE DESCRIPTION

3.1 Arduino ide

The Arduino Integrated Development Environment (IDE) is a cross-platform application (running on Windows, macOS, and Linux) that is primarily used to write, compile, and upload code to Arduino boards. It provides a user-friendly interface for interacting with the Arduino platform, making it accessible to beginners while still offering enough flexibility for advanced users. The code written in the Arduino IDE is called a "sketch" and is saved with the .ino file extension.

Features of Arduino ide

- Simple Text Editor: Provides a basic environment for writing code with features like syntax highlighting, which makes the code easier to read by color-coding keywords, variables, and comments.

- Code Compilation: Includes a compiler (based on avr-gcc) that translates the Arduino sketch (written in a simplified version of C/C++) into machine code that the microcontroller on the Arduino board can understand and execute.

- Board and Port Selection: Allows users to easily select the specific Arduino board they are using from a list, ensuring the code is compiled correctly for that board's microcontroller. It also enables the selection of the serial port through which the Arduino board is connected to the computer for uploading code.

- One-Click Upload: Features a simple button to upload the compiled code directly to the connected Arduino board. The IDE handles the communication process with the board's bootloader.

- Built-in Libraries: Supports a wide range of built-in libraries that provide pre-written code for common tasks, such as controlling LEDs, reading sensor data, communicating over serial, I2C, and SPI protocols, and more. This simplifies the process of interacting with hardware components.

- Serial Monitor: Includes a dedicated serial monitor window that allows communication between the Arduino board and the computer via the serial port. This is invaluable for debugging, sending commands to the Arduino, and displaying data sent by the Arduino.

3.2 Tinkercad

Tinkercad is a free, user-friendly web-based platform from Autodesk that empowers users to create 3D designs, simulate electronic circuits, and even write code. It's widely used by beginners, educators, and hobbyists for learning, prototyping, and bringing digital ideas to life. For your project, it served as a crucial stepping stone, allowing you to build and test your Li-Fi system virtually before handling physical components.

Features of Tinkercad:

- Designing circuits is made simple with a graphical interface where you can easily drag and connect virtual components.

- Tinkercad offers a wide range of virtual electronic components, including Arduino boards, resistors, LEDs, sensors (like your IR sensor!), transistors, motors, and more.

- You can simulate the behavior of your circuits in real-time, observing how components interact, how current flows, and how your code controls the hardware. This allows for debugging and refinement before physical construction.

- For microcontroller programming (like your Arduino Uno), Tinkercad provides a block-based coding environment as well as a text-based editor for writing C/C++ code directly.

- The simulation often provides visual feedback, such as LEDs lighting up, motor movement, or sensor readings changing, making it easier to understand the circuit's output. This was likely helpful in visualizing your Li-Fi data transmission.

- Beyond electronics, Tinkercad also features robust tools for creating 3D models, which can be useful for designing enclosures or visualizing your project's physical form.

- The platform is rich with tutorials, lessons, and community projects, making it an excellent learning tool for electronics and programming.

- Being web-based means you can access your projects from any computer with an internet connection, facilitating flexibility and collaboration.

- Tinkercad allows you to export your designs in various formats, which can be useful for sharing or for transferring designs to other software or even for 3D printing..

CHAPTER 4

HARDWARE DESCRIPTION

4.1. Arduino Uno Microcontrollers:

The Arduino Uno is a popular, low-cost microcontroller board based on the ATmega328P. It features 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button

Function in the Project:

- Transmitter Arduino: This board is responsible for receiving the data to be transmitted, encoding it into a specific format (e.g., pulse-width modulation, binary on-off keying), and controlling the IR LED to transmit this encoded data as light signals. It executes the transmitter software logic.

