Smart Street Lighting System

A PROJECT REPORT

Submitted in partial fulfillment of the

requirements for the award of the degrees

of

BACHELOR OF TECHNOLOGY

in

ELECTRICAL ENGINEERING

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CANDIDATE’S DECLARATION

I hereby declare that the project entitled **‘Smart Street Lighting System’** submitted in partial fulfillment for the award of the degree of Bachelor of Technology in **‘Electrical Engineering’** completed under the supervision of **Dr. Santosh Kumar Vishvakarma, Associate Professor, Discipline of Electrical Engineering,** IIT Indore is an authentic work.

Further, we declare that we have not submitted this work for the award of any other degree elsewhere.

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Discipline of Electrical Engineering

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CERTIFICATE by BTP Guide

It is certified that the above statement made by the students is correct to the best of my knowledge.

Signature of BTP Guide with dates and their designation

Preface

This report on “Smart Street Lighting System" is prepared under the guidance of Dr. Santosh Kumar Vishvakarma.

Through this report I have presented my work on my prototype of Smart Street Lighting System and tried to discuss in detail the features of the proposed model. I have discussed and tested the various techniques that are used in the model of street light to transfer data using visible light communication. I have tried to implement alternate approaches to tackle various limitations that were present to the best of my ability.

The advantages of my model over the existing conventional model is also discussed.

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B.Tech. IV Year

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Acknowledgements

We would like to thank our BTP supervisor, Dr. Santosh Kumar Vishvakarma, for his constant support in structuring the project and for his valuable feedback which helped us in the course of the project. He gave us the opportunity to discover and work in this domain. He guided us thoroughly and pulled us out of the craters of failures we faced all through the period.

We are especially grateful to Dipesh Monga sir who guided us, made us familiar with the nuances in various IoT technologies and provided us the pathway for this project in right manner. He simultaneously guided us with useful direction to proceed along whenever necessary.

We are also thankful to all our family members, friends and colleagues who have been a constant source of motivation. Finally, we offer sincere thanks to everyone else who knowingly or unknowingly helped us complete this project.

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Abstract

At the moment when our government is trying to extend its Smart City Mission to various cities, the smart street lights can play a monumental role in realising this mission. The conventional street lights are used to just provide light and has no additional utility.

The Arduino based 'Smart Street Light' will contain various sensors like smoke, dust, temperature and humidity, UV sensor to measure these parameters and send this data to the user with the help of Light (Visible Light Communication) as well as to the respective departments. The goal is to achieve this transfer of information using visible light communication such that errors in the information is minimized and a higher speed is achieved.

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List of Figures :

Chapter 1

Introduction

This chapter highlights the background and motivation for the project. The problem statement has been described of the project and the importance of the results is also clearly portrayed. Towards the end, the objectives are briefly outlines and the future scope is also discussed.

1.1 Overview

The Smart City Mission by the government is a milestone in modernising our country's cities, I believe that smart street lights can prove out to be vital in this mission, since there is a sundry of problems associated with the present street lights.
Also, there is a huge scope for its improvement.

Although different municipalities use different street lighting systems and have a different approach to their management, there is a range of problems that is common for all of them.

- The first, without any doubt, is the high energy consumption. Each year, in the world, several trillion kWh are expended on street lighting. A high consumption means a high amount of generated energy, which in turn translates into a high level of noxious emissions.
  By Dimming the lights when the traffic is low, a significant amount of energy can be saved thus reducing the emissions.
- Secondly, in city as well as rural areas the problem of pollution is proliferating these days, and data regarding temperature, smoke and pollution levels in such areas are rarely taken and assessed.
  By incorporating pollution, temperature sensors within the street light, the need for separate sensor stations will be eliminated and this option would prove out to be much more economical.

Also in many regions across the country especially the rural areas, there is a problem of lack of connectivity as internet connections are scarce in such regions. Just 12.8 % of rural population and 27% of overall population are broadband subscribers and over 800 million people in India have no internet access(as of 2016) , this hampers the growth and development. A Li-Fi enabled Street Light will help to provide free and high speed internet facilities to people in internet deprived regions.

This would be also a very cost effective and efficient solution for the Government in its mission to digitize India.

TABLE III

INTERNET/BROADBAND SUBSCRIBERS

Internet/broadband subscribers	In million	Subscriber density (Subscribers/100 population)
Total	342.65	26.98
Urban	230.71	58.28
Rural	111.94	12.80

Source: The Indian Telecom Services Performance Indicators January 2016 - March 2016, TRAI

1.2 Light Fidelity (Li-Fi)

Li-Fi is a bidirectional, high-speed and fully networked wireless communication technology similar to Wi-Fi. The term was coined by Professor Harald Haas in 2011 and is a form of visible light communication and a subset of optical wireless communications (OWC) and could be a complement to RF communication (Wi-Fi or cellular networks), or even a replacement in contexts of data broadcasting.

It is wire and UV visible-light communication or infrared and near-ultraviolet instead of radio-frequency spectrum, part of optical wireless communications technology, which carries much more information and has been proposed as a solution to the RF-bandwidth limitations.

In visible Light communication, data transfer is achieved by blinking LEDs at a very fast rate such that it can't be perceived by the human eye.
An ON would signify the bit '1' and an OFF would mean a '0'.

Thus, by blinking the LEDs a stream of 1s and 0s is transmitted.

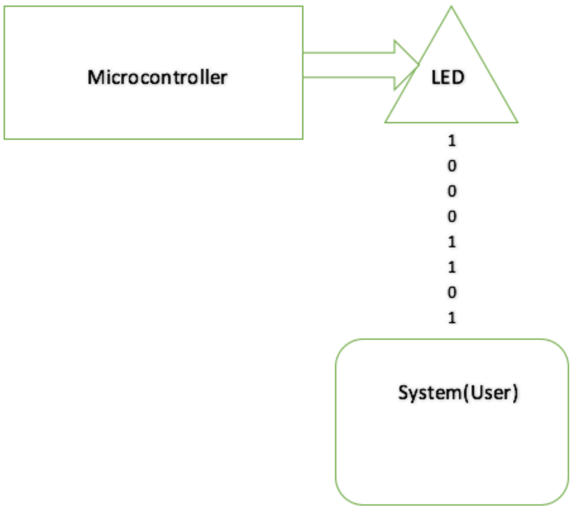

Fig1 : Data Transfer through blinking LED

Li-Fi has a range of advantages over the conventional radio communication which are:

1. **Speed** : It is believed that the technology can yield a speed more than 10 Gbps.
2. **Efficiency**: Li-Fi works on visible light technology. Since homes and offices already have LED bulbs for lighting purposes, the same source of light can be used to transmit data. Hence, it is very efficient in terms of costs as well as energy. Light must be on to transmit data, so when there is no need for light, it can be reduced to a point where it appears off to human eye, but is actually still on and working.
3. **Availability**: Wherever there is a light source, there can be Internet, hence Li-Fi in street lights will help in enhancing connectivity to practically everywhere in a region.
4. **Security**: One main advantage of Li-Fi is security. Since light cannot pass through opaque structures, Li-Fi Internet is available only to the users within a room and cannot be breached by users in other rooms or buildings.

