Chapter 4: Air Quality Monitoring System

4.1 Problem statement

This section of the research depicts the problem statement of the project, which has encouraged us to go on with the project. According to research, the average annual PM 2.5 concentrations in Bangladesh were 77.1 micrograms per cubic meter (mcg/m3) of air, which is seven times higher than the WHO exposure guidelines, with Dhaka standing second among 106 countries. Investigators from IQAir, a worldwide air quality information and technology enterprise, evaluated pollution data from 106 nations, specifically detecting PM2.5, a microscopic pollutant that can pose serious health concerns.

To eliminate the climate change crisis, we have chosen a set of sensors with a microcontroller to detect the concentration of pollutants and monitor the data patterns. It will be turned to an IoT based device after the set of sensors are connected to the development board.

4.2 Proposed solution

We want to create an online web based big data driven solution which will help us monitor air quality and will help us make data driven decision making

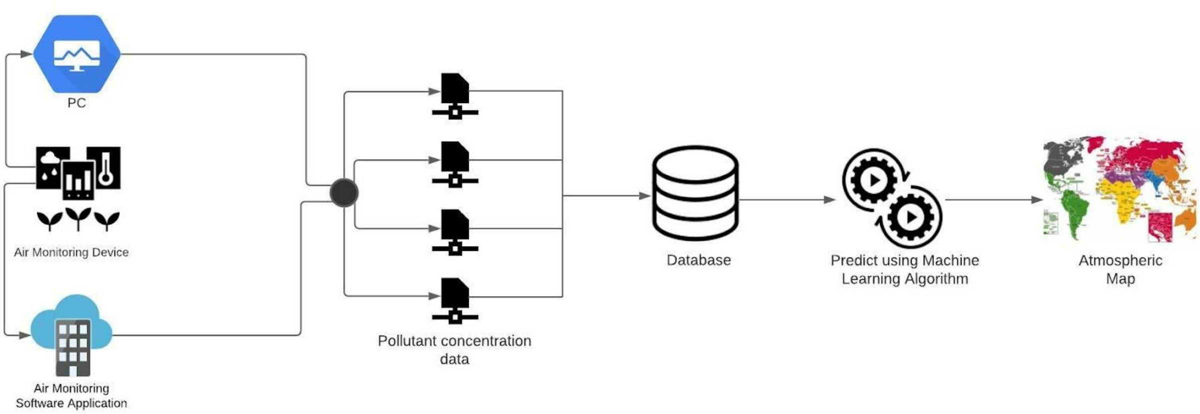


Figure 4.2: Rich picture of Proposed solution

4.2.1 Data Collection

The process of perceiving a mitigating solution to the universal catastrophe, comes with a proposed methodology to prove a hypothesis. Doing literature review is one of the classic ways to gather information on the ways to collect data by getting introduced to multiple mechanisms - which we did in our paper. After doing multiple literature reviews on Q1 category journal papers, we deduced to a method to execute our project proposal. This chapter of the report is a thoughtful process which can lead the project to a fruitful conclusion. However, the design, implementation and evaluation will be discussed here.

For the detection of contaminating toxic gases, it is necessary to outsource the sensors with greater accuracy that is available and inexpensive, keeping in mind about the budget friendly factor. After sourcing the sensors, it is vital to narrow down the suitable methodologies that will lead the project to its outcome. To determine the most-fitted procedure, it is better to do a literature review to execute the goal and fix the steps. The stated process above will be executed according to the proposition.

According to the proposition design, the sensors will be mounted to multiple cars as nodes.When the car is in motion, the device takes readings from sensors every minute and uploads the data to the website with the location and time stamp. Whenever the vehicle is in idle position, the set of data is only taken a few times an hour for data efficiency. When a car is within the coverage area of an available WiFi hotspot, all data is uploaded to the server, processed and published on the SensorMap portal. Given a sufficient number of nodes and diverse mobility patterns, a detailed picture of the air quality in a large area will be obtained at a low cost. These readings along with temperature and relative humidity data and GPS information are stored on the website. A 2x16 character LCD panel provides immediate visual feedback about the status of the system (connected interfaces, GPS lock, time, motion detection, sensor readings). The Arduino Mega microcontroller controls every aspect of the system since it is incorporated with all the sensors. Lipo batteries are used to power the system.