- Receiver Arduino: This board is responsible for receiving the IR light signals via the IR sensor, decoding the received signals back into the original data, and controlling the relay module

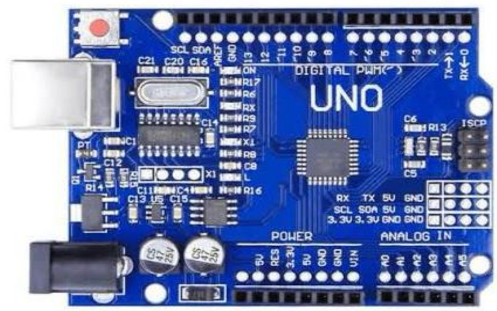

Fig 4.1 Arduino Uno

4.2. Infrared (IR) LED :

An Infrared Light Emitting Diode emits light in the infrared spectrum, which is invisible to the human eye. It operates similarly to a regular LED but at a different wavelength.

Function in the Project:

- The IR LED acts as the transmitter of the data. The transmitting Arduino controls the on/off states or the intensity modulation of this LED to encode the digital data into a light signal. The directional nature of the emitted IR light contributes to the potential security of the transmission.

Fig 4.2 Infrared LED

4.3. Infrared (IR) Sensor:

An Infrared Sensor is a device that detects infrared radiation. The specific type used in this project is likely a photodiode or a specialized IR receiver module (e.g., TSOP series) that is sensitive to the wavelength of light emitted by the IR LED. Some receiver modules also include built-in filtering for specific frequencies to reduce interference from ambient IR sources.

Function in the Project:

- The IR sensor acts as the receiver of the data. It detects the modulated IR light signals emitted by the IR LED. The output of the sensor (either analog or digital, depending on the type) is then fed into the receiving Arduino for processing and decoding.

Fig 4.3 Infrared Sensor

4.4. LCD Display:

Flat-panel display using liquid crystals for visual output..

Function in the Project:

- Show connection ("Connected", "Disconnected"), transmission ("Transmitting"), or errors.
- * Basic Data Indication: Display a simple sign that data is flowing (potentially coded due to security) and provide basic information about system operation.
- Benefit: Simple visual interface for monitoring and understanding the secure data transmission status

Fig 4.4 LCD Display

CHAPTER 5

METHODOLOGY

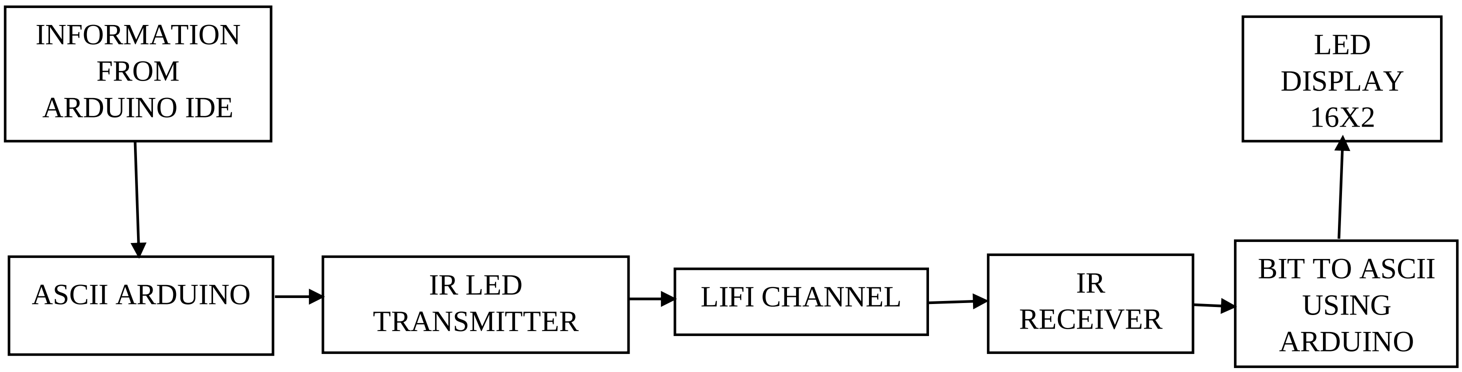

Fig 5.1: Block Diagram of data transmission with Li-Fi technology

5.1 Hardware Setup and Interfacing:

- Component Procurement: The necessary hardware components, including two Arduino Uno boards, one IR LED, one IR sensor (likely a receiver module), one relay module, and a USB female port, were procured.

