IOT SOLUTIONS FOR SMART CITIES

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Abstract-* *Natural resources are excessively basic for our survival on this planet. With growing population, urbanization, the natural resources are being consumed in abundance. The expansion of cities also results in the pollution of the natural ecosystem. To ensure there is no wastage of resources, this project has been designed to optimize utilization of natural resources.

The project focusses on fabrication of smart lighting system, water leakage detection, smart waste management techniques and real-time air pollution monitoring all integrated together by the usage of a user-friendly APP.This paper comes to present how IoT enabled devices can help to diagnose any liability through data analysis. NODE MCU, Arduino UNO are employed to control the sensors and send data to the cloud. Various sensor networks like ultrasonic sensor HC-SR04, water level depth detection sensor, LDR collect data and provide it to a centralized server(cloud) using internet. Analysis of this data provides an overview to the user regarding the consumption and wastage of resources.

The data collected from the sensors is sent to ThingSpeak Analytics platform via NODE MCU wherein it will be used to create graphs which will be displayed to the user on the APP.

Smart bins are designed to inform the user whenever the bin is full and also the fill levels are displayed in the form of a graph to let the user reflect on the production of waste. Smart lighting system incorporates sensors to automatically switch on the street lights during night time and also controls the intensity of the LEDs depending on the presence or absence of vehicles. The APP also includes real time Air Pollution levels obtained from an external API. In case of leakage from water tanks, geysers, the alert button turns RED on the APP.

Keywords: Smart city; Internet of things (IoT); communication technologies, Smart Dustbin, Smart Street Lighting System, MIT App Inventor, water leakage detection, External API.

1. INTRODUCTION

A. Depletion of Natural Resources

Natural resources are excessively basic for our survival on this planet. With growing population, urbanization, the natural resources are being consumed in abundance. According to a study by WHO, 785 million people lack even basic drinking water service. This calls for some serious consideration on the wastage of water. The power consumption in cities reduces by 63% when they employ smart lighting system. Nowadays, most of the lighting systems use LEDs which use about 75% less energy and they last 25 times longer than incandescent bulbs. Waste generated in India amounts to about 62 million tonnes per year and only 70% of it gets collected and around 31 million tonnes are dumped into landfills. These figures indicate that there are huge amounts of waste being generated and there is also no efficient system between municipality and residents to enable smooth functioning of waste collection. The drastic increase in the pollution levels due to industrialization has been of great concern to us since they affect physical and biological entities in our environment. In our project, we have also collected real time data showing the air pollution levels. This summarizes the importance of natural resources and our focus is to ensure its judicious consumption.

B. State of the Art Technologies

A number of studies in recent research work has focused on Smart cities as an interdisciplinary approach. Some of the existing work related to smart cities concepts are briefly discussed below.

"Smart Cities" in 2018 IEEE Digital [1] special issue brings together recent international research on one of the most challenging and multidisciplinary subjects of present and future engineering, architectural, medical, economic, information, and social sciences: the smart city paradigm. It provides an analysis of how designing smart cities is an interdisciplinary approach.

"Leak Detection System using Arduino" in International Journal of Engineering Research & Technology (IJERT) describes a modern, efficient leak detection system with fast and accurate data transfer [2]. The system makes use of IoT for leak detection in real time.

"Design a Smart Waste Bin for Smart Waste Management" in 2017 5th International Conference on Instrumentation, Control, and Automation (ICA) Yogyakarta, Indonesia [3] summarizes the main concept of smart waste management system which is to handle all the waste in the city and monitoring all the process. The real time accurate data from the implemented system could be used for the efficient solid waste management system.

"Smart Street Lighting" in International Journal of Engineering Research & Technology (IJERT) [4] explains how smart street lighting controls the luminosity of light based on the motion and performs automatic light dimming which is an aspect that serves to reduce energy consumption. It potentially reduces streetlights' operation and maintenance costs, offers additional benefits in terms of safety, security, efficiency, versatility, and scalability, and sets the stage for further smart city applications.