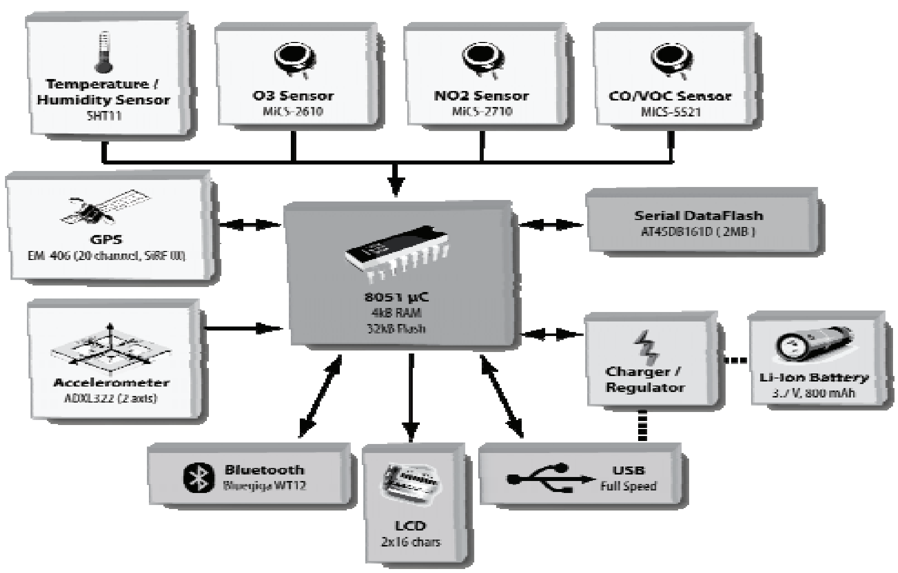


Figure 4.2.1: Block diagram of Proposed System

4.2.2 Data Preprocessing

Data preprocessing is a data mining technique that involves transforming raw data into an understandable format. To make the process easier, data preprocessing is divided into four stages: data cleaning, data integration, data reduction, and data transformation.

4.3 Result Analysis

Sensor mobility is handled using the SensorMap mobile proxy feature. Overall air quality will be displayed in the form of contour maps utilizing image overlays. The time series data for a given sensor and/or a given geographic location will be also available. The figure below illustrates the visualization techniques employed by the MAQUMON system.

4.3.1 Reporting

The demonstration will have two main parts. First, the prototype hardware platform will be shown, and its operation demonstrated. Secondly, the visualization of sensor map. The following area wise reporting are shown in the below figures.