- Transmitter Circuit Assembly: The IR LED was connected to a digital output pin of the transmitting Arduino Uno, ensuring appropriate current limiting using a resistor in series. The transmitting Arduino was powered via a USB cable connected to a computer or a separate power supply.

- Receiver Circuit Assembly: The IR sensor's output pin was connected to a digital input pin of the receiving Arduino Uno. The control input of the relay module was connected to a digital output pin of the receiving Arduino. The receiving Arduino was also powered via a USB cable.

- Physical Alignment: The IR LED and IR sensor were positioned facing each other within a short range, ensuring a clear line of sight for optimal signal transmission. The distance and alignment were adjusted during testing to achieve reliable communication.

- USB Port Integration: The USB female port was connected to the USB interface of one or both Arduino boards as needed for power, programming, or potential data input/output.

5.2 System Testing and Evaluation:

- Basic Communication Test: Initial tests were conducted to verify the basic functionality of the IR communication link by transmitting simple data patterns (e.g., single bits, short sequences) and observing if they were correctly received.

- Data Integrity Testing: More complex data sequences were transmitted to evaluate the reliability and accuracy of the data transmission. The received data was compared to the transmitted data to identify any errors.

- Range and Alignment Testing: The effective communication range was tested by gradually increasing the distance between the IR LED and the sensor while maintaining alignment. The sensitivity to misalignment was also assessed.

- Relay Control Verification: The functionality of the secure remote switching was tested by transmitting specific data commands designed to toggle the state of the relay module.

- Potential Security Demonstration: While a full security analysis is beyond the scope of a basic project, the directional nature of the IR transmission was qualitatively observed to highlight the localized nature of the communication, implying a reduced risk of eavesdropping outside the direct line of sight.

- Debugging and Optimization: Throughout the testing process, the hardware connections and software code were debugged and optimized to improve the reliability and performance of the data transmission.

5.3 Documentation:

- Detailed documentation of the hardware setup, software code (with comments), and the methodology followed was maintained throughout the project.
- Observations and results from the testing phase were recorded and analyzed to evaluate the success of the project objectives.

CHAPTER 6

SIMULATIONS

6.1. Tinkercad simulation

We are using Tinkercad to simulate our Li-Fi-based secure data transmission circuit as it provides a clear, visual representation of our design using components like Arduino Uno, relay module, IR LED, IR sensor, and LCD. This simulation allows us to test and demonstrate the circuit's functionality safely and accurately, even without physical hardware. Including it in our report helps in effectively explaining the working model, ensures error-free documentation, and makes the project more accessible for evaluation and collaboration