C. Scope And Innovation

The concept of smart cities involves feeding data into an online platform. This project has made use of ThingSpeak Analytics. The major objectives of this project are:

a. To design energy efficient and environmentally sustainable smart city solutions using IoT and sensors, like, smart lighting system, water leakage detection, smart waste management techniques and real-time air pollution monitoring.
b. Usage of data to plot appropriate graphs which can be efficiently processed for implementation

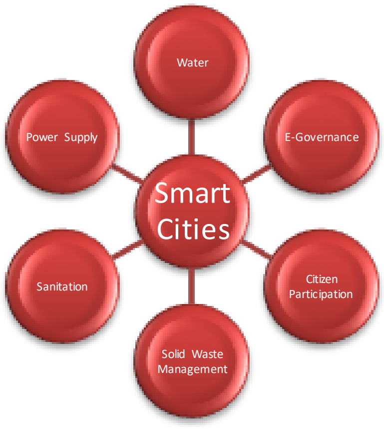

Figure 1: Components of Smart Cities

2. METHODOLOGY

A. ARCHITECTURE

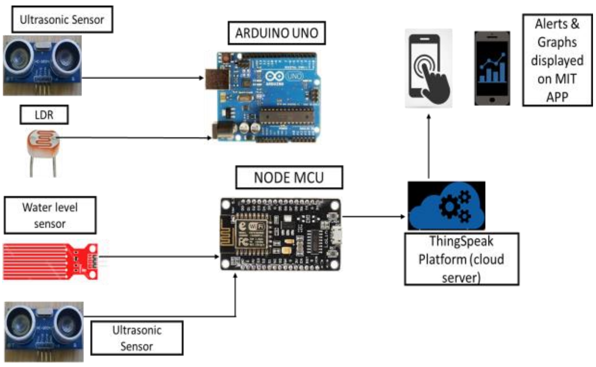

Figure 2: Architecture Block Diagram

The project focusses on fabrication of smart lighting system, water leakage detection, smart waste management techniques and real-time air pollution monitoring all integrated together by the usage of a user-friendly APP.This paper presents how IoT enabled devices can help to diagnose any liability through data analysis. NODE MCU, Arduino UNO are employed to control the sensors and send data to the cloud. Various sensor networks like ultrasonic sensor HC-SR04, water level depth detection sensor, LDR collect data and provide it to a centralized server(cloud) using internet. Analysis of this data provides an overview to the user regarding the consumption and wastage of resources.

The data collected from the sensors is sent to ThingSpeak Analytics platform via NODE MCU wherein it will be used to create graphs which will be displayed to the user on the APP created using MIT APP Inventor. Smart bins are designed to inform the user whenever the bin is full and also the fill levels are displayed in the form of a graph to let the user reflect on the production of waste. Smart lighting system incorporates LDR sensors to automatically switch on the street lights during night time and also controls the intensity of the LEDs depending on the presence or absence of vehicles detected by the ultrasonic sensors. The APP also includes real time Air Quality Index (measure of toxicity) obtained from an external API. In the leakage detection system, water level sensors are placed in the pan which surrounds the tank. They are used to check if there is leakage and the alert button turns RED on the APP if water is detected.

B. MICROCONTROLLER BOARDS AND SENSORS

The main components used in this project are Arduino UNO, NODE MCU, HC-SR04 (ultrasonic sensor), water level depth detector, LDR, servomotor and LEDs.

Arduino UNO:-

Arduino is an open source platform develpoed by Arduino.cc which makes use of ATmega328P microcontroller board. It has 14 digital pins, 6 analog pins and an in-built LED. It is programmable on Arduino IDE. It has a flash memory of 32 KB, SRAM of 2 KB.

Figure 3: Arduino UNO

NODE MCU:-

NODE MCU is also an open source platform IOT platform similar to Arduino but it also integrates Wi-fi by having an inbuilt ESP8266 Wifi Module. It has low power consumption and has only 1 analog pin and 11 digital pins.

Figure 4: NODE MCU

HC-SR04 Ultrasonic Sensor:-

It is an instrument that measures the distance of objects by employing a crsytal oscillator of piezoelectric material 4MHz. It uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. It has 4 pins- Vcc, GND, Echo Pin and Trig Pin. It requires a Vcc voltage of 5V for operation.

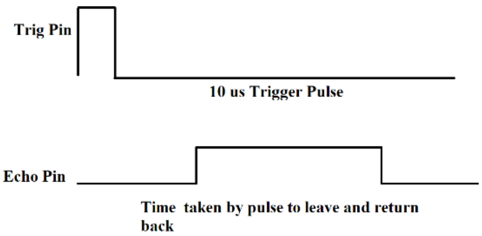

Figure 5: Working of Ultrasonic Sensor

Distance= (time * speed of sound)/2

This formula is used to calculate the distance.

Figure 6: Ultrasonic Sensor

Water Level Sensor:-

It is a vertical sensor containing parallel metallic strips that are separated from one another. As the water level changes, the water acts as a conductor between the strips thereby changing the resistance of the water level sensor. This enables to find the water level of the container in which it is placed. It has 3 pins- S,+ and –

Figure 7: Water level sensor

LDR:-

Light Depedent Resistor, also known as, photoresistor, is a light sensitive device used to measure the intensity of light. As the illumination of the light increases, resistance decreases.

Figure 8: LDR

Servomotor:-

It is an electrical device which contains DC motor, rotating shaft, gears and potentiometer which is used to rotate part of a system to different angles as specified by the code.

C. THINGSPEAK IOT PLATFORM

ThingSpeak is an open source IOT application which can store and retrieve data coming from various sensors. It enables the creation of various public and private channels wherein the analysis of this data is undergone by generation of graphs and widgets. Each channels is provided with two API KEYS – Read API KEY(to obtain data stored on the cloud), Write API KEY(to store data into the cloud). It also has built-in MATLAB Analytics which processes the data from IOT enabled devices and performs various mathematical calculations to generate the desired output. By including the unique channel ID and WRITE API KEY in the code for NODE MCU, we can send data recorded by the sensor directly to the cloud. The directory <thingspeak.h> files must be included in order to accomplish this. ARDUINO IDE has this directory under "Library" and it must be installed at the start.

D. MIT APP INVENTOR

MIT APP Inventor is an online platform that allows the creation, design and expansion of APPs. It is provided by the Massachussets Institute of Technology(MIT). It has a user-friendly interface that allows easy app development even eithout much in-depth knowledge. It basically has two tabs under app development- Designer, Blocks. Designer tab includes a pre-defined pallate that has allows display of various items like buttons, lists, text headers, labels, etc. The properties of these items such as size, colour, background,etc. can be varied, thereby, allowing the user to have a customized APP. The Blocks tab, on the other hand, has a list of in-built functions that can be dragged and dropped onto the main screen. Therefore, this tab covers the programming aspect of the APP. The use of blocks enhances code readability.

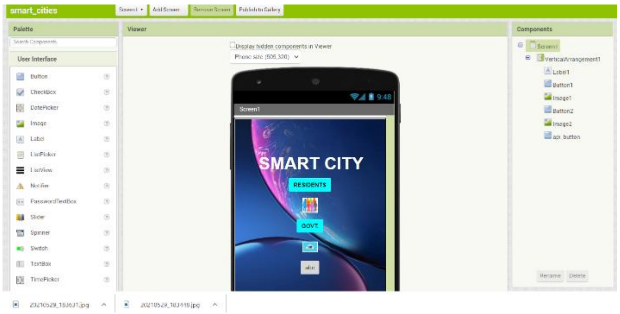

Figure 9: Interface of MIT APP Inventor

There is a viewer section which continuously displays the APP's view.

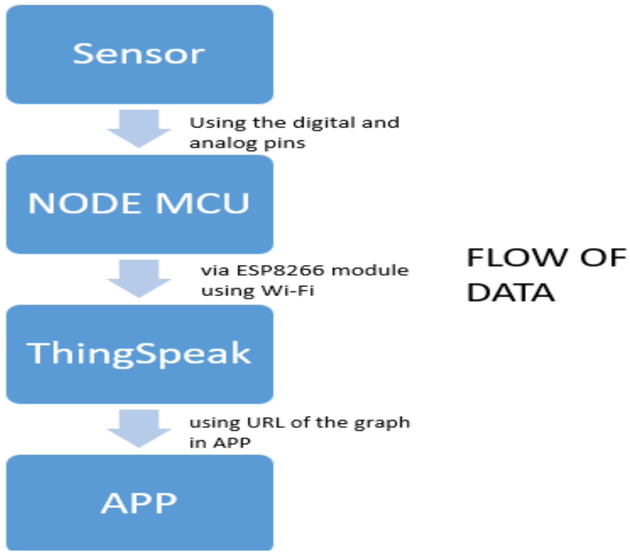

Figure 10: Flow of Data

3. IMPLEMENTATION

a. Smart Dustbin system

Smart Dustbins consist of a servo motor for automatic opening and closing of the lid and another ultrasonic sensor for detection of waste. One ultrasonic sensor is fixed at the bottom of the lid using which the depth of the dustbin can be determined. Corresponding to the depth of the dustbin, the level up to which it is filled can be determined and hence if it is filled or not. The data of level of dustbins filled, is uploaded to the cloud, ThingSpeak. ThingSpeak generates a graph with this data, that can be used to analyse the level up to which dustbin is filled at different instants (at an interval of 20 seconds). Also, a widget called Button is added on the cloud, which is initially pale in colour, when dustbin is not 100% filled. As soon as it gets completely filled i.e., 100%, the button turns brighter. The URL of the ThingSpeak button is put into the APP. So, the changes in colour of button and graph are displayed on the app simultaneously. Every time the dustbin gets filled; the button turns brighter, hence alerting the users to empty the bin. In this way, the sensors and motor, along with the cloud and app are integrated for the smart functioning of waste management system.

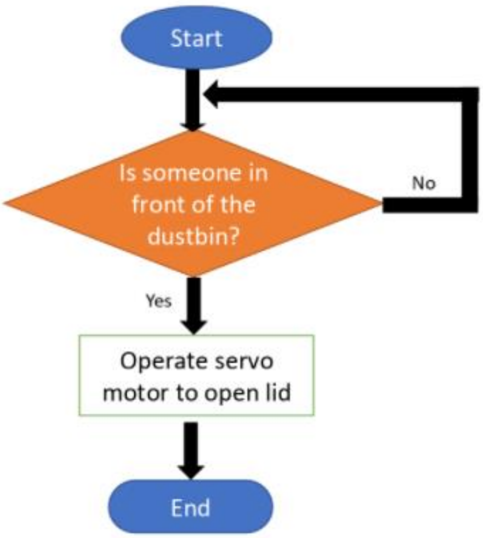

Figure 11: Flowchart

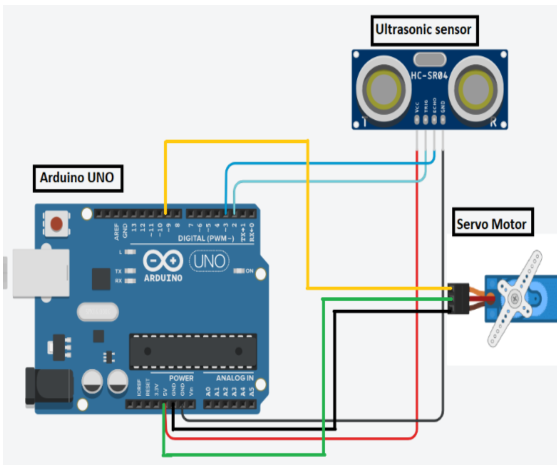

Figure 12: Block diagram showing connections for Arduino UNO

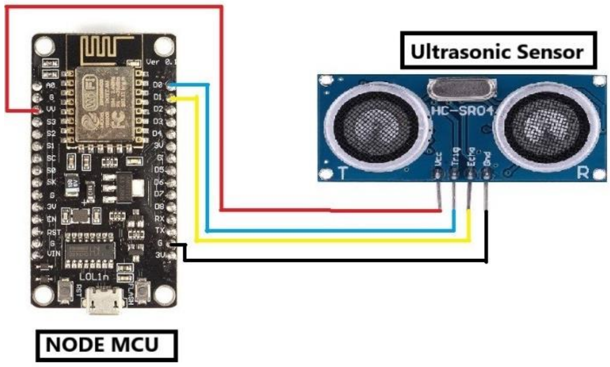

Figure 13: Block diagram showing connections for NODE MCU

Code for automatic opening of dustbin lid:

```
if(distance<5)
{
 for (pos = 0; pos <= 300; pos += 1)
{   myservo.write(pos);

   delay(15);
  }
  for (pos = 270; pos >= 0; pos -= 1)
{    myservo.write(pos);

   delay(15);
  }
}
else{
  myservo.write(0);
}
```

Code for sending fill level to ThingSpeak:

```
if(distance<200)

{

  ThingSpeak.writeField(myChannelNumber,
3, 0, myWriteAPIKey);

}
  else if(distance>200 && distance<=375)
```

```
{
  ThingSpeak.writeField(myChannelNumber,
3, 25, myWriteAPIKey);

}
  else if(distance>375 && distance<=550)
{

  ThingSpeak.writeField(myChannelNumber,
3, 50, myWriteAPIKey);

}
  else if(distance>550 && distance<=725)
 {

 ThingSpeak.writeField(myChannelNumber,
3, 75, myWriteAPIKey);

}
  else if(distance>725)
  {

ThingSpeak.writeField(myChannelNumber, 3,
100, myWriteAPIKey);

}
  delay(20000);
```

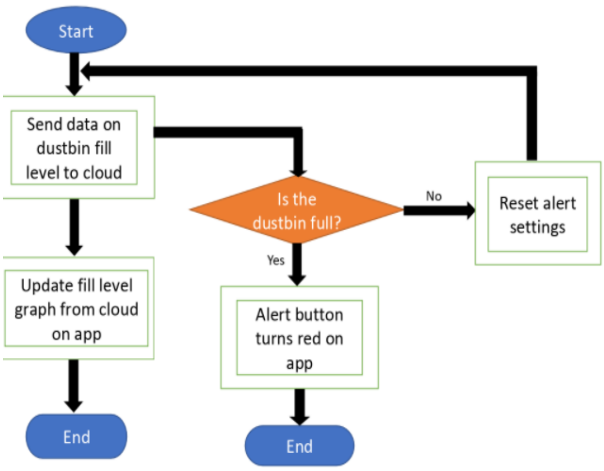

Figure 14: Flowchart for smart dustbin system

b. Smart street lighting

The street light's luminosity is based on the intensity of the sun light on LDR and the motion of objects sensed by the ultrasonic sensors. If the intensity of sunlight on LDR is low, lights are required to switch ON with low intensity. If the object detected by the ultrasonic sensor is within a certain range from a particular street light, then the intensity of that street light increases while the others glow at the same intensity (since it's beyond certain range of distance from the others). In this way, for every street light incorporated with an ultrasonic sensor, it can be determined if the object has moved closer/farther and if it is within/beyond a particular range of distance, at any instant. In this way, the smart street light system functions.

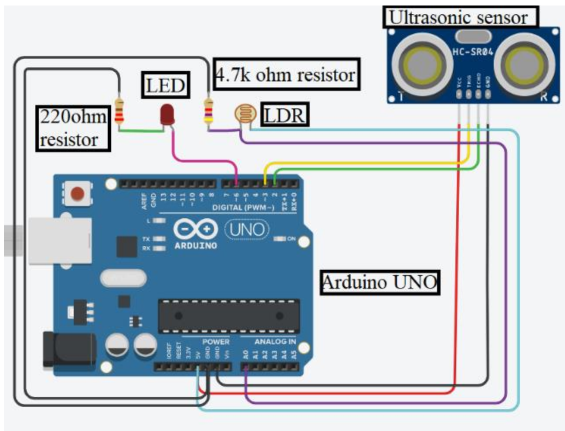

Figure 15: Block Diagram showing connections

Program to operate smart street lighting system: -

```
duration1=pulseIn(echo1,HIGH);

distance1=(duration1*(0.0343))/2;

if(sensor<25)

{

 if(distance1<12)

{

  analogWrite(LED1,255);

  delay(50);
```

```
}
else
{
 analogWrite(LED1,15);
}
else
{
  digitalWrite(LED1, LOW);
}}
```

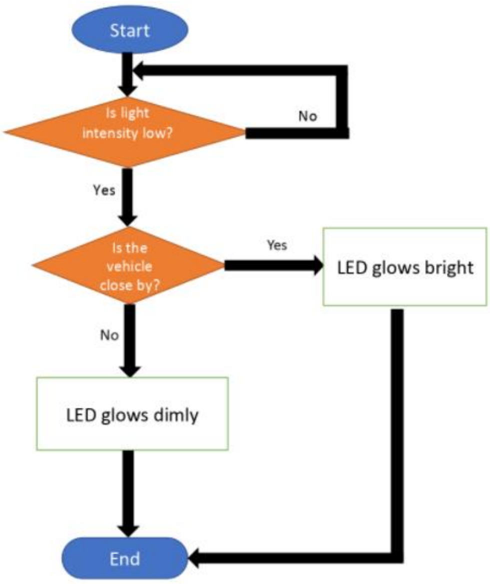

Figure 16: Flowchart depicting working of smart lights

c. Water leakage detection

The system comprises of a water level sensor, that is used to detect the leakage. In practical use, the water level sensor is placed in a pan surrounding the tank. In case of a leakage, the water flows into the pan from the tank and the sensor is immersed in water. Change in the water level contributes to change in the output voltage. This output is uploaded to the cloud, ThingSpeak. On the cloud, a widget called Button is added which is initially pale in color for no leakage detected. Every time a leakage is detected (output voltage higher than certain threshold), the button immediately turns brighter in color. By establishing a connection between ThingSpeak and MIT app, the data can be read from the cloud onto the app. Hence, the color transition of the button is reflected on the app also simultaneously i.e., as soon as leakage is detected the button visible on the app turns brighter else remains pale, thus alerting the user of the leakage detected. In this way,

water leakage can be identified and notified efficiently.

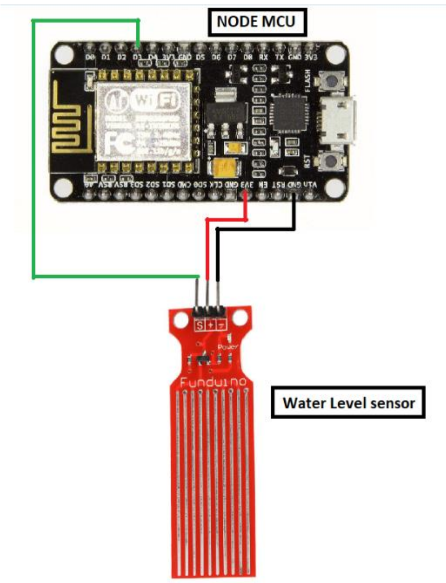

Figure 17: Connections for water level sensor

Program to send water level sensor value to ThingSpeak:

```
sensor=analogRead(A0);
ThingSpeak.writeField(myChannelNumber, 3, sensor, myWriteAPIKey);
```

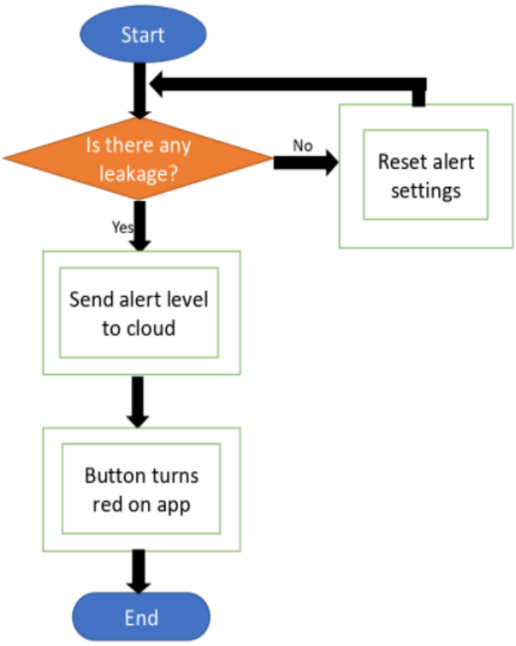

Figure 18: Flowchart for leakage detection

d. Air Pollution Monitoring

In order to obtain real-time data of air conditions of a particular place, an external API is used. The external API specifies the concentrations of different components of air and hence determines the AQI i.e., Air Quality Index of desired location. The data from the API is transferred onto the app, wherein, the users can view and analyse the conditions of air of a particular location, in an organized way. In this way, air pollution levels of any location can be monitored.

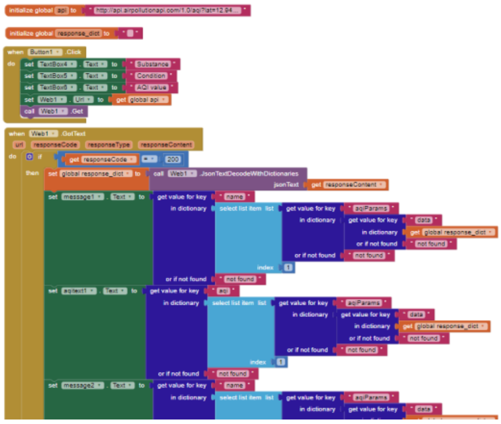

Figure 19: Code for getting data from external API

4. RESULTS AND DISCUSSIONS

A prototype of the solutions provided in the project is made which includes Smart Street Lighting System, Waste Management System, Water leakage Detection System and Air pollution monitoring. This system has been tested practically as shown from fig.20 to fig.26.

- Implementation of this system enables the user to obtain all necessary alerts on the app created as shown in fig.23.
- The smart lighting system is functional in reducing power consumption in cities by a large amount.
- The smart dustbin system provides a report to the user about their waste consumption in the form of an easily understandable graph and alerts them when the bin is full using a button. Further, the dustbin usage statistics can be analyzed by the municipality or other concerned bodies to redistribute the bins in an area to optimize the usage of bins without spending more on buying more dustbins.
- The water leakage detection system provides an alert to the user on the app using a button in case of a leakage. In this way, quick action can be taken thereby reducing wastage of water.
- The air pollution monitoring system enables the user to be aware of the air quality of their region.

Figure 20: Automatic Opening of smart dustbin

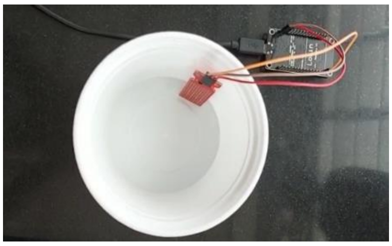

Figure 21: Water leakage detection system

Figure 22: Practical application of water level sensor

Figure 23: Overview of APP

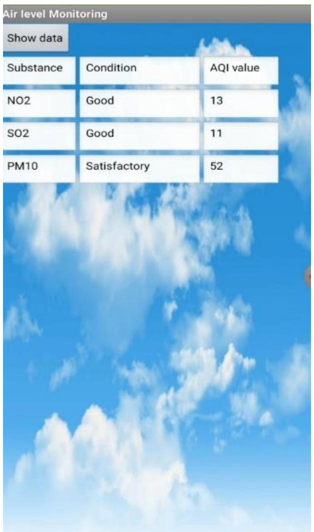

Figure 24: Air Pollution Monitoring

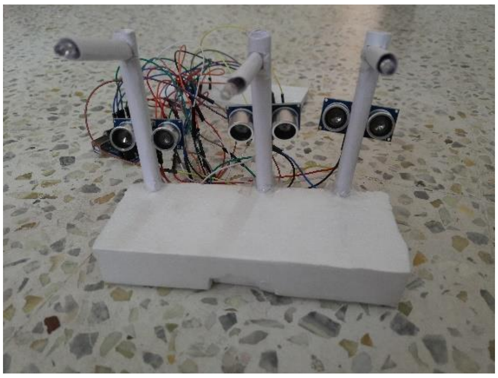

Figure 25: Smart Street Light System

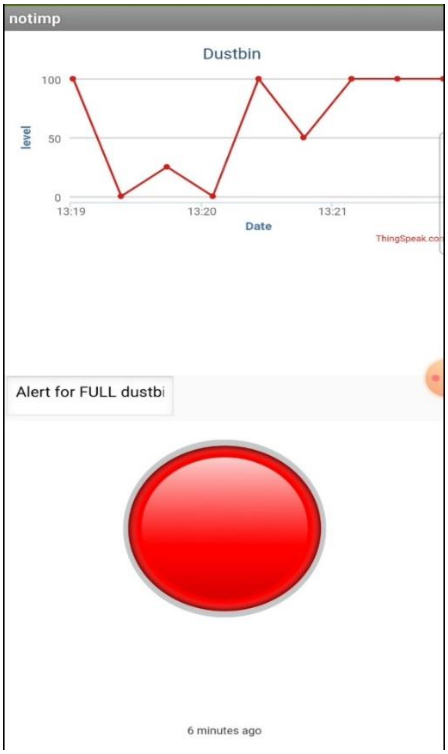

Figure 26: Alert for full level and graph corresponding to smart dustbin on the APP

5. REFERENCES

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