It has its Disadvantages too :

1. Because it uses visible light, and light cannot penetrate walls, the signal's range is limited by physical barriers.
2. Other sources of light may interfere with the signal.

Chapter 2

Smart Street Lights

2.1 Overview

Imagine only needing to hover under a street lamp to get public internet access, or downloading a movie from the lamp on your desk. This Smart street light will use the concept of Light Fidelity to achieve high speed internet for its users.
In addition to this, the following sensors will be incorporated in the proposed model of smart street lights.

- Temperature and humidity: Senses the temperature and humidity and sends this data to the respective government department.

- Traffic density: Measures the traffic levels which can be used to dim the lights accordingly.

- Smoke and pollution levels which will provide data about pollution levels in different parts of cities.

- UV sensor will provide the UV index of the region.

- Sound Sensor will indicate the noise level.

- Dust sensor will measure the dust levels.

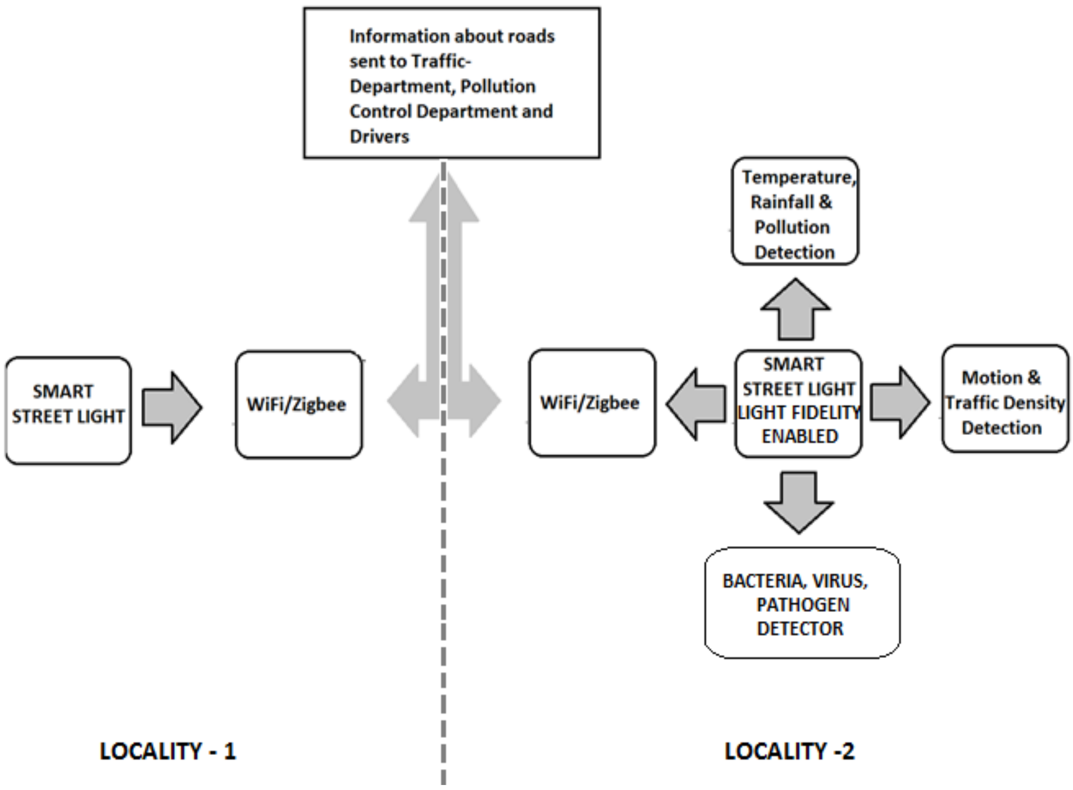

Fig 2 : Block Diagram of proposed Smart Street Lighting System

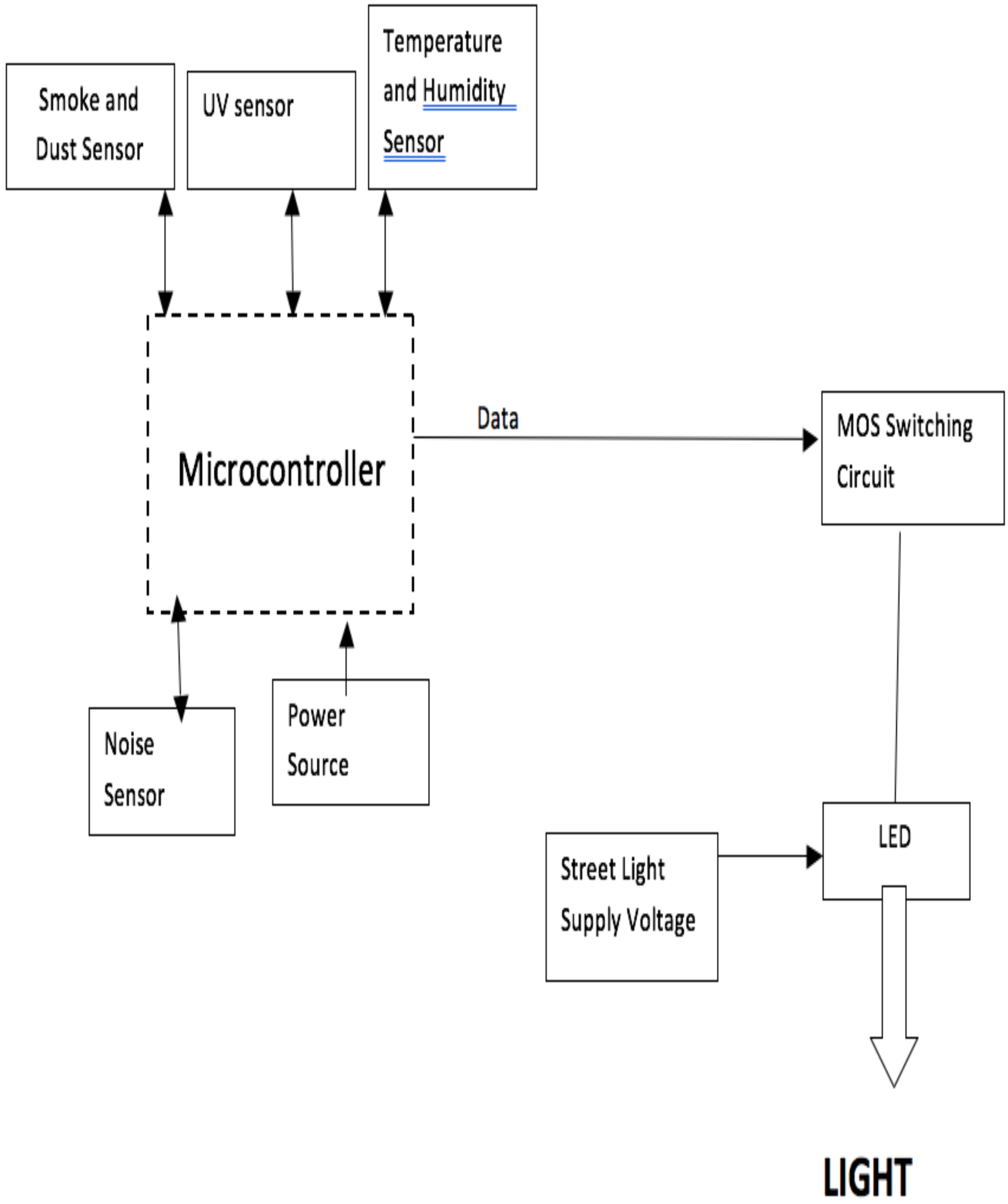

Fig 3: Smart Street Light(Transmitter) Block Diagram

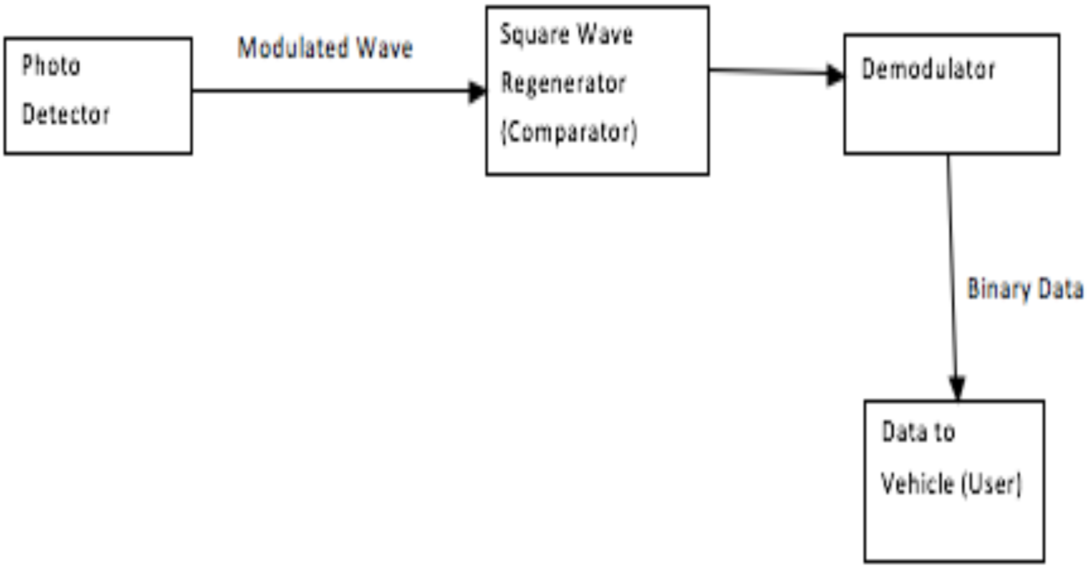

Fig 4: Receiver for the Street Light

2.2 Hardware

The Smart Street Light consists of various sensors namely, Dust sensor, gas sensor, Temperature and humidity sensor, UV sensor, Noise sensor connected to the Arduino which measures the corresponding raw values given by the sensors and calibrates these values to give meaningful indices and sends this information to the user. The TX pin of the microcontroller is given to the LED for transmitting this data via visible light communication.

2.2.1 Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.

The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source.

Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.

External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.

PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.

SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).

LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
The USB connection on the board was used for programming the chip and getting serial output for troubleshooting. The interface between USB and the ATMega328’s UART was provided by the Arduino’s built in USB to serial converter chip. The device showed up as a virtual COM port on the host PC, and could be interfaced with any program capable of reading and writing to a serial port. The board came pre-built from the distributor, so no major hardware assembly was required for use. Male headers are attached to each of the I/O and power ports, allowing wires to be inserted rather than soldered to each connection. The connections to the AREF pin, the analog pins, and the ground/VCC pins were all wired in this way. No major modifications of the stock hardware were required.

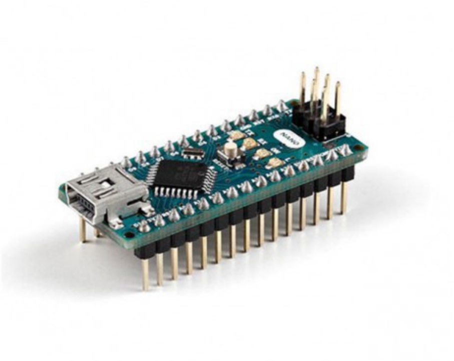

Fig 5: Arduino Nano

2.2.2 **Temperature and Humidity Sensor**

The Matrix-Temperature and Humidity Sensor module is used to detect temperature and humidity. It utilizes the DHT11 temperature and humidity sensor. Its humidity range is 20% - 80% and the accuracy is 5%. Its temperature range is 0℃ - 50℃ and the accuracy is ±2℃.

The sensor contains 3 pins which are Sig, Vcc , Gnd which are connected to the Analog pin, 5V and ground pin of the Arduino respectively.

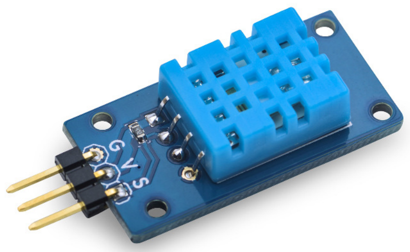

Fig 6 : Temperature and Humidity Sensor

2.2.3 Gas Sensor

It is suitable for detecting H2, LPG, CH4, CO, Alcohol, Smoke or Propane. Due to its high sensitivity and fast response time, measurement can be taken as soon as possible. The sensitivity of the sensor can be adjusted by potentiometer.
This can be used to detect smoke if the pollution level is extreme.

The sensor contains 4 pins which are Sig, Vcc , Gnd which are connected to the Analog pin, 5V, ground pin of the Arduino respectively. The 4rth pin NC is not connected to the Arduino.

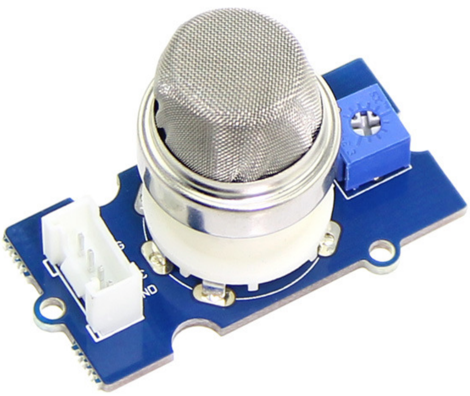

Fig 7 : Grove Gas Sensor(MQ2)

2.2.3 Dust Sensor

Sharp's GP2Y1010AU0F is an optical air quality sensor, designed to sense dust particles. An infrared emitting diode and a phototransistor are diagonally arranged into this device, to allow it to detect the reflected light of dust in air. It is especially effective in detecting very fine particles like cigarette smoke, and is commonly used in air purifier systems.

The sensor has a very low current consumption (20mA max, 11mA typical), and can be powered with up to 7VDC. The output of the sensor is an analog voltage proportional to the measured dust density, with a sensitivity of 0.5V/0.1mg/m^3.

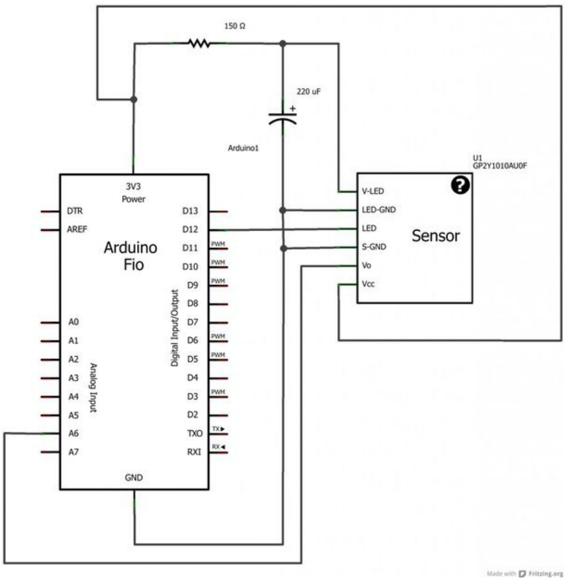

Fig 8 :Connection of dust sensor with the Arduino

Fig 9: Optical Dust Sensor - GP2Y1010AU0F

2.2.4 UV Sensor

The Grove – UV Sensor is used for detecting the intensity of incident ultraviolet(UV) radiation. This form of electromagnetic radiation has shorter wavelengths than visible radiation. The Grove - UV Sensor is based on the sensor GUVA-S12D which has a wide spectral range of 200nm-400nm. It has a very high sensitivity, low power consumption and high sensitivity.

The sensor contains 4 pins which are Sig, Vcc , Gnd which are connected to the Analog pin, 5V, ground pin of the Arduino respectively. The 4rth pin NC is not connected to the Arduino.

The theory of UV sensor is: In sunlight, the UV index and Photocurrent are a linear relationship.

In the UV Sensor, the output voltage and the UV index is linear:
illumination intensity = 307 * V_{sig}
V_{sig} is the value of voltage measured from the SIG pin of the Grove interface, unit V.
illumination intensity unit: mW/m^2 for the combination strength of UV light with wavelength range: 240nm~370nm

UV Index = illumination intensity / 200

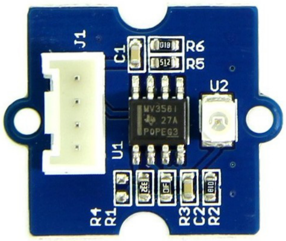

Fig 10 : Grove UV Sensor

2.2.5 Noise Sensor

Grove - Sound Sensor can detect the sound intensity of the environment. The main component of the module is a simple microphone, which is based on the LM386 amplifier and an electret microphone. It is operated at 5V and gives an Analog output.

The sensor contains 4 pins which are Sig, Vcc , Gnd which are connected to the Analog pin, 5V, ground pin of the Arduino respectively. The 4rth pin NC is not connected to the Arduino.

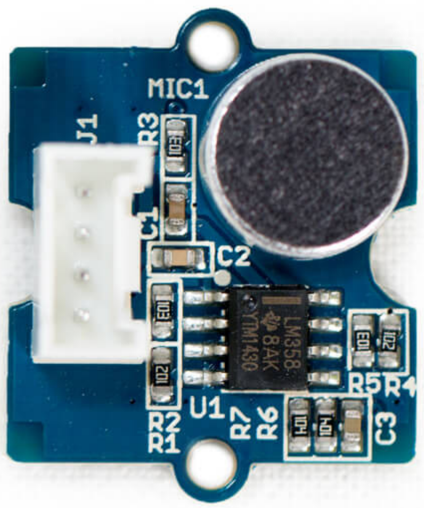

Fig 11: Sound Sensor

2.2.6 LM-311 Comparator

The LM311 is a single comparator, that is it is composed internally of one comparator.

It compares these voltage inputs and determines which is the larger value. Based on this, electronic decisions can be made based on which input is greater and which is smaller. Thus, a comparator is very useful in circuits where we measure levels and want our circuit to act a certain way based on whether the level of an input is greater or smaller than a certain threshold.

An LM311 is an 8-pin chip.

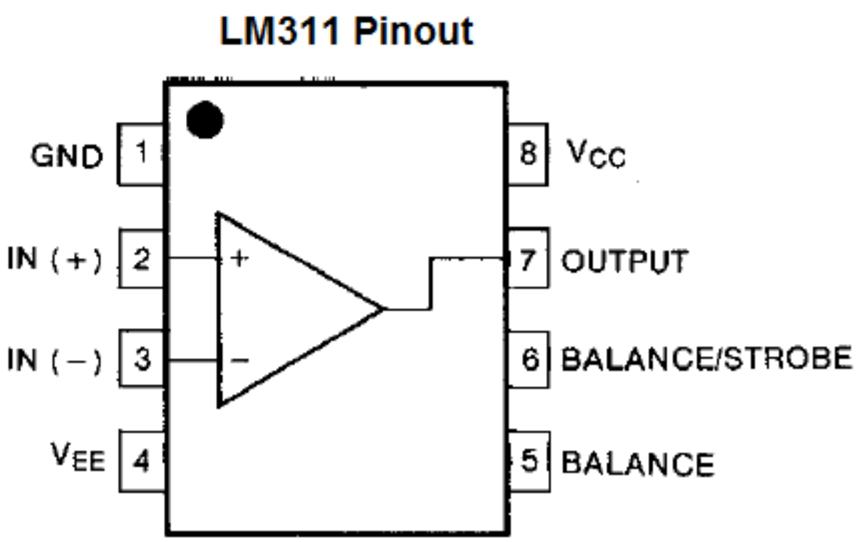

Fig 12 : LM311 Pin diagram

2.3.7 Photodiodes

LDR (Light dependent Resistor)

As the intensity of light on this increases, the value of its resistance decreases, in this manner it is able to detect the light.

The most common type of LDR has a resistance that falls with an increase in the light intensity falling upon the device (as shown in the image above). The resistance of an LDR may typically have the following resistances:

Daylight = 5000Ω

Dark = 20000000Ω

But LDR has a very Slow response time and hence not viable for high speed data transfer.

Fig 13 : LDR

Solar Photodiode

A photodiode is a photovoltaic semiconductor device; however, these are optimised for light detection.

These can detect blinking in range of MHzs (avalanche up-to 1Ghz), hence can be used for data transfer at a much faster rate efficiently.

Fig14 : Photodiode

Chapter 3

Visible Light Communication

3.1 Serial Communication

Serial communication is the process of sending data one bit at a time, sequentially, over a communication channel or computer bus.
In Arduino, data can be transferred serially using the pins TX and RX which are used for serial communication.

In the model of the Smart Street Light, the data from the Arduino to the street light was sent using MOSFET as a switch, where it was used to give pulses of 1s and 0s which caused the blinking of LED.

The TX pin is given to the gate of the MOSFET whereas a 5V and Ground is given using Arduino in the Drain and Source respectively.

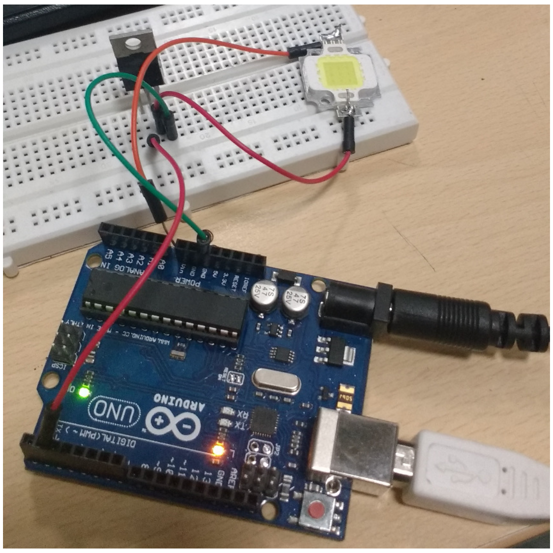

Fig 15：Serial Communication over TX

On the receiver side a solar receiver is used whose signals are given in the comparator which is then given to the RX pin of the receiving Arduino, through which it is fed into the system of the user.
LM311 is used as a comparator where voltage of 5V is given to its pin 2 through a potentiometer and the light sensor (Solar photodiode) is given to its pin 3

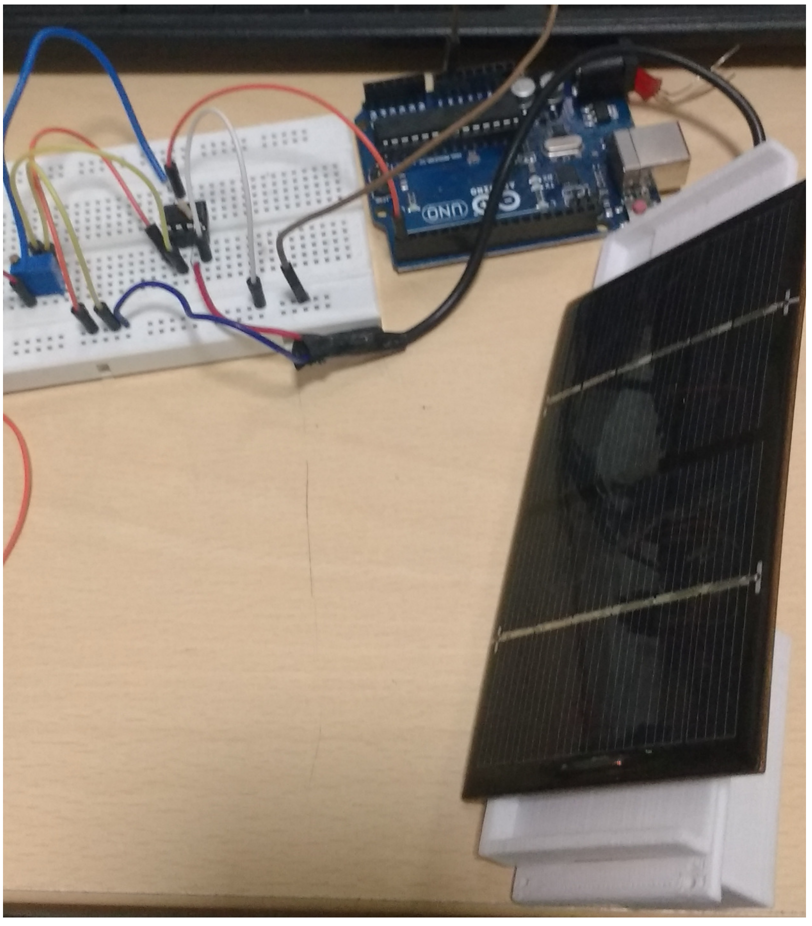

Fig 16 : Receiver Circuit

3.2 FSK Modulation

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier signal. The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

In this 1s and 0s are transmitted using different square waves of frequencies 1070 and 1270 Hz respectively.

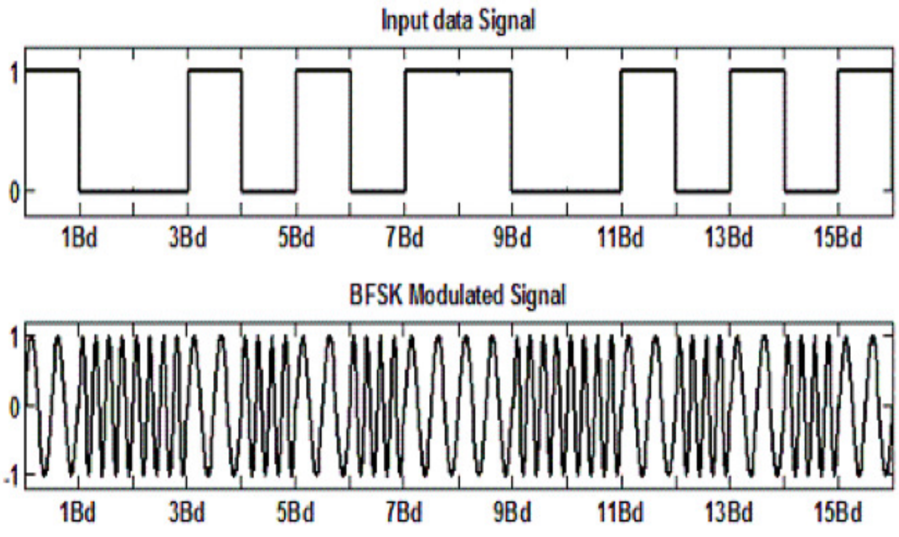

Fig 17 : FSK Modulation

FSK Modulator circuit

$V_{cc} = 5V$

R1 = 3 kΩ, C1 = 47 pF, R2 = open, R3 = 0 Ω, C2 = open

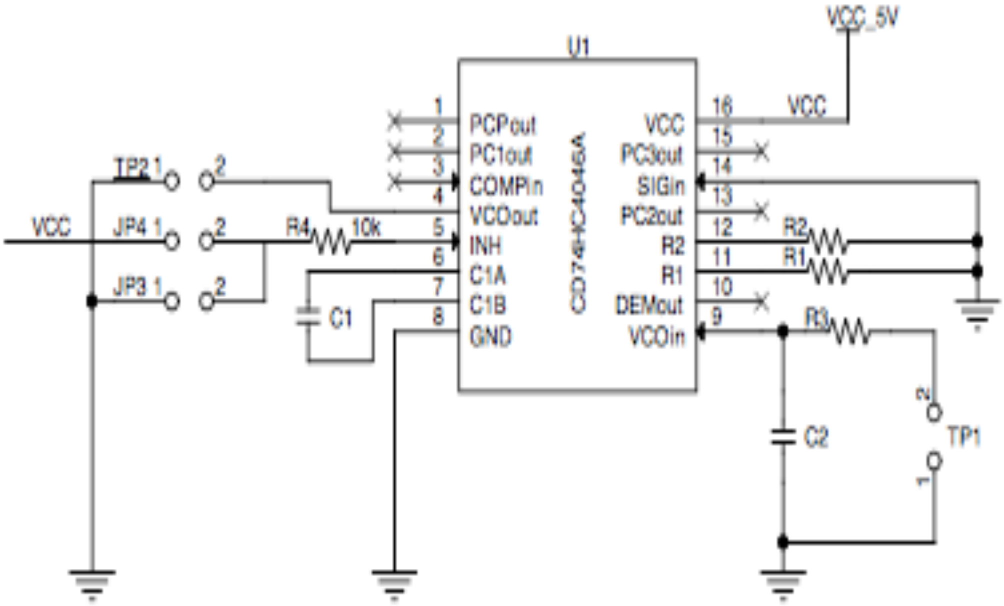

Fig 18: FSK Modulator Circuit

FSK Demodulator Circuit

$V_{cc} = 5V$

R1 = 3 kΩ, C1 = 47 pF, R2 = open,

R3 = 36 kΩ, C2 = 120 pF

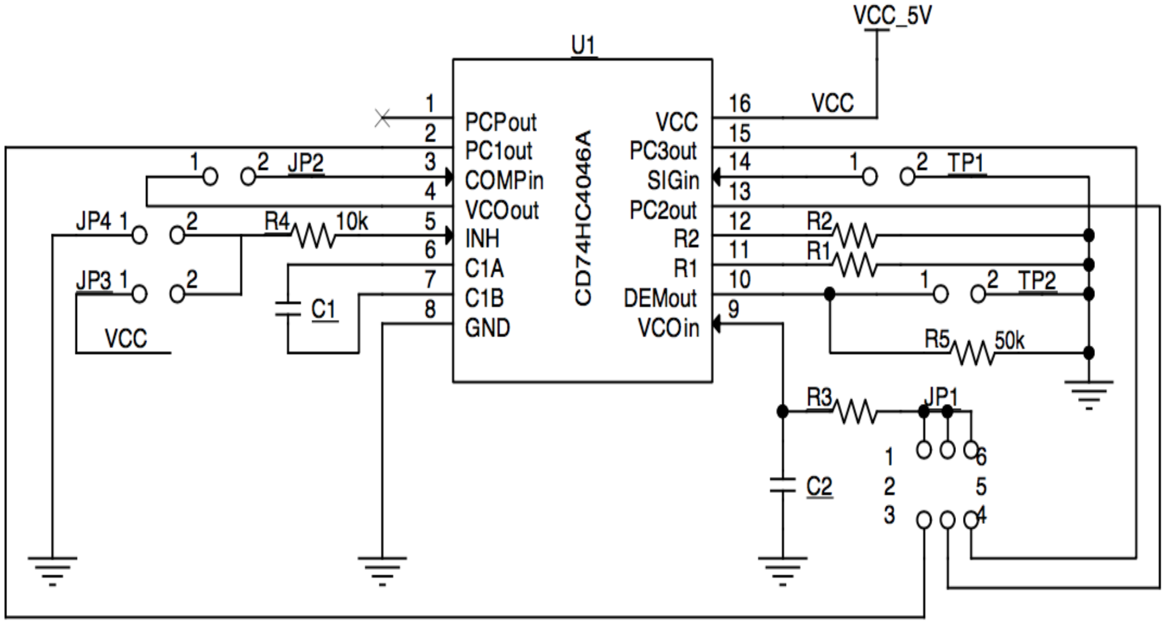

Fig 19 : FSK Demodulator Circuit

3.3 Manchester Encoding

Manchester encoding is a special case of binary phase shift keying(BPSK), where the data controls the phase of a square wave carrier whose frequency is the data rate.

In this each bit (1 or 0) is transmitted in a fixed period. It has transition at two places, in the middle and at the boundaries.

The direction of transition in the middle signifies the data while those at the boundaries do not carry any information.

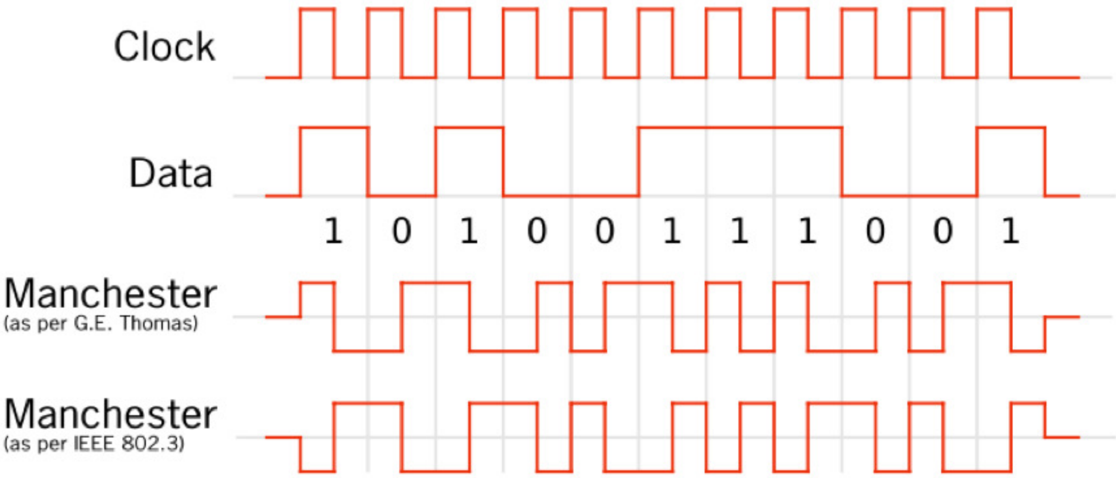

Fig 20 : Manchester Encoding

CHAPTER 4

Results

- The data from the sensors (Temperature and humidity, gas sensor, dust sensor, UV sensor, Noise sensor) was successfully obtained, converted to meaningful units and transferred to the user via smart street light.

- Using Serial Communication without using any Modulation technique, data in form of text was transmitted at a maximum baud rate of 9600, beyond which the data was not efficiently transmitted.
  Also the data was transmitted till a distance of maximum 30cms.

- Whereas, a Modulation technique enables data to be transmitted at farther distances as well as without errors.
  This will also help in transmitting data at much higher speeds.

FSK modulation waveforms for letters:

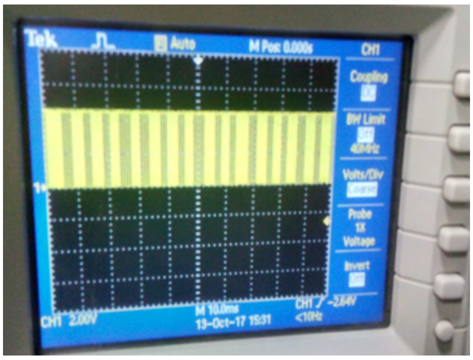

Fig 21 : FSK Modulated Waveform for ‘P’

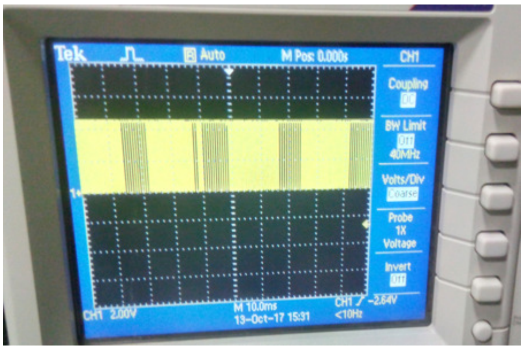

Fig 22 : FSK Modulated Waveform for ‘W’

- Through Manchester encoding a Baud rate of 38400 could be achieved.

CHAPTER 5

Conclusions

- The smart street light was successful in measuring the values of various parameters like Temperature, humidity, smoke, Dust, Noise and UV index which were converted to meaningful units and transmitted to the user using Visible Light Communication.

- Use of Photodiode in the receiver is more suited than using an LDR.

- Modulation technique is required to transfer the data at a faster rate and without errors. Two techniques, Frequency Shift Keying (FSK) and Manchester Encoding were tested successfully.

Future Scope :

Since the photodiode is a photovoltaic semiconductor device, it can provide energy to the system along with receiving data from the Street Lights.

Also with the Smart street lights, collected data about various parameters can also be sent to the respective departments like Pollution control department, Health Department and weather Department, since this data will be collected from every Smart street light, it will be quite diverse and will cover every part of the city, thus obviating the need to collect this data from various places by building special sensor stations.

Also using some other advanced Modulation techniques a data rate in Gbps can be achieved.

Connecting various street lights together to interact with each other can help save energy by dimming the lights when a low traffic is detected. This will help in saving a lot of energy which is being wasted by the conventional street lights.

With all these the Smart street can have a significant contribution in the Smart City Mission.

REFERENCES:

- An IEEE Standard for Visible Light Communicationsvisiblelightcomm.com, dated April 2011.Tsonev, D.; Sinanovic, S.; Haas, Harald (15 September 2013). "Complete Modelling of Nonlinear Distortion in OFDM-Based Optical Wireless Communication". IEEE Journal of Light wave Technology 31 (18): 3064–3076.doi:10.1109/JLT.2013.2278675

- http://ijarcsms.com/docs/paper/volume3/issue6/V3I6-0035.pdf : paper on advantages of Visible light communication over the conventional Wireless Fidelity .

- https://www.researchgate.net/publication/316738011_Index_Modulation_Techniques_for_Next-Generation_Wireless_Networks_IEEE_Access_Special_Section : Modulation Techniques for Visible Light Communication.

- https://www.arduino.cc : for different Arduino commands.