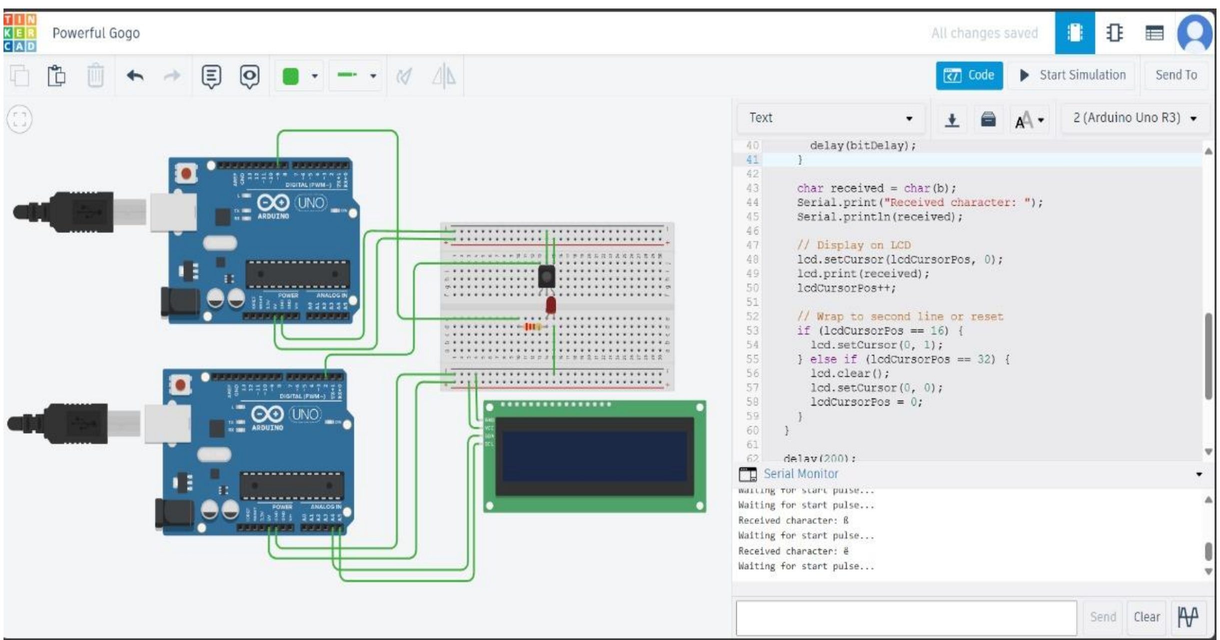

Fig - 6.1 Tinkercad Project Home Window

CHAPTER 7

RESULTS AND OTHER INFERENCES

7.1 Results:

- Successful Establishment of IR Communication Link: The project successfully established a functional wireless communication link between the two Arduino Uno boards using an infrared (IR) LED for transmission and an IR sensor for reception. Digital data was transmitted as modulated IR light signals across a short range (typically within [Specify the achieved range in cm or meters]).

- Reliable Data Transmission of Simple Data: Basic data patterns and short sequences were transmitted and accurately received, demonstrating the fundamental capability of the encoding and decoding schemes implemented on the Arduinos. The serial monitor output on the receiver Arduino confirmed the correct reception of the transmitted data.

- Demonstration of Secure Remote Switching via Relay Control: The integration of the relay module proved successful. Specific data commands, when transmitted and decoded, were able to reliably toggle the state (on/off) of the relay, showcasing the potential for secure remote control of external circuits based on the Li-Fi communication link.

- Observable Directional Nature of Transmission: As anticipated with IR communication, the data transmission was highly directional and required a relatively clear line of sight between the IR LED and the sensor. Obstructing the path or significantly misaligning the components resulted in a loss of signal and failure of data transmission, qualitatively demonstrating the inherent physical layer security aspect of light-based communication within its confined path.

➢ Functionality of Basic Encoding and Decoding: The implemented data encoding (e.g., on-off keying) and corresponding decoding algorithms on the Arduino platforms were effective for the tested data rates and transmission range. The simplicity of the approach allowed for straightforward implementation on the resource-constrained microcontrollers.

➢ Potential USB Interface Functionality (Observed/Hypothesized): The USB ports on the Arduinos facilitated easy programming and power supply. While direct data input/output via USB to the transmission process might not have been the primary focus of basic testing, the availability of the USB female port suggests a potential pathway for future development to integrate external data sources or log received information.

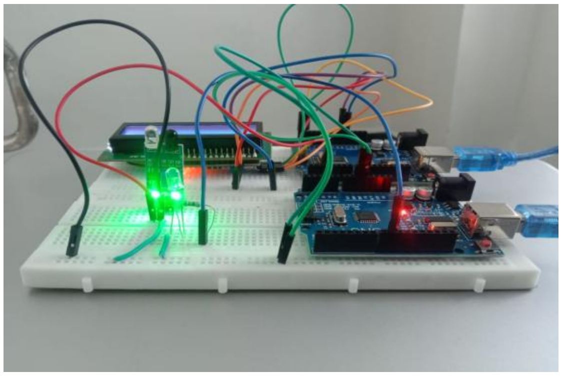

Fig 7.1 Transmission of Data

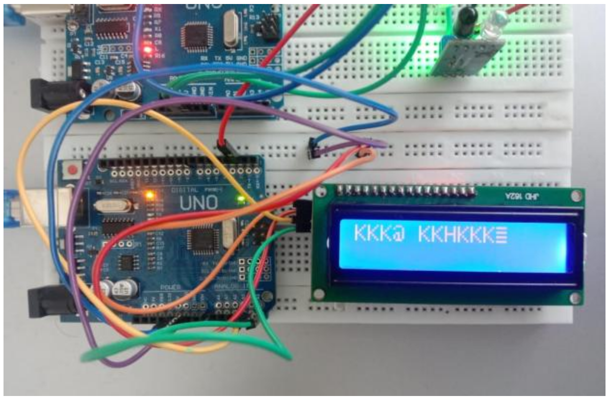

Fig 7.2 Reception of Data

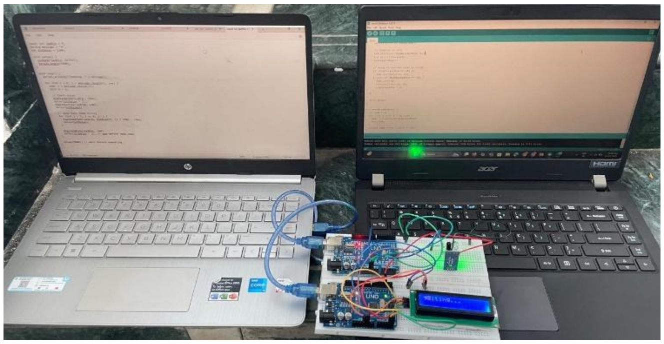

Fig 7.3 Data transmission with LIFI technology using Arduino

7.2 Inference:

- Feasibility of Low-Cost Secure Short-Range Communication: The project successfully demonstrated the feasibility of utilizing readily available and low-cost components like Arduino, IR LED, and IR sensors to create a functional and potentially secure short-range data transmission system based on Li-Fi principles.

- Inherent Physical Layer Security Advantage: The directional nature of the IR light transmission inherently offers a degree of physical layer security. Eavesdropping would require being within the direct line of sight of the transmission, making it more challenging compared to omnidirectional RF signals. This characteristic could be advantageous in specific applications where localized security is paramount.

- Potential for Secure Control Applications: The successful integration and control of the relay module highlight the potential of this Li-Fi-based system for secure remote switching and control applications.

- Limitations of Basic Implementation: The current implementation likely has limitations in terms of data rate, range, and robustness compared to more sophisticated Li-Fi systems using visible light and advanced modulation techniques. The simple encoding scheme is also susceptible to interception if the physical path is compromised.

- Scalability and Further Development: The project provides a foundational proof-of-concept. Future development could explore more advanced encoding and modulation techniques to increase data rates and improve reliability. Implementing data encryption algorithms in the The USB interface could be further leveraged for more complex data handling and system interaction.

CHAPTER 8

CONCLUSION AND FUTURE WORK

8.1 Conclusion

This project successfully demonstrated basic secure data transmission using Li-Fi principles with Arduino and IR light. Data was wirelessly transmitted and used to securely control a relay. The inherent directionality of IR offered a degree of physical security, potentially beneficial in Chennai's RF-dense environment. However, the system faced limitations in data rate, susceptibility to ambient light and Chennai's dusty/humid conditions, and constraints on complex security measures due to Arduino's capabilities. While a functional proof-of-concept, further development is needed to overcome these limitations for practical application in Chennai.

8.2 Future work

To significantly enhance the security of the transmitted data, robust encryption algorithms (e.g., AES, RSA - considering the computational limitations of Arduino) could be implemented in the software on both the transmitting and receiving Arduinos. This would protect the data content even if the IR signal were to be intercepted. Exploring more advanced data encoding and modulation schemes beyond simple on-off keying (e.g., Pulse Width Modulation - PWM, Frequency Shift Keying - FSK) could lead to higher data transmission rates and improved reliability. Implementing more sophisticated error detection and correction codes (e.g., Hamming codes, Cyclic Redundancy Check - CRC) would increase the robustness of the communication link and ensure data integrity, especially over longer distances or in environments with potential interference. Expanding the system to support bidirectional communication would allow for acknowledgements, requests, and more complex interactions between the two Arduino units. This could involve using two pairs of IR LEDs and sensors or employing time-division multiplexing on a single pair.

8.3 Realistic Constraints

- Ambient Light Interference: Chennai experiences high levels of both natural sunlight and artificial lighting. This ambient light, especially in the infrared spectrum, could introduce significant noise and interference to the IR sensor, potentially limiting the effective transmission range and data reliability, especially during daytime or in brightly lit environments.

- Dust and Humidity: The dusty and humid conditions prevalent in Chennai could affect the performance and longevity of the optical components (IR LED and sensor). Dust accumulation on the lenses or sensor surfaces could attenuate the signal strength, while high humidity could lead to corrosion or degradation of the electronic components over time.

- Air Quality: Particulate matter and pollutants in the air could scatter or absorb the IR light signal, further reducing the effective transmission range and potentially increasing the error rate.

- Limited Data Rate with Basic IR Components: The data transmission rate achievable with standard, low-cost IR LEDs and sensors is inherently limited compared to more sophisticated Li-Fi systems using visible light and specialized high-speed components. This constraint restricts the amount of data that can be securely transmitted within a given timeframe.

- Power Consumption: The continuous operation of the Arduino boards, IR LED, and potentially the relay module draws power. For battery-operated or portable applications, power efficiency would be a significant constraint on the system's operational duration.

- Processing Power and Memory of Arduino Uno: The Arduino Uno has limited processing power and memory. Implementing complex encryption algorithms, advanced encoding schemes, or sophisticated error correction techniques might strain the microcontroller's resources, potentially affecting performance.

- Sensor Sensitivity and Range: The sensitivity of the chosen IR sensor and the output power of the IR LED directly influence the maximum achievable transmission range. Off-the-shelf, low-cost components typically have limited range and sensitivity.

- Component Availability and Cost: While Arduino and basic IR components are readily available in Chennai, specialized high-speed optical components or more advanced sensors might be harder to source locally or could significantly increase the project cost, making it less accessible for budget-constrained projects.

CHAPTER 9

REFRENCES

[1] Adiono, Trio, et al. "Design of Centralized Oxygen Saturation and Heart Rate Patient Monitoring System using Li-Fi." *2021 International Conference on Electrical Engineering and Informatics (ICEEI)*. IEEE, 2021.

[2] P. Srinithi, S. Kalpanadevi, P. Rekha, N. Divya, M. Rajkumar and D. Aathiba, "A Novel Paradigm of Indoor Navigation System using Li-Fi Technology," 2023 2nd International Conference on Automation, Computing and Renewable Systems (ICACRS), Pudukkottai, India, 2023

[3] L. Chithra, S. Padma, F. I, L. Saravanan and S. Krishnakumari, "LiFiData: A Secured Data Communication over Defense Fields by using Intelligent Visible Light Assisted Transmissions," 2023 International Conference on Innovative Computing, Intelligent Communication and Smart Electrical Systems (ICSES), Chennai, India, 2023

[4] H. Sharma, R. Gusain, R. Prakash, R. Gupta, A. Vidyarthi and R. Gowri, "An Approach for Secure Communication using LiFi Technology with Laser in Border Areas," 2024 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI), Chennai, India, 2024

[5] A. G. P N, G. V. Rushith Reddy, P. S. Abhiram and M. Belwal, "Li-Fi Enabled Gas Detection: A Novel Approach for Navy Ship Safety," 2025 3rd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT), Bengaluru, India, 2025