4.3.1.1 Country wise overall monitoring

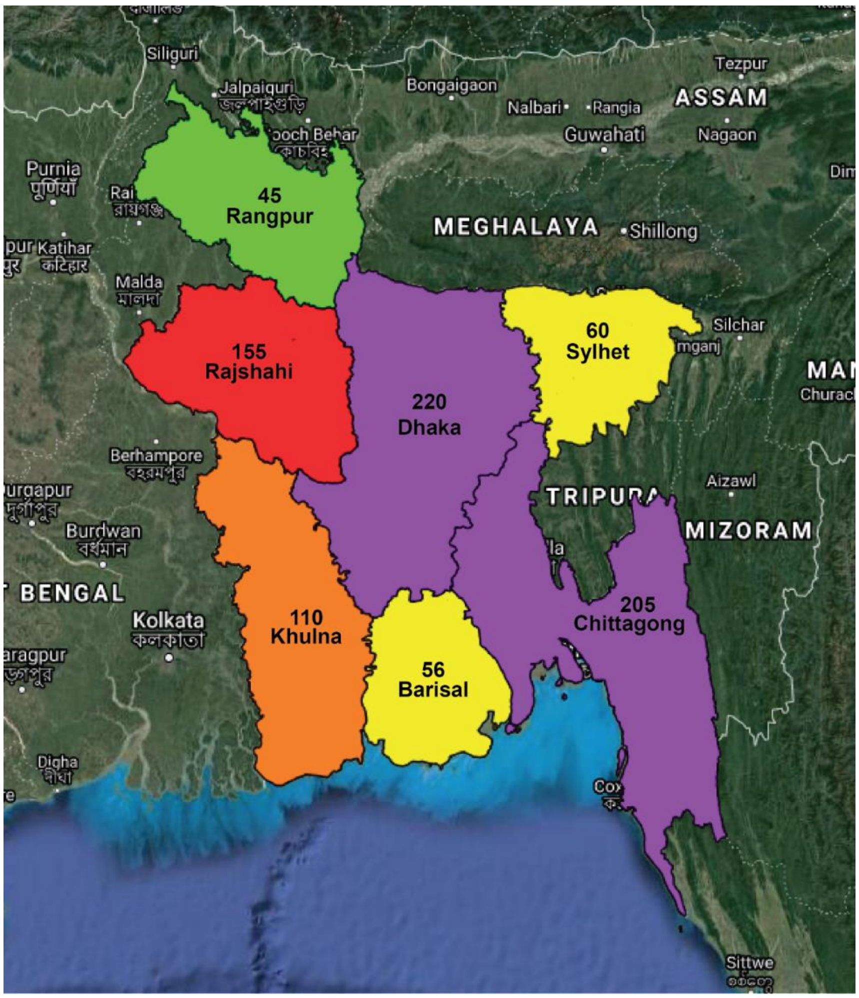


Figure 4.3.1.1: Country wise monitoring

4.3.1.2 Specific region monitoring (for industrial areas / power plant)

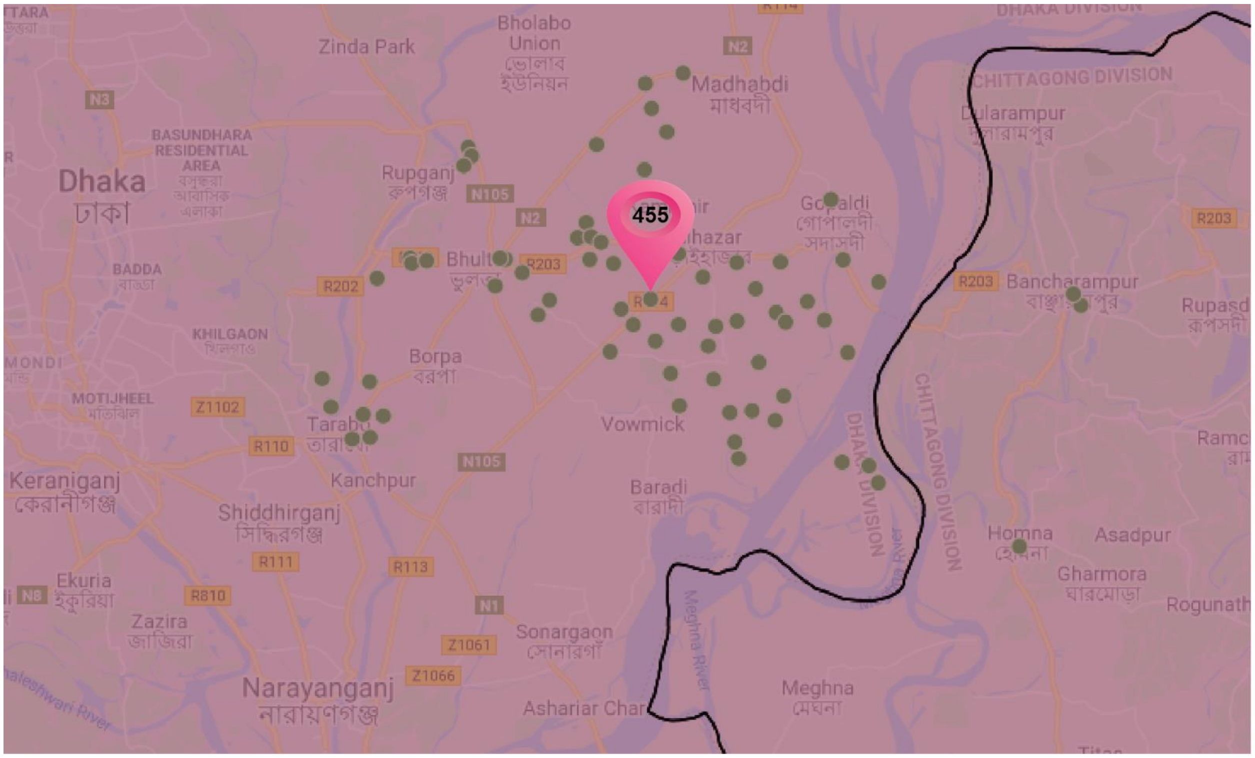


Figure 4.3.1.2: Industrial Area monitoring

4.3.1.3 Transportation route monitoring for both land and marine

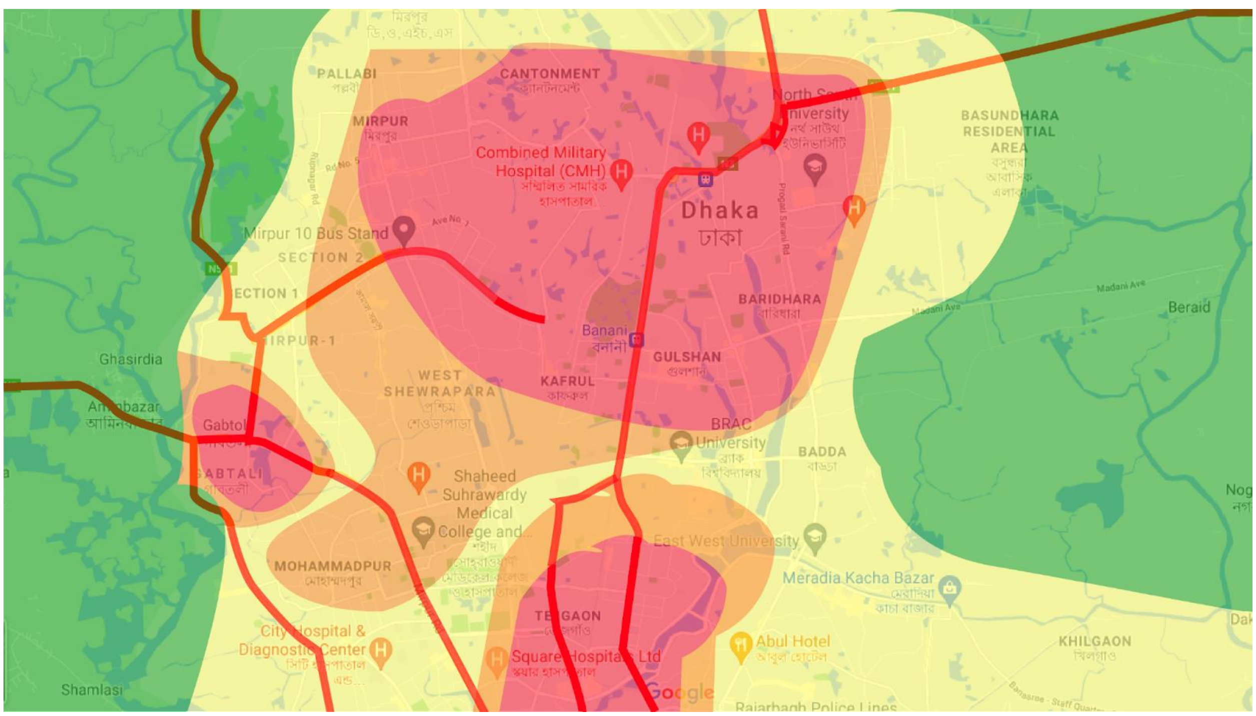


Figure 4.3.1.3: Transportation Route monitoring

Chapter 5: RefinAir

5.1 Overview

The main concern of this project is to focus on IoT based devices and to distinguish if the IoT based device is as equal as the industrial graded device, by looking into the data and evaluating accuracy of the device that we have made and provide a low-cost solution. Collation of data is determined to be done to examine the accuracy of the data retrieved from the IoT based device. Errors are measