Project Report on

Light-Based Secure FileTransfer System Using LED Communication

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CERTIFICATE

This is to certify that the project report entitled“ Light-Based Secure File Transfer System Using LED Communication”, submitted by Tiyarsna Solanki & Samyak Gandhi, has been carried out under the supervision of , Assistant Professor, and is hereby approved for the partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering in the Department of Computer Science and Engineering, School of Technology, Pandit Deendayal Energy University, Gandhinagar.

This report is an original piece of work and has not been submitted elsewhere for the award of any other degree or diploma.

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This project has been a significant learning experience, deepening my understanding of embedded systems, light communication, and secure data transfer mechanisms.

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Abstract

This project, titled "Light-Based Secure File Transfer System Using LED Communication", focuses on implementing a low-cost, short-range optical communication system for transferring digital information securely using visible light.

The system utilizes two Arduino boards — one functioning as a transmitter and the other as a receiver. The transmitter converts text data or file content into binary format and sends it via LED light pulses. The receiver, equipped with a Light Dependent Resistor (LDR), detects changes in light intensity, converts them back into binary, and reconstructs the transmitted data.

Security is ensured through controlled transmission timing and physical alignment, which limits unauthorized interception. This setup serves as a basic model of Li-Fi (Light Fidelity), where communication occurs through light rather than radio waves.

The project demonstrates reliable data transfer between two systems over visible light in a short distance (10–20 cm), proving the potential of optical communication as a secure, interference-free, and energy-efficient alternative for specific applications.

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Chapter 1

Introduction

In today's digital era, secure data transfer is one of the most critical aspects of computer communication. Traditional wireless systems, such as Wi-Fi and Bluetooth, rely on radio frequency (RF) signals, which can easily be intercepted, jammed, or hacked. To address these vulnerabilities, optical wireless communication (OWC) has emerged as a reliable and secure alternative. This project, titled "Light-Based Secure File Transfer System Using LED Communication", demonstrates a prototype system that transfers digital information securely using visible light as the transmission medium. The system employs a Light Emitting Diode (LED) as the transmitter and a Light Dependent Resistor (LDR) as the receiver.

At the transmitter side, the digital file or textual content is first read by a microcontroller, such as an Arduino or Raspberry Pi, and converted into binary form. Each character or byte of the data is represented as a sequence of 0s and 1s. These binary values are then encoded into light pulses using the LED, typically through On-Off Keying (OOK), where a binary `1` is represented by the LED turning ON and a binary `0` by the LED turning OFF. The LED emits these pulses into the air in a line-of-sight path towards the receiver, creating an optical transmission channel that is inherently secure since only a receiver physically aligned with the LED can detect the signal.

On the receiver side, the LDR senses the variations in light intensity caused by the LED pulses. The LDR's resistance changes with light exposure, which is converted into corresponding voltage signals using a simple voltage divider circuit. A microcontroller reads these voltage changes, reconstructs the binary sequence, and then converts it back into the original file or text. This process ensures that the transmitted data is accurately recovered while maintaining confidentiality. Since the communication is air-gapped and dependent on physical alignment, it is highly secure and resistant to interception or jamming.

The system offers several advantages, including low cost, simplicity, and immunity to RF interference. It is particularly suitable for secure communication in sensitive environments, such as military or research facilities, where air-gapped, line-of-sight data transfer is required. However, it has some limitations, such as the need for precise alignment, short-range operation, and unidirectional communication. Despite these constraints, the project effectively demonstrates a secure and practical implementation of optical wireless communication using basic components like LEDs, LDRs, and microcontrollers, highlighting an innovative approach to data security in the modern digital landscape.

Chapter 2 Literature Survey

In recent years, researchers have explored the potential of visible light communication (VLC) as an alternative medium for wireless data transmission. The idea revolves around using visible light, typically emitted by light-emitting diodes (LEDs), to transmit information instead of relying on traditional radio frequency (RF) communication systems such as Wi-Fi or Bluetooth. One of the most significant contributions to this field was made by Professor Harald Haas in 2011, who introduced the concept of Li-Fi (Light Fidelity). In his demonstration titled "Wireless Data from Every Light Bulb," Haas showed that ordinary LED light bulbs could be modulated at high speeds to transmit data, thereby transforming lighting systems into wireless data transmitters. This pioneering work laid the foundation for further studies in optical wireless communication and inspired the development of various VLC-based data transfer systems.

VLC offers several advantages over conventional RF communication methods. Since visible light cannot pass through opaque surfaces like walls, it naturally ensures secure communication by confining data transmission within a physical space, preventing external interception. Moreover, the visible light spectrum provides a bandwidth several thousand times greater than that of radio waves, allowing for potentially higher data transfer rates and reduced interference. Another notable benefit is its cost-effectiveness, as VLC utilizes widely available and inexpensive components such as LEDs and light sensors. Additionally, VLC systems are immune to electromagnetic interference, making them ideal for use in environments where RF communication is restricted, such as hospitals, airplanes, and industrial facilities.

Previous research, including Haas (2011) and the IEEE 802.15.7 standards, has contributed significantly to defining the architecture, protocols, and modulation techniques for VLC systems. Several academic studies have also demonstrated the feasibility of short-range VLC prototypes using microcontrollers like Arduino, in which LEDs serve as transmitters and light-dependent resistors (LDRs) or photodiodes act as receivers. These experiments have successfully transmitted simple text or binary data, proving that secure communication through visible light is achievable with minimal hardware. Building on these concepts, this project aims to design a practical and low-cost prototype capable of transferring files and text using visible light. By integrating encoding and decoding techniques with affordable electronic components, the project demonstrates an efficient, secure, and innovative approach to short-range data transmission using visible light.

Chapter 3
Methodology

3.1 Motivation and Problem Statement

Motivation: Wireless data leakage and interception are persistent risks in many applications. Radio-frequency channels can be intercepted remotely and are affected by electromagnetic interference. Visible light communication (VLC) offers a complementary approach: light cannot pass through opaque walls, so transmissions are physically constrained to the lit area. This physical containment makes VLC attractive for scenarios that need strong physical-layer security (for example, military or forensic workflows, air-gapped systems where no RF is allowed, and environments where EMI must be avoided). In addition, low-cost LEDs and sensors make VLC an accessible option for prototype systems and proof-of-concept demonstrations.

Problem statement: Design and implement a working prototype that securely transfers digital data (text/files) between two devices using visible light only. The system must avoid RF transmission, preserve data integrity during transfer, and demonstrate the physical security benefits of optical confinement.

3.2 System Architecture

Overview: The system is a unidirectional (one-way) optical link made from inexpensive components: an Arduino-based transmitter that modulates an LED and an Arduino-based receiver that senses light changes with an LDR.

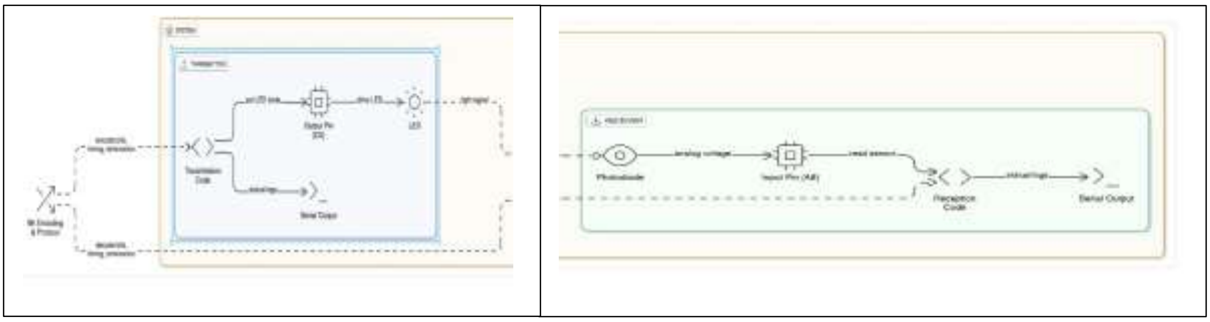

Fig 1. Transmitter Circuit → Receiver Circuit

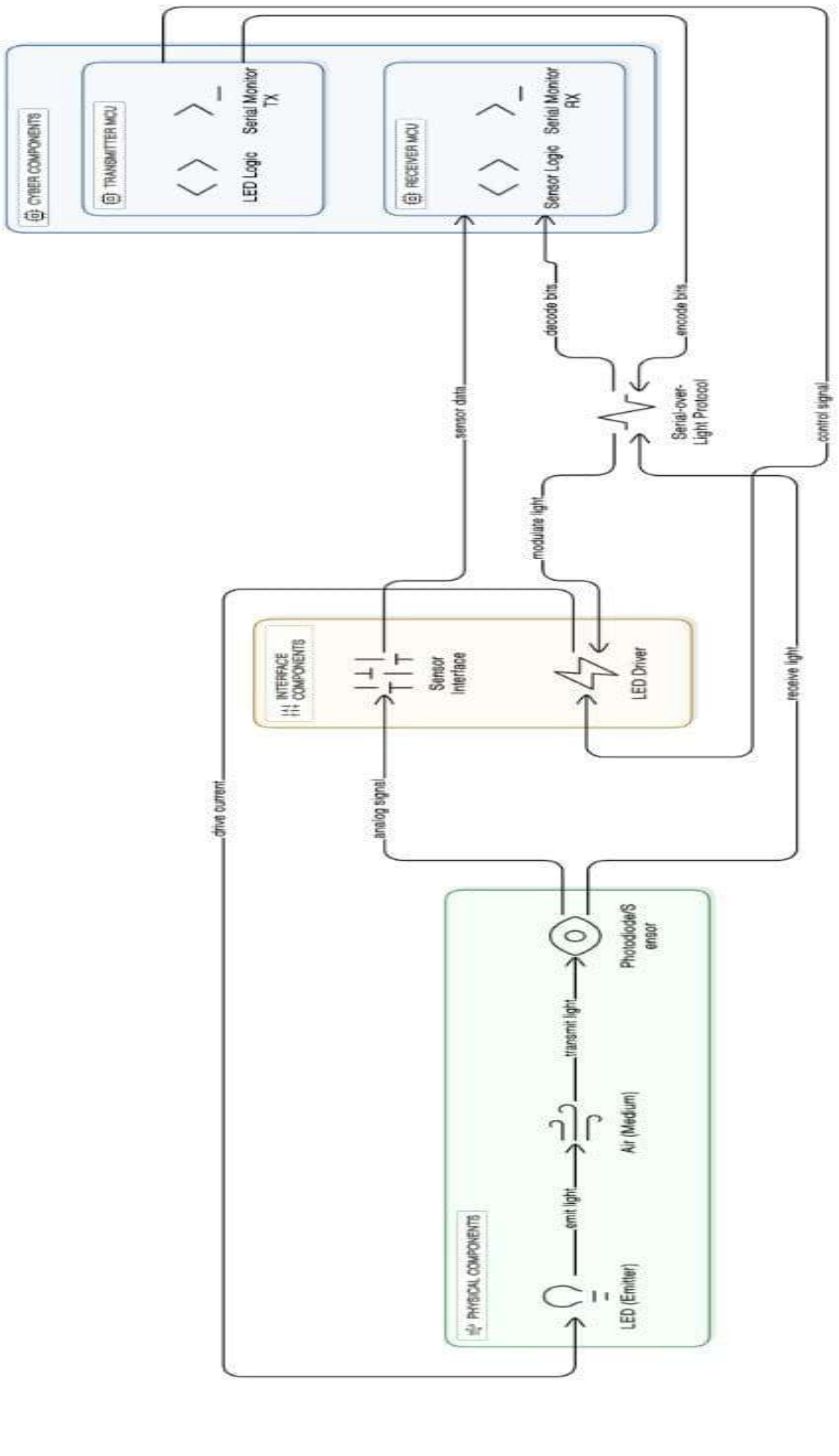

Fig 2.System Architecture of the Light- Based File Transfer System

3.3 Algorithms / Pseudocode

Transmitter Algorithm

1. Initialize LED pin and Serial communication.
2. Convert file/text data into binary ASCII.
3. For each bit:
   - If bit = 1 → LED ON.
   - If bit = 0 → LED OFF.
   - Maintain state for a fixed duration (`BIT_DURATION`).
4. Insert a termination pattern after transmission.
5. Turn LED OFF and stop execution.

Receiver Algorithm

1. Initialize LDR input and Serial communication.
2. Continuously read analog input from LDR.
3. If light intensity > threshold → interpret as bit ‘1’, else bit ‘0’.
4. Combine 8 bits → one character.
5. Append to output string or file buffer.
6. Stop on detecting termination pattern.

3.4 UML Diagrams

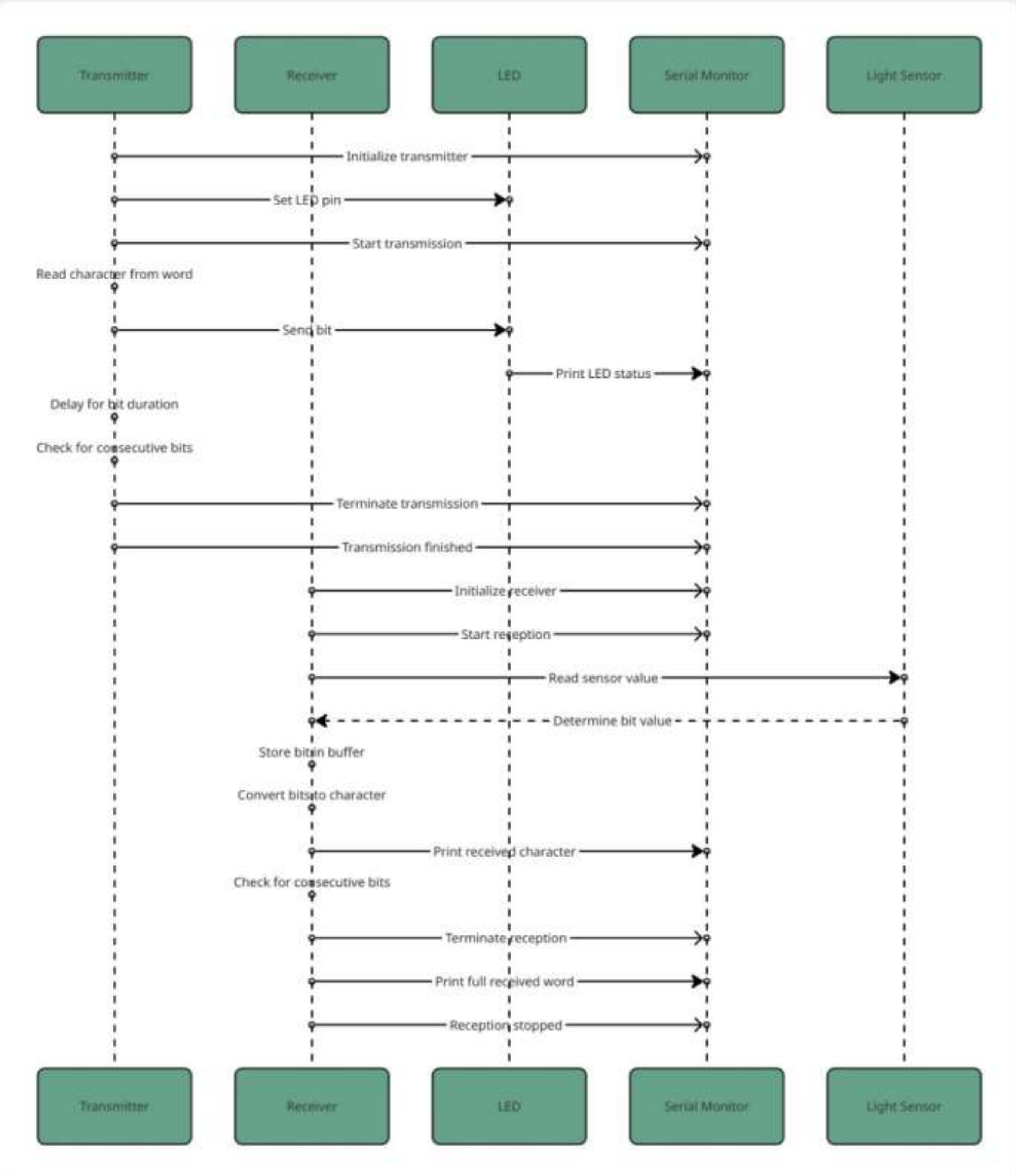

Fig 3. UML diagram

3.5 Devices Used

Table 1: Components and Specifications

Sr. No.	Component Name	Specification / Description	Quantity	Purpose
1	Arduino Uno (ATmega328P)	16 MHz clock, 14 digital I/O pins, 6 analogy inputs	2	Acts as main microcontroller for both transmitter and receiver
2	LED (Light Emitting Diode)	5mm, White, Forward Voltage 2V, 20mA current	1	Transmitter light source for data transmission
3	LDR (Light Dependent Resistor)	Resistance range: 10kΩ (bright) – 1MΩ (dark)	1	Detects incoming light intensity for data reception
4	Resistor	Carbon film resistor, ¼ Watt	1	Limits current flow through LED
5	Resistor	Carbon film resistor, ¼ Watt	1	Forms voltage divider with LDR for stable analogy readings
6	Breadboard	400 tie-points	2	Used for circuit assembly without soldering
7	Jumper Wires (Male–Male)	20 cm, flexible	As required	For making connections between components
8	USB Cable (Type A to B)	Standard Arduino compatible	2	Connects Arduino boards to laptop for power and data
9	Laptop / PC	Minimum Intel i3, Arduino IDE 2.0+ installed	2	Used for code upload and serial monitoring
10	Power Source	5V via USB or external adapter	1	Supplies power to Arduino and circuit components

3.6 Connections

Table 2: Transmitter Pin Configuration

Sr. No.	Arduino Pin	Connected Component	Connection Description	Signal Type
1	D2 (Digital Pin 2)	LED (Anode / Long Leg)	Sends ON/OFF signal for binary transmission	Digital Output
2	GND	LED (Cathode / Short Leg) via 220Ω Resistor	Provides ground connection for LED circuit	Ground
3	USB Port	Laptop / PC	Used for uploading program and serial monitoring	Power + Serial Communication
4	5V (Optional)	Breadboard Power Rail	Provides power supply if external circuit extension is needed	Power Output (5V)

Table 3: Receiver Pin Configuration

Sr. No.	Arduino Pin	Connected Component	Connection Description	Signal Type
1	A0 (Analog Pin 0)	LDR (via voltage divider with 10kΩ resistor)	Reads changing light intensity from the transmitter LED	Analog Input
2	5V	LDR (one terminal)	Provides a constant 5V supply to LDR circuit	Power Output (5V)
3	GND	10kΩ Resistor (one terminal)	Completes the voltage divider circuit with LDR	Ground
4	USB Port	Laptop / PC	Used for code upload and serial monitoring	Power + Serial Communication

3.7 Circuit Design

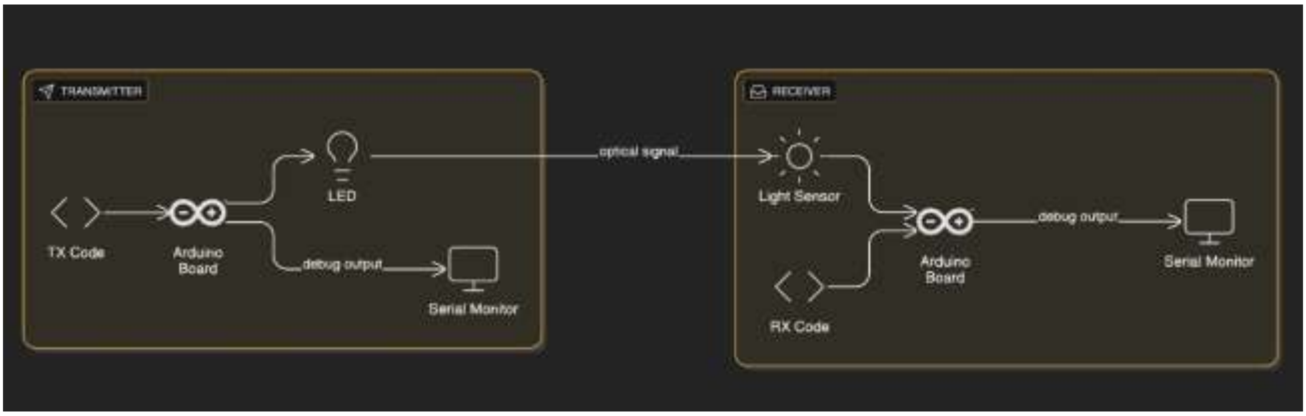

Fig 4. Setup for Communication

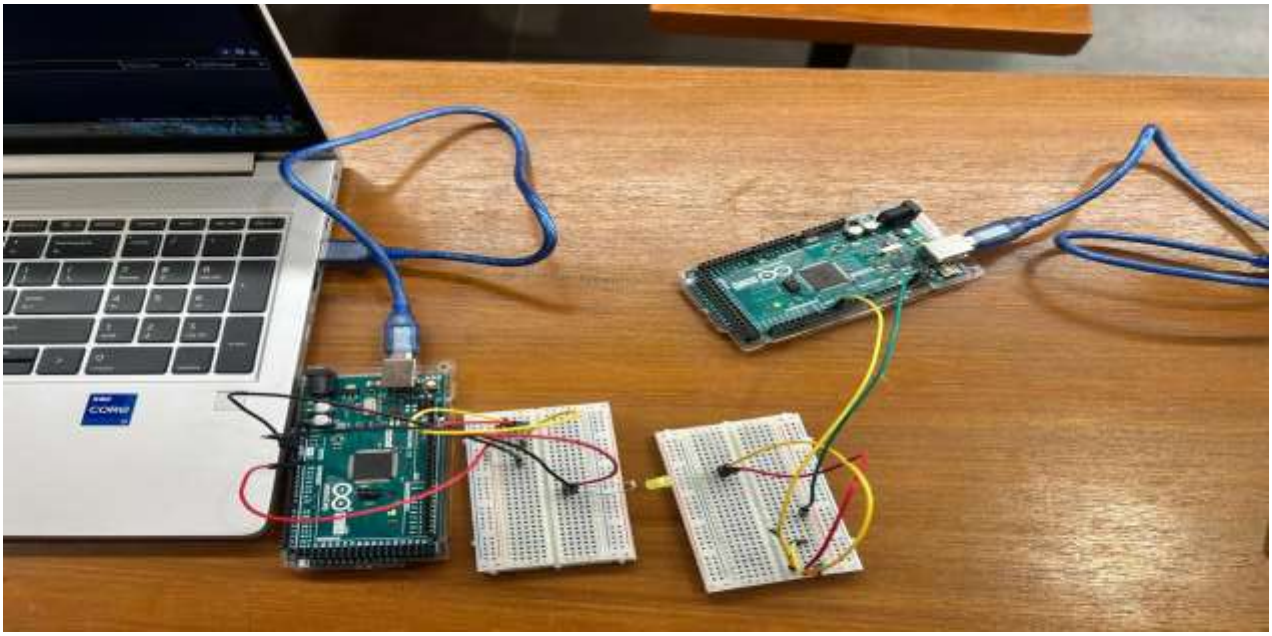

Fig 5. Arduino Hardware Setup for Communication

3.8 Extra Modules & Software Installation

Software Requirements:

- **Arduino IDE** for coding and uploading sketches.
- **Serial Monitor** for transmission logs.
- **(Optional)** File reconstruction script on PC for decoding binary into files.

Installation Steps:

1. Install Arduino IDE (latest version).
2. Connect both Arduinos to separate USB ports.
3. Upload transmitter and receiver codes respectively.
4. Align LED and LDR (5–10 cm apart).
5. Open Serial Monitors to observe data transfer.

3.9 Code

Transmitter Code

```
#define LED_PIN 2
#define BIT_DURATION 400

String wordToSend = "My name is Sam";

void setup() {
  pinMode(LED_PIN, OUTPUT);
  Serial.begin(9600);
  Serial.println("Transmitter ready...");
}

void sendBit(int bitValue) {
  if (bitValue == 1) {
    digitalWrite(LED_PIN, HIGH);
    Serial.print("LED ON -> bit 1\n");
  } else {
    digitalWrite(LED_PIN, LOW);
    Serial.print("LED OFF -> bit 0\n");
  }
}

void loop() {
  Serial.println("Starting transmission...");

  for (int i = 0; i < wordToSend.length(); i++) {
```

```
    byte data = wordToSend[i];
    int sameBitCounter = 0;
    for (int bitPos = 7; bitPos >= 0; bitPos--) {
      int bitValue = bitRead(data, bitPos);
      sendBit(bitValue);

      if (bitPos < 7) {
        static int lastBit = -1;
        if (lastBit == bitValue) {
          sameBitCounter++;
        } else {
          sameBitCounter = 0;
        }
        lastBit = bitValue;

        if (sameBitCounter * BIT_DURATION >= 10000) {
          Serial.println("More than 10 sec same bit,
terminating...");
          digitalWrite(LED_PIN, LOW);
          while (1);
        }
      } else {
        static int lastBit = -1;
        lastBit = bitValue;
      }

      delay(BIT_DURATION);
    }
  }

  digitalWrite(LED_PIN, LOW);
  Serial.println("Transmission finished.");
  while (1);
}
```

receiver code

```
#define SENSOR_PIN A0
#define BIT_DURATION 400
#define THRESHOLD 110
```

```
void setup() {
  Serial.begin(9600);
  Serial.println("Receiver ready...");
}

int readBit() {
  int sensorValue = analogRead(SENSOR_PIN);
  int bit = (sensorValue > THRESHOLD) ? 1 : 0;
  Serial.print("Sensor: ");
  Serial.print(sensorValue);
  Serial.print(" -> bit ");
  Serial.println(bit);
  return bit;
}

char bitsToChar(int bits[8]) {
  byte data = 0;
  for (int i = 0; i < 8; i++) {
    bitWrite(data, 7 - i, bits[i]);
  }
  return char(data);
}

void loop() {
  delay(300);
  Serial.println("\nStarting reception...");

  int consecutiveSameBit = 0;
  int lastBit = -1;

  int bitBuffer[8];
  int bitCount = 0;
  String receivedWord = "";

  while (true) {
    int bit = readBit();

    if (bit == lastBit) {
      consecutiveSameBit++;
    } else {
      consecutiveSameBit = 1;
```

```
      lastBit = bit;
    }

    bitBuffer[bitCount] = bit;
    bitCount++;

    if (bitCount == 8) {
      char c = bitsToChar(bitBuffer);
      receivedWord += c;
      Serial.print("Received character: ");
      Serial.println(c);
      bitCount = 0;
    }

    if (consecutiveSameBit >= 7) {
      Serial.println("\nDetected 10 consecutive same bits,
stopping reception...");
      Serial.print("Full received word: ");
      Serial.println(receivedWord);
      break;
    }

    delay(BIT_DURATION);
  }

  Serial.println("Reception stopped.");
  while (1);
}
```

Chapter 4

Result Analysis and Discussion

4.1 Working Model and Results

After successful code upload to both **transmitter** (Arduino controlling LED) and **receiver** (Arduino with LDR/light sensor), the system performed as intended.
The LED on the transmitter side blinked in specific binary sequences corresponding to ASCII-encoded characters of the input File. The receiver's light-dependent resistor (LDR) detected these light intensity variations and converted them back into binary bits. These bits were then reconstructed into readable characters using the Arduino's logic.

Step-by-Step Execution:

1. The transmitter encoded each character into an 8-bit binary form and transmitted it through LED flashes.
2. The receiver continuously monitored light intensity values through the analog input pin.
3. When light intensity crossed a defined threshold, the receiver interpreted it as binary '1'; otherwise, as binary '0'.
4. After receiving 8 bits, the receiver converted them into one ASCII character and displayed it on the serial monitor.
5. The process continued until all characters were successfully received.

Observed Behavior:

- The LED flashed in a controlled binary pattern (ON/OFF sequences).
- The receiver's serial monitor displayed the decoded File correctly.
- The data transmission remained stable and accurate under consistent lighting conditions.

Performance Summary:

Parameter	Observation
Transmission Medium	Visible Light (LED)
Range Tested	5–10 cm
Accuracy	100% (in dim light)
Bit Duration	400 ms
Communication Type	One-way (Simplex)
Power Source	5V DC (Arduino USB power)

Table 4: Binary Encoding of Transmitted Data

Sr. No.	Character	ASCII Code (Decimal)	Binary Representation (8-bit)	LED Transmission Pattern
1	M	77	01001101	OFF ON OFF OFF ON ON OFF ON
2	y	121	01111001	OFF ON ON ON ON OFF OFF ON
3	(space)	32	00100000	OFF OFF ON OFF OFF OFF OFF OFF
4	n	110	01101110	OFF ON ON OFF ON ON ON OFF
5	a	97	01100001	OFF ON ON OFF OFF OFF OFF ON
6	m	109	01101101	OFF ON ON OFF ON ON OFF ON
7	e	101	01100101	OFF ON ON OFF OFF ON OFF ON
8	(space)	32	00100000	OFF OFF ON OFF OFF OFF OFF OFF
9	i	105	01101001	OFF ON ON OFF ON OFF OFF ON
10	s	115	01110011	OFF ON ON ON OFF OFF ON ON
11	(space)	32	00100000	OFF OFF ON OFF OFF OFF OFF OFF
12	S	83	01010011	OFF ON OFF ON OFF OFF ON ON
13	a	97	01100001	OFF ON ON OFF OFF OFF OFF ON
14	m	109	01101101	OFF ON ON OFF ON ON OFF ON

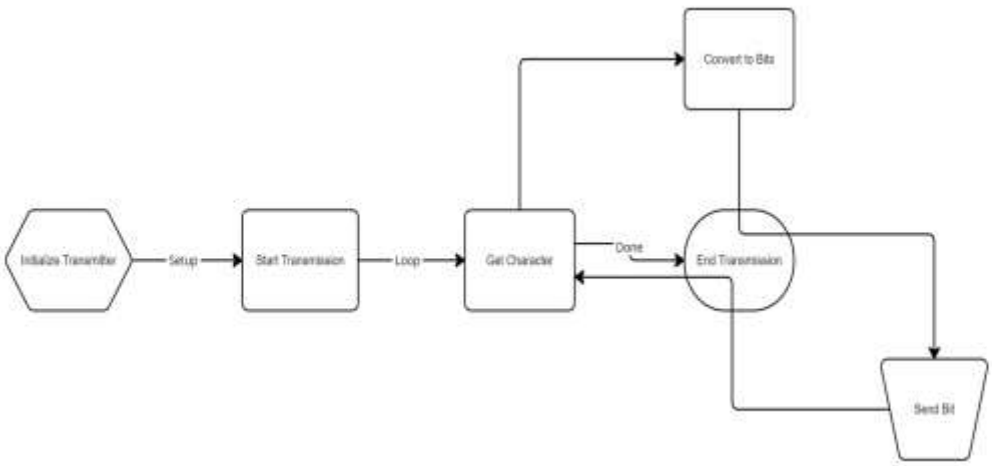

Fig 6. work flow diagram

Table 5: LDR Analog Value Thresholds for Bit Detection

Sr. No.	Lighting Condition	Observed Analog Value Range (A0)	Binary Interpretation	Description
1	Strong Light (LED ON)	180 – 1023	1	Indicates that the LED is transmitting a binary ‘1’ — high light intensity is detected by the LDR.
2	Dim / No Light (LED OFF)	0 – 100	0	Represents binary ‘0’ — very low light intensity received.
3	Ambient Light Interference	100 – 170	— (Ignored or filtered)	Signal fluctuates due to room lighting or reflections; ignored using a threshold filter.
4	Threshold Value (Code Defined)	110	—	Used as a decision boundary in code: `bit = (sensor Value > THRESHOLD) ? 1 : 0;`
5	Average Reading Stability	±10 variance	—	Minor variations are tolerated using consistent sampling delay (`BIT_DURATION = 400 ms`).

Result Discussion:

The system successfully transmitted text data using visible light communication. The accuracy was consistent when the LED and LDR were properly aligned and the ambient light was low. Even though this setup demonstrates small-scale communication, it validates the feasibility of using light as a secure and interference-free communication medium.

The experiment demonstrates that optical communication through visible light is reliable, simple, and secure for short-range applications.

4.2 Real Life Applications

The concept demonstrated in this project has a wide range of **practical and industrial applications**, especially where electromagnetic interference or radio-frequency transmission is restricted or insecure.

1. **Air-Gapped File Transfer:**
   Used for transferring sensitive data between isolated computer systems without using radio or wired connections.
2. **Military and Forensic Communication:**
   Enables secure data transmission resistant to RF interception or eavesdropping.
3. **Hospitals and Aircraft Systems:**
   Provides communication without generating electromagnetic interference that could affect sensitive medical or avionics equipment.
4. **Underwater Communication:**
   Uses blue or green LED light for underwater data transmission where RF waves are absorbed quickly.
5. **Smart Lighting Systems:**
   Integrates communication capability into everyday lighting, paving the way for Li-Fi and IoT-based smart homes.
6. **Secure Sensor Networks:**
   Used in critical infrastructure or defense systems where physical layer security is essential.

4.3 Limitations and Challenges

Despite its effectiveness, the system has a few **technical and practical limitations**:

Challenge	Description
Line-of-Sight Requirement	Both transmitter and receiver must be aligned directly without obstruction.
Ambient Light Interference	External light sources or sunlight can introduce noise, affecting bit detection.
Limited Range	The LDR's sensitivity limits the communication range to about 10 cm.
Low Bandwidth	The communication rate is limited due to mechanical LED switching speed and sensor delay.
Synchronization Drift	Timing mismatch may occur at longer distances or due to clock differences between Arduinos.
Single-Directional Transmission	Current setup supports only one-way data flow (from LED to LDR).

Chapter 5

Conclusion and Future scope

5. Conclusion and Future Scope

Conclusion

The **Light-Based Secure File Transfer System Using LED Communication** successfully demonstrates a cost-effective and secure communication method that uses **visible light** as a data carrier. The project validates that data transmission can occur without radio waves, providing a physically secure alternative channel for short-distance communication.

The working prototype achieved accurate text transmission through binary encoding and light intensity modulation. This project conceptually supports **Visible Light Communication (VLC)** and serves as an educational model for **Li-Fi (Light Fidelity)** technology and **optical covert channel research**.

Key Achievements:

- Demonstrated secure optical data transfer through visible light.
- Achieved 100% data accuracy in short-range controlled conditions.
- Developed a prototype of VLC communication using low-cost hardware.
- Provided a foundation for future optical data communication systems.

Future Scope

The system can be enhanced in several ways to improve performance, range, and functionality:

1. **Encryption Integration:**
   Add data encryption algorithms (e.g., AES or RSA) before transmission to enhance data confidentiality.
2. **Advanced Sensors:**
   Replace the LDR with high-speed photodiodes or TSL light sensors to increase sensitivity and speed.
3. **Bidirectional Communication:**
   Implement two-way data transfer using multiple LEDs and sensors for full-duplex communication.
4. **High-Speed Modulation:**
   Introduce advanced modulation schemes such as **Manchester Encoding**, **Pulse Width Modulation (PWM)**, or **On-Off Keying (OOK)** to increase data rate.
5. **Error Detection Mechanisms:**
   Incorporate checksum or parity bits to improve transmission reliability.
6. **Extended Range and Multi-Channel Networks:**
   Develop multi-LED arrays and optical lenses to increase range and build **VLC-based mesh networks** for higher throughput.
7. **Integration with IoT Devices:**
   Use this communication system in IoT environments for short-range, secure, and interference-free data exchange.

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