- An IEEE paper on Integrated LiFi(Light Fidelity) for smart communication through illumination (http://ieeexplore.ieee.org/document/7831599/)

- IEEE 802.15.7 visible light communication: modulation schemes and dimming support (http://ieeexplore.ieee.org/document/6163585/)

APPENDIX

Main Code:

```
#include <dht.h>
dht DHT;
#define DHT11_PIN 7
long int del=10000;
const int dustPin = A5;
const int uv_pin= A0;
const int noise_pin= A1;




void noise_sensor()
{
      long noise = 0;
    for(int i=0; i<32; i++)
    {
        noise += analogRead(noise_pin);
    }

    noise >>= 5;
    Serial.print("Noise = ");
    Serial.println(noise);
}

void temp_sensor()
{
    int chk = DHT.read11(DHT11_PIN);
  Serial.print("Temperature = ");
  Serial.print(DHT.temperature);
```

```
  Serial.println("  C ");
  Serial.print("Humidity = ");
  Serial.print(DHT.humidity);
  Serial.println(" % ");


}


void uv_sensor()
{
   int uvValue;
   long  sum=0;
   for(int i=0;i<1024;i++)// accumulate readings for 1024 times
   {
      uvValue=analogRead(uv_pin);
      sum=uvValue+sum;
      delay(2);
   }
   long meanVal = sum/1024;  // get mean value
   Serial.print("The current UV index is:");
   Serial.print((meanVal*1000/4.3-83)/21);// get a detailed calculating expression for UV
index in schematic files.


}


void dust_sensor()
{

float voMeasured = 0;
float calcVoltage = 0;
float dustDensity = 0;
```

```
  voMeasured = analogRead(dustPin); // read the dust value

  // 0 - 3.3V mapped to 0 - 1023 integer values
  // recover voltage
  calcVoltage = voMeasured * (5.0 / 1024);


  dustDensity = 0.17 * calcVoltage - 0.1;

 // Serial.print("Raw Signal Value (0-1023): ");
//  Serial.print(voMeasured);

  //Serial.print(" - Voltage: ");
  //Serial.print(calcVoltage);

  Serial.print(" - Dust Density: ");
  Serial.print(dustDensity);
  Serial.println(" mg/m3 ");

}



// Setup function
void setup()
{
  Serial.begin(9600);

}


// Main function
```

```
void loop()
{

 noise_sensor();
 temp_sensor();
 uv_sensor();
 dust_sensor();
 delay(del);
}
```

Code For Receiver:

```
char a;
void setup()
{

  Serial.begin(9600);

}

void loop()
{
	if(Serial.available())
	{
		a=Serial.read();
		Serial.print(a);


	}


}
```

Code for Manchester Encoding :

```
#include "ManchesterRF.h"
#define TX_PIN 3 //any pin can transmit
#define LED_PIN 13

ManchesterRF rf(MAN_38400);
#define asize 8
uint8_t data[asize];

void setup()
{
  Serial.begin(38400);
  pinMode(LED_PIN, OUTPUT);
  digitalWrite(LED_PIN, HIGH);
  rf.TXInit(TX_PIN);
}

void loop()
{

        for (int i = 0; i < asize; i++)
        {
                data[i] = 23;
        }
  rf.transmitArray(asize, data);
  Serial.print(*data);
```

```
  delay(100);
}
```

Code for Manchester Decoding:

```
#include"ManchesterRF.h"
#define RX_PIN 4
#define LED_PIN 13

ManchesterRF rf(MAN_38400);
uint8_t size;
uint8_t *data;

void setup() {
  Serial.begin(9600);
  pinMode(LED_PIN, OUTPUT);
  digitalWrite(LED_PIN, HIGH);
  rf.RXInit(RX_PIN);
}

void loop()
 {


        if (rf.available())
        {
        //something is in RX buffer
```

```
        if (rf.receiveArray(size, &data))
        {
            //process the data
            for (int i = 0; i < size; i++)
            {
                data[i]; //do something with the data
            }
            Serial.print(*data);


        }
    }

}
```

Executed Model :

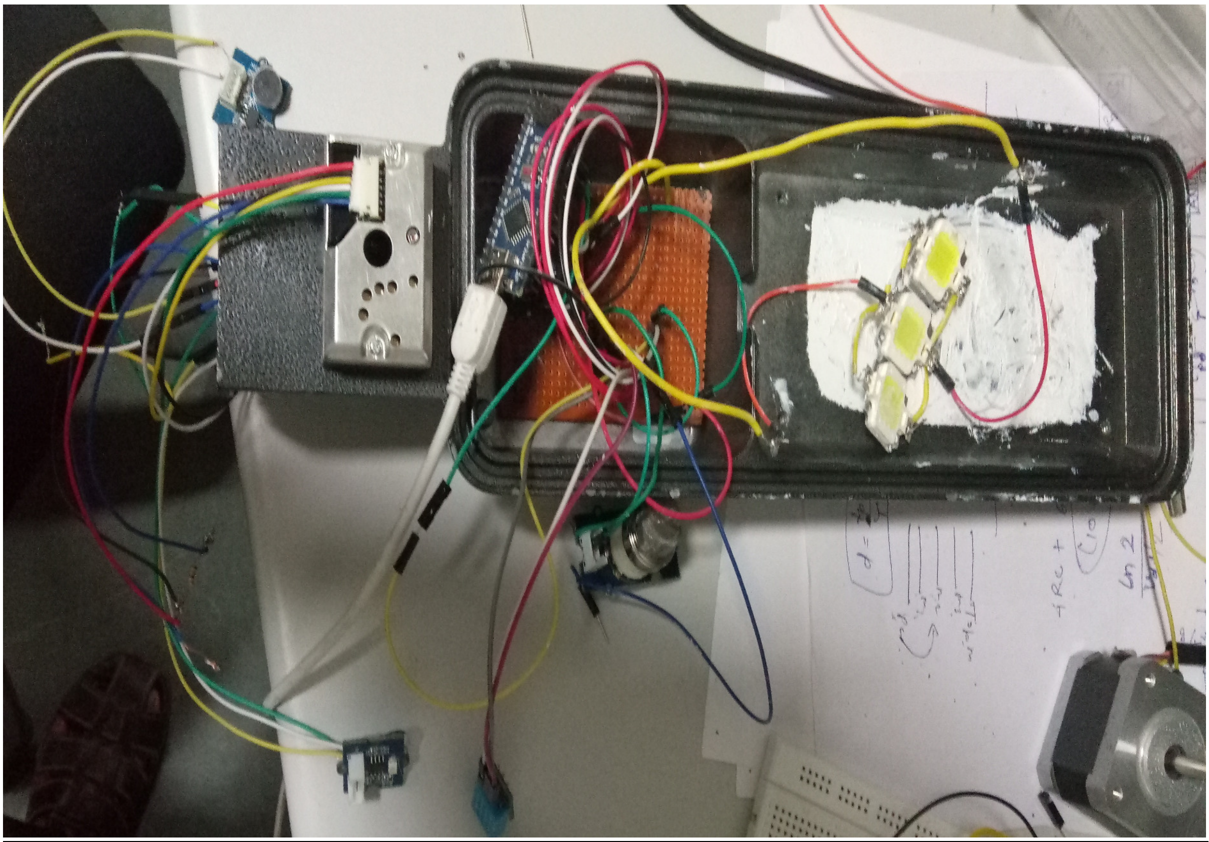

Fig 23 : Smart Street Light Model