DATA TRANSMISSION

USING LI-FI

A

PROJECT REPORT

SUBMITTED IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION

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CANDIDATE'S DECLARATION

We hereby certify that the work presented in the Project entitled "**DATA TRANSMISSION USING LI-FI**" in partial fulfilment of the requirement for the award of the degree of **Bachelor of Engineering** in Electronics and Communications Engineering from University Institute of Engineering and Technology, Panjab University, Chandigarh, is an authentic record of our own work carried out under the supervision and guidance of Dr. Preeti Singh (Assistant Professor).

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ABSTRACT

Li-Fi stands for Light Fidelity. The technology is very new and was proposed by the German physicist Harald Haas in 2011 TED (Technology, Entertainment, Design) Global Talk on Visible Light Communication (VLC). Li-Fi is a wireless optical networking technology that uses light-emitting diodes (LEDs) for transmission of data. The term Li-Fi refers to visible light communication (VLC) technology that uses light as a medium to deliver high-speed communication in a manner similar to Wi-Fi.

Li-Fi is designed to use LED light bulbs similar to those currently in use in many energy-conscious homes and offices. However, Li-Fi bulbs are outfitted with a chip that modulates the light imperceptibly for optical data transmission. Li-Fi data is transmitted by the LED bulbs and received by photoreceptors.

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CHAPTER 1

INTRODUCTION

Thirty years after the introduction of the first commercially-available mobile communication systems, wireless connectivity has evolved into a fundamental commodity like gas and electricity. The exponential increase in mobile data traffic during the past two decades has led to the massive deployment of wireless systems. As a consequence, the limited available RF spectrum is subject to aggressive spatial reuse and co-channel interference has become a major capacity limiting factor. Therefore, there have been many independent warnings of a looming "RF spectrum crisis"1as the mobile data demands continue to increase while the **network spectral efficiency saturates** despite newly-introduced standards and great technological advancements in the field. It is estimated that by 2017, more than 11 Exabyte's of data traffic will have to be transferred through mobile networks every month.2 Most recently, VLC (**Visible light communication**) has been identified as a potential solution for mitigating the looming RF spectrum crisis.

Over the past decade, significant research efforts have been directed towards exploring alternative parts of the electromagnetic spectrum that could potentially offload a large portion of the network traffic from the overcrowded RF domain.

The use of the visible light spectrum for high-speed data communication is enabled by the emergence of the light emitting diode (LED) which at the same time is at the heart of the next wave of energy-efficient illumination. In that sense, the concept of combining the functions of illumination and communication offers the potential for tremendous cost. However, even if the illumination is not required energy efficient intensity modulation (IM) techniques exist that would allow data communication even if the lights are visually off.

Optical radiation, in general, does not interfere with other radio waves or with the operation of sensitive electronic equipment. Therefore, it is ideal for providing wireless coverage in areas which are sensitive to electromagnetic radiation – some examples which include hospitals, airplanes, petrochemical, and nuclear power plants, etc. Furthermore, the inability of light to propagate through walls offers an inherent level of network security. The same feature can be exploited to eliminate interference between neighboring cells.

1.1 Differences between RF (Radio Frequency) and VLC (Visible light communication):

Although both VL and RF communication employs electromagnetic radiation as the information medium, the two concepts differ significantly in their inherent properties. Waves in the visible region of the spectrum cannot penetrate through most surfaces that are present in everyday surroundings. Radio waves, on the other hand, are particularly apt at providing sufficient connectivity through the majority of commonly-used materials. As previously mentioned, this offers very interesting benefits. Information may be contained within the confined space of the specific premises where a VLC system is deployed. This practically eliminates the possibility for casual eavesdropping. More importantly, it eliminates interference between spatially isolated communication systems, removing one of the biggest challenges in RF communications. There tabular comparison has described in table 1.1.

PROPERTY	**VLC (Visible Light Communication)**	**RF (Radio Frequency)**
Bandwidth	Unlimited	Limited
EMI (Electromagnetic Interference)	NO	Yes, HIGH
Harmless for human body	NO	YES
Power Consumption	Relative Low	Medium
Coverage Distance	Short	Medium
Security	More Secure	Less Secure

Table 1.1 VLC vs. RFC

CHAPTER 2

THEORY RELATED TO PROJECT

In the era of overcrowded (data communication) world, **Li-Fi** is a new way of wireless communication that uses LED lights to transmit data wirelessly. In the current wireless network, with the increase in the number of devices which access the Internet, the availability of fixed bandwidth makes it much more difficult to enjoy high data transfer rates and to connect a secure network. **Li-Fi** has got a much broader spectrum for transmission compared to conventional methods of wireless communications that rely on radio waves. This technology uses a part of the electromagnetic spectrum that is still not greatly utilized- The Visible Spectrum.

Li-Fi is typically came to work using white LED light bulbs at the downlink transmitter. The LEDs are used for illumination only on applying a constant current to them. However, by fast and subtle variations of the current, the optical output can be made to vary at extremely high speeds. This very property of the optical current is used in Li-Fi technology setup. Its operation is very simple as when the LED is on then a logic “1” is transmitted and when the LED is off then a logic “0”is transmitted. This so happens at a very fast rate flickering of LED which is not visible to the human eye. Further enhancements can be made in this method, like using an array of LEDs for parallel data transmission, or using mixtures of red, green and blue LEDs to alter the light’s frequency with each frequency encoding a different data channel. Such advancements promise a theoretical speed of 10Gbps.

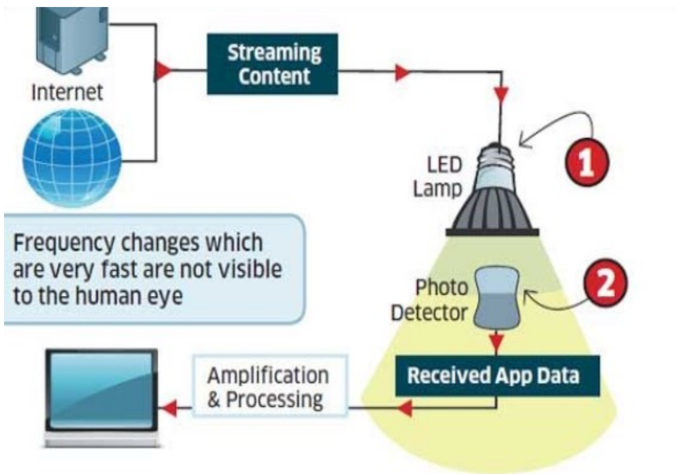

Fig.2.1 Internet Connectivity Using Li-Fi

The internet connection is connected to the lamp driver. A switch with lamp driver and LED lamp also connected to this lamp driver through fiber optic cable. Fig 2.1 is shown for better understanding. Now a receiving device, the photodetector is used to receive a signal and then to perform further processing, this device is then connected to PC’s or Laptop’s LAN port. On one end all the data will be streamed to a lamp driver when the LED is switched on the microchip converts the digital data or the logic data in light form. The light detector receives the light signal and then converts it again into the original digital form. Hence we can retrieve the data or the information by using a simple circuitry of Li-Fi.

Along with all these benefits, there are also some disadvantages of a Li-Fi connection. Since it uses visible light to transmit data, Li-Fi would be rather useless in conditions where there is no light. That means no Internet while lying in your bed at night. If you have a Wi-Fi router installed in one room of your house, you can connect your devices sitting anywhere in the house, but this is not the case with Li-Fi. Fig 2.2 Shows the Li-Fi and Wi-Fi practical implementation. Since visible rays cannot pass through walls, you have to be in the immediate vicinity of the source of light to access the Internet on your device, which may not sound particularly convenient to many people. There's no doubt that Li-Fi is going to transform the world of Internet connectivity, but it seems unlikely that its rise would necessarily mean the death of Wi-Fi, since the latter is deeply embedded in the lifestyles of billions of people. A more likely scenario, though, is that we'll eventually have a wide range of technologies available at our disposal and will be free to choose the most appropriate one.

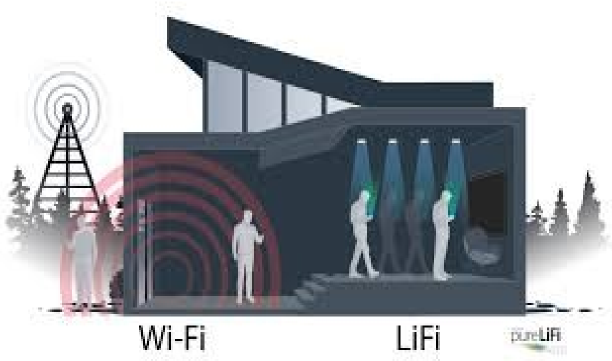

Fig.2.2 Wi-Fi vs. Li-Fi

After understanding the problems or issues we face in our regular time, we have made miniature or prototype which shows how easy the data transmissions through a single LED (transmitter) and a photodiode (receiver) using Arduino Uno R3 as a microcontroller, help to decode and encode the data from/to binary formats and many other like alphabets, numeric etc.

The information, of any form, to be transmitted is first converted into a digital signal (binary data) using programming techniques. The digital signal obtained is then applied at the LED. The LED, in turn, flickers according to the digital signal applied. The flickering in the LED is observed at the receiver section using photodiode (LDR), whose resistance varies as the intensity of light varies, and the data received is stored. The binary data is then converted into its original form using different programming techniques.

CHAPTER 3

IMPLEMENTATION

3.1 MATERIALS REQUIRED

Both the hardware as well as the software requirements are discussed in detail in the sections 3.1.1 and 3.1.2.

3.1.1 HARDWARE REQUIREMENTS

Hardware components used in the project are as follows:

I. Arduino Uno
II. Light Dependent Resistor (LDR)
III. Light Crystal Display (LCD)
IV. Light Emitting Diode (LED)
V. Potentiometer
VI. Resistors

I. Arduino UNO

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328Pmicrocontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by a USB cable or by an external 9 volt battery, though it accepts voltages between 7 and 20 volts. It is also similar to the Arduino Nano and Leonardo. The hardware reference design is

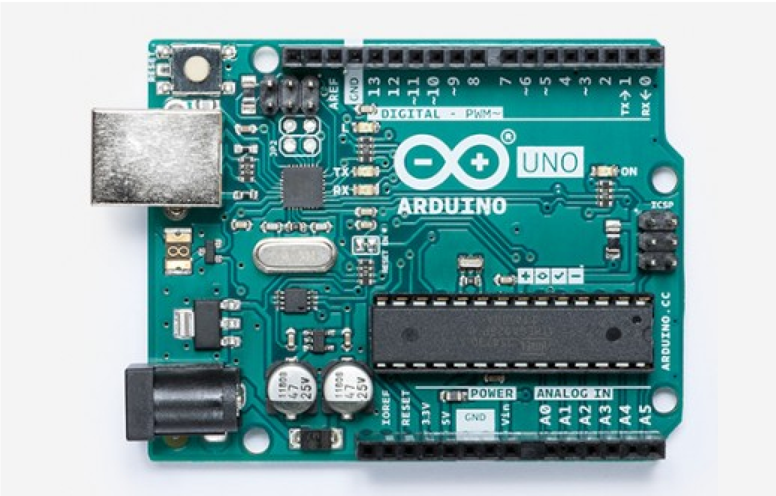

Fig.3.1 Arduino UNO

distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform. The ATmega328 on the Arduino Uno comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Uno also differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it uses the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

II. Light Dependent Resistor (LDR)

A photoresistor (or light-dependent resistor, LDR, or photo-conductive cell) is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. A photoresistor can be applied in light-sensitive detector circuits, and light-activated and dark-activated switching circuits.

Fig.3.2 LDR

A photoresistor is made of a high resistance semiconductor. In the dark, a photoresistor can have a resistance as high as several megohms (MΩ), while in the light, a photoresistor can have a resistance as low as a few hundred ohms. If incident light on a photoresistor exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electrons (and their hole partners) conduct electricity, thereby lowering resistance. The resistance range and sensitivity of a photoresistor can substantially differ among dissimilar devices. Moreover, unique photoresistors may react substantially differently to photons within certain wavelength bands.

A photoelectric device can be either intrinsic or extrinsic. An intrinsic semiconductor has its own charge carriers and is not an efficient semiconductor, for example, silicon. In intrinsic devices the only available electrons are in the valence band, and hence the photon must have enough energy to excite the electron across the entire bandgap. Extrinsic devices have impurities, also called dopants, added whose ground state energy is closer to the conduction band; since the electrons do not have as far to jump, lower energy photons (that is, longer wavelengths and lower frequencies) are sufficient to trigger the device. If a sample of silicon has some of its atoms replaced by phosphorus atoms (impurities), there will be extra electrons available for conduction. This is an example of an extrinsic semiconductor.

III. Light Crystal Display (LCD)

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden, such as preset words, digits, and seven-segment displays, as in a digital clock.

They use the same basic technology, except that arbitrary images are made up of a large number of small pixels, while other displays have larger elements. LCDs can either be normally on (positive) or off (negative), depending on the polarizer arrangement. For example, a character positive LCD with a backlight will have black lettering on a background that is the color of the backlight, and a character negative LCD will have a black background with the letters being of the same color as the backlight. Optical filters are added to white on blue LCDs to give them their characteristic appearance.

Fig.3.3 LCD

LCDs are used in a wide range of applications, including LCD televisions, computer monitors, instrument panels, aircraft cockpit displays, and indoor and outdoor signage. Small LCD screens are common in portable consumer devices such as digital cameras, watches, calculators, and mobile telephones, including smartphones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks. LCD screens have replaced heavy, bulky cathode ray tube (CRT) displays in nearly all applications. LCD screens are available in a wider range of screen sizes than CRT and plasma displays, with LCD screens available in sizes ranging from tiny digital watches to very large television receivers. LCDs are slowly being replaced by OLEDs, which can be easily made into different shapes, and have a lower response time, wider color gamut, virtually infinite color contrast and viewing angles, lower weight for a given display size and a slimmer profile (because OLEDs use a single glass or plastic panel whereas LCDs use two glass panels; the thickness of the panels increases with size but the increase is more noticeable on LCDs) and potentially lower power consumption (as the display is only "on" where needed and there is no backlight). OLEDs, however, are more expensive for a given display size due to the very expensive electroluminescent materials or phosphors that they use. Also due to the use of phosphors, OLEDs suffer from screen burn-in and there is currently no way to recycle OLED displays, whereas LCD panels can be recycled, although the technology required to recycle LCDs is not yet widespread. Attempts to increase the lifespan of LCDs are quantum dot displays, which offer similar performance as an OLED display, but the Quantum dot sheet that gives these displays their characteristics cannot yet be recycled.

IV. Light Emitting Diode (LED)

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons.

This effect is called electroluminescence. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device. Appearing as a practical electronic component, in 1962 the earliest LEDs emitted low-intensity infrared light.

Fig.3.4 LED

Infrared LEDs are used in remote-control circuits, such as those used with a wide variety of consumer electronics. The first visible-light LEDs were of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with high light output.

Early LEDs were often used as indicator lamps, replacing small incandescent bulbs, and in seven-segment displays. Recent developments have produced white-light LEDs suitable for room lighting. LEDs have led to new displays and sensors, while their high switching rates are useful in advanced communications technology.

LEDs have many advantages over incandescent light sources, including lower energy consumption, longer lifetime, improved physical robustness, smaller size, and faster switching. Light-emitting diodes are used in applications as diverse as aviation lighting, automotive headlamps, advertising, general lighting, traffic signals, camera flashes, lighted wallpaper and medical devices.

V. Potentiometer

A potentiometer is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat.

The measuring instrument called a potentiometer is essentially a voltage divider used for measuring electric potential (voltage); the component is an implementation of the same principle, hence its name.

Potentiometers are commonly used to control electrical devices such as volume controls on audio equipment.

Fig.3.5 Potentiometer

Potentiometers operated by a mechanism can be used as position transducers, for example, in a joystick. Potentiometers are rarely used to directly control significant power (more than a watt), since the power dissipated in the potentiometer would be comparable to the power in the controlled load.

VI. Resistor

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat, may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Fig.3.6 Resistor

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits.

The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance falls within the manufacturing tolerance, indicated on the component.

3.1.2 SOFTWARE USED

The software used in this project is Arduino IDE.

Arduino IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main( ) into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

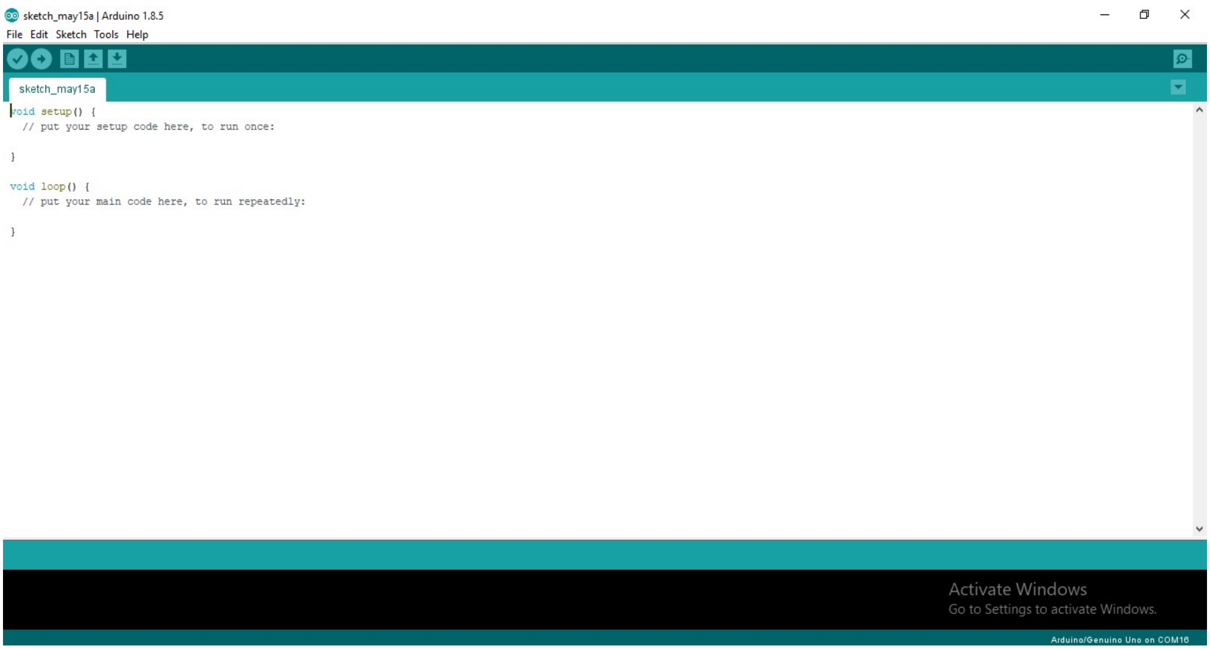

Fig.3.7 Arduino IDE

HARDWARE

Sr. No.	COMPONENT	QUANTITY	COST
1	Arduino Uno R3	1	400
2	LDR (Light Dependent Resistor)	1	20
3	LED (Light Emitting Diode)	1	5
4	Resistor and Connecting Wires	10	20
5	LCD (Liquid Crystal Display)	1	150

Table 3.1

SOFTWARE

Sr. No	PLATFORM	DESCRIPTION
1	Arduino IDE	Platform to write down the codes for hardware

Table 3.2

3.2 METHODOLOGY

The block diagram (fig.3.8) for the Data Transmission using Li-Fi along with its detailed description is given below.

1. As shown in the above figure the micro controller, Arduino Uno, acts as the main control unit that makes all the decision and coordinate all the components together.

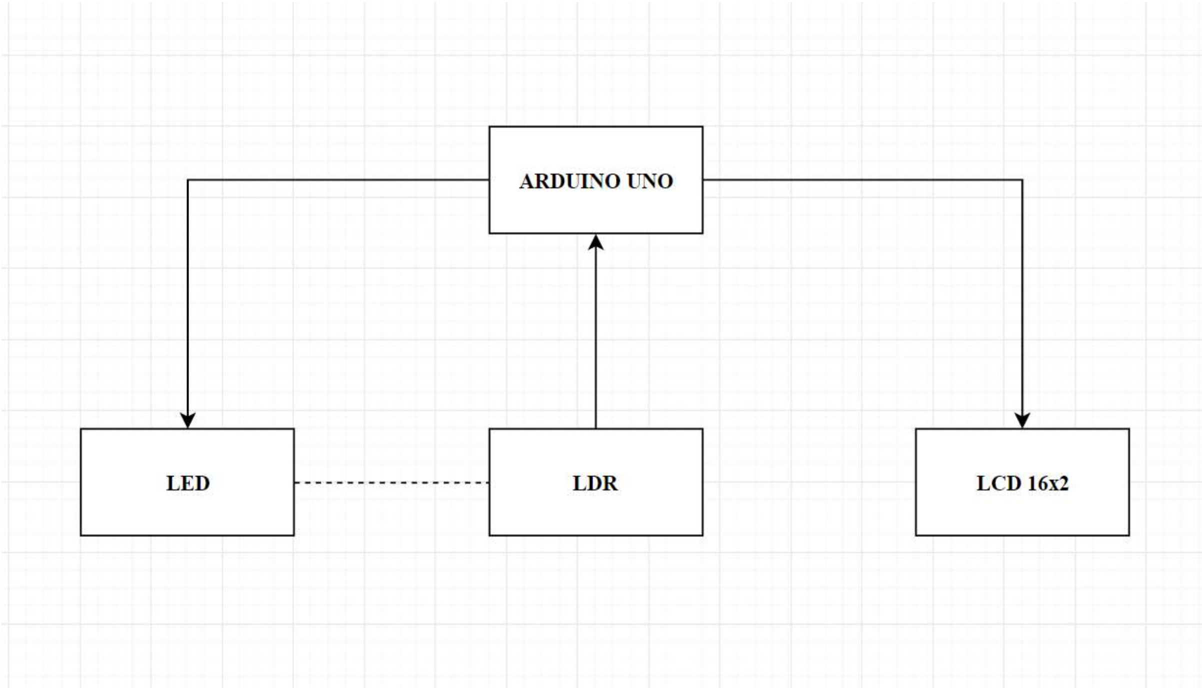

Fig.3.8 Block diagram of Data Transmission using Li-Fi

2. First, it converts the data that we want to send via Li-Fi into a binary sequence and then according to the 0's and 1's in that binary sequence it turns the LED on (For binary 1) or off (For binary 0).

3. This flickering of LED light is done in the direction of the LDR (line of sight) which detects these small changes in light and changes its value of resistance according to the intensity of light.

4. LDR sends an analog value in the range of 0-1023 to the Arduino's analog pin and depending on a threshold value the Arduino decides whether the received value is considered as binary 1 or binary 0.

5. After receiving the block of binary data it converts it back to its original form in which the message was initially sent.

6. In our case we sent a string through Li-Fi so, first, the string was converted into ASCII then into binary and after receiving the binary sequence it was converted back into ASCII then into string.

7. The string was then displayed on a 16x2 Liquid Crystal Display (LCD).

3.3 WORKING

The communication process involves a light source (LED) in the transmission section and a photodiode (LDR) in the receiver section. Fig.3.9 shows the hardware implementation of the project. It consists of an Arduino UNO, a LDR (Light dependent Resistor), a LED (Light emitting diode), a potentiometer and a LCD.

The information, of any form, to be transmitted is first converted into a digital signal (binary data) using programming techniques. The information (text) is entered using the Serial monitor of Arduino IDE as shown in fig.3.10. This information is then converted into binary data using the program code. The digital signal(binary data) obtained is then applied at the LED, using digital pins of Arduino. The LED, in turn, flickers at a very high rate according to the digital signal applied.

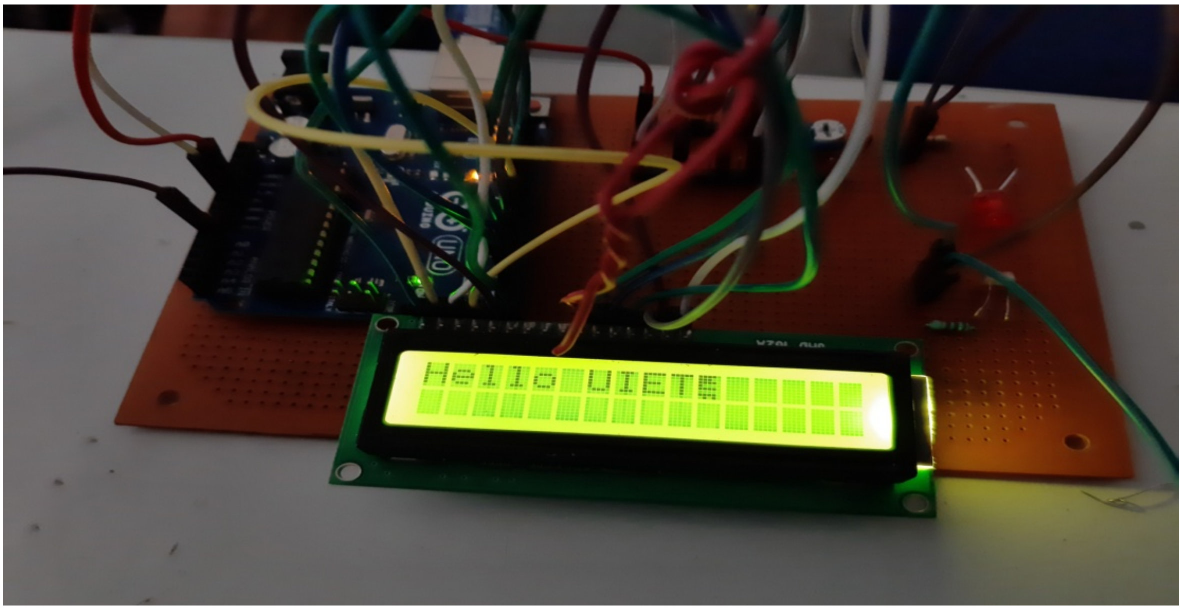

Fig.3.9 Project Model

The flickering in the LED is observed at the receiver section using photodiode (LDR). The LDR’s resistance varies as the intensity of light varies. Hence the flickering of the LED is converted into binary data through following process :- if the light intensity measured using LDR is below a predefined threshold level, the binary symbol ‘0’ is stored and the intensity is above the threshold, then the binary symbol ‘1’ is stored.

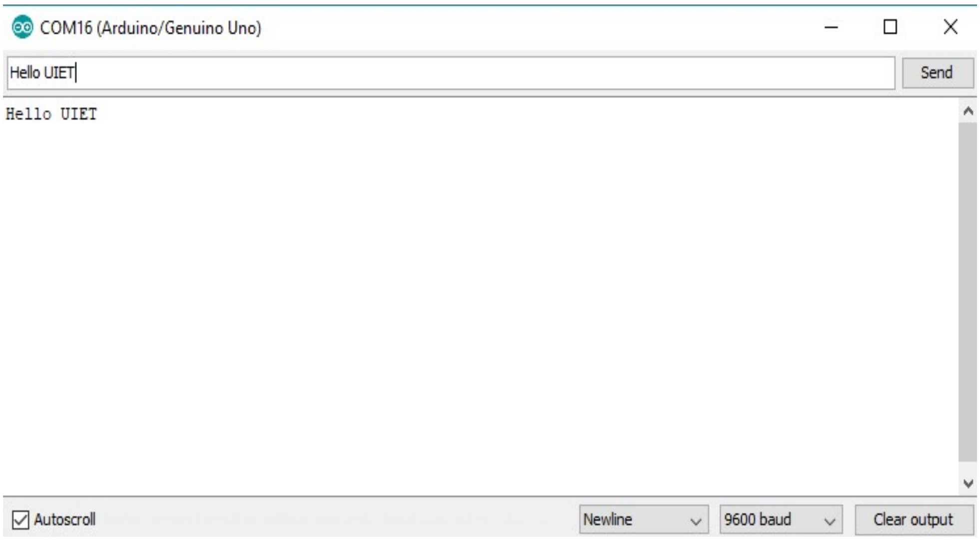

Fig.3.10 Serial Monitor (Arduino IDE)

The binary data is so received is converted back into text using our program code. Various forms of data can be transmitted using this method. Further its practical implementation is shown in next chapter with material used and methodology.

In figure 3.9 and 3.10, it is shown that the text “Hello UIET” is given at the input using Serial monitor and with the help of LCD we can observe that the same text “Hello UIET” is received.

CHAPTER 4

CHALLENGES, RESULTS & CONCLUSION

4.1 CHALLENGES

1. **Uploading:** We have come up to unidirectional Data communication i.e. source to the client but bidirectional communication is one of the major challenge considering the acknowledgment of reception of signal or information.
2. **Night Time:** Li-Fi faces issues in night time transmissions. Li-Fi works on the visible light spectrum so during night time/ Low light, Li-Fi may cause disturbance to the user.
3. **Sync:** Rate of receiver section and transmitter section may be different which may result in redundant data and loss of information.
4. **Data Formats:** Proper techniques should be followed to Encode and decode data at different devices. Example: If we are transmitting audio file by encoding it into binary form, at receiver section we should be aware to decode it back to audio file rather than converting it into text or any other format.
5. **Security:** Data transmitted have to be in encrypted/password protected form so that in the presence of multiple clients at the same time, only the intended client can access the data.

4.2 CONCLUSION

LI-FI is an emerging technology and it has vast potential. Researchers are developing micron sized LEDs which flicker on and off 1000 times faster than larger LEDs. They provide faster data transfer and also take up less space. Moreover, 1000 micron sized LEDs can fit into area required by 1 sq. mm large single LED. A 1 sq. mm sized array of micron sized LEDs could hence communicate 1000×1000 (i.e. a million) times as much information as a single 1mm LED.. As the amount of available bandwidth is limited, the airwaves are becoming increasingly clogged, making it more and more difficult to get a reliable, high-speed signal. LI-FI technology can solve this crisis. Moreover, it will allow internet access in places such as operation theaters and aircraft where internet access is usually not allowed. We can conclude, Li-Fi is the future of communication technology.

4.3 FUTURE SCOPE /ADVANTAGES:

1. **Underwater Explorations and Communications:** The Li-Fi communication technology can further be used for underwater transmission and reception of data. Fig.4.1 shows the underwater communication**.** Underwater Remotely Operated Vehicles, operate from large cables that supply their power and allow them to receive signals from their pilots above. ROVs work great, except when the tethers aren't long enough to explore an area, or when it gets stuck on something

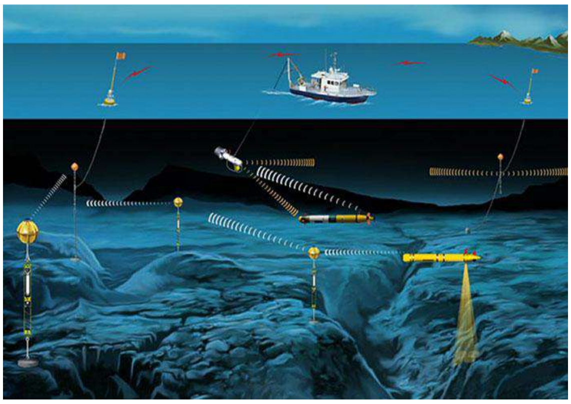

Fig.4.1 Underwater Scope

2. **Medical and Healthcare:** WI-FI is not allowed operation theaters because they can interfere with **medical** equipment. Moreover, their radiations pose risks for patients. LI-FI uses light and hence can be used in place of WI-Fi. Lights are an essential part of operating rooms and Li-Fi can thus be used for modern medical instruments. Moreover, no electromagnetic interference is emitted by Li-Fi and thus it does not interfere with any medical instruments such as MRI scanners. Fig.4.2 shows the same

Fig.4.2 Medical and Health

3. **Power Plants and Hazardous Environments:** Wi-Fi is not suitable for sensitive areas like power plants. However, power plants still require fast and interconnected

data systems for monitoring grid intensity, demand, temperature etc. In place of Wi-Fi, Li-Fi can provide safe connectivity throughout the power plant. Li-Fi offers a safe alternative to electromagnetic interference due to radio waves in environments such as petrochemical plants and mines.

4. **Airlines and Aviation:** Wi-Fi is often prohibited in aircrafts. However, since aircrafts already contain multiple lights, thus Li-Fi can be used for data transmission. Fig.4.3 shows the same

Fig.4.3 Airlines and aviation

5. **Road Traffic:** Li-Fi can be used for communications between the LED lights of cars to reduce and prevent traffic accidents. LED headlights and tail-lights are being implemented for different cars. Traffic signals, signs and street lamps are all also transitioning to LED. With these LED lights in place, Li-Fi can be used for effective vehicle-to-vehicle as well as vehicle-to-signal communications. This would of course lead to increased traffic management and safety. Fig.4.4 shows the same.

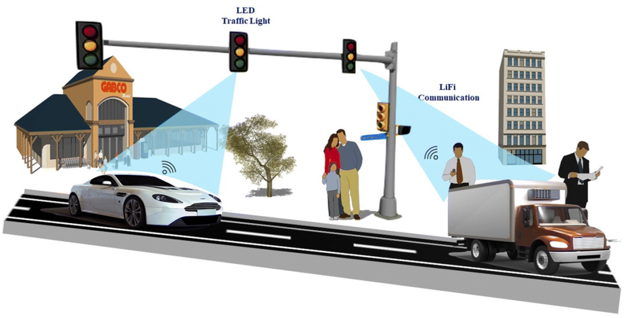

Fig.4.4 Road Traffic Controlling

6. **Green Information technology:** Li-Fi can be called as Green information technology as it does not effect on the birds, human body's etc., like the radio waves or any other communication waves. It does not have any side effect on any living thing.

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5. https://purelifi.com/lifi-technology/

APPENDIX: SOURCE CODE

```
#include<stdio.h>
#include<stdlib.h>
#include <LiquidCrystal.h>

const int rs = 8, en = 9, d4 = 2, d5 = 3, d6 = 4, d7 = 5;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

int a = 0;
int outdata[8]={0,0,0,0,0,0,0,0};
int  w[]= {128,64,32,16,8,4,2,1};
int sum = 0;


void setup() {

 Serial.begin(9600);
 pinMode(12,OUTPUT);
 pinMode(A0,INPUT);
 lcd.begin(16, 2);

}

void loop() {

  while(!Serial.available()){}

  String input_data = Serial.readString();

  for(int i=0; i<input_data.length(); i++)
  {
    char input_char = input_data.charAt(i);

    for(int j=7; j>=0; j--)
    {
      byte input_bytes = bitRead(input_char,j);
      //Serial.print(input_bytes,BIN);
      //delay(1000);

     if(input_bytes == 1)
      {
        digitalWrite(12,HIGH);
        delay(10);
        if(analogRead(A0)>40)
```

```
        outdata[a] = 1;

        else
        outdata[a] = 0;
      }

      else
      {

        digitalWrite(12,LOW);
        delay(10);
        if(analogRead(A0)>40)
        outdata[a] = 1;

        else
        outdata[a] = 0;
      }
      a = a+1;
      }


     for(int k =0 ; k< 8; k++){

      sum = sum + outdata[k]*w[k];
      //Serial.print(outdata[k]);
      //Serial.println(sum);
      }
      lcd.write(sum);
      Serial.write(sum);
      sum=0;


    }
    delay(2000);
    lcd.clear();
    Serial.println("");

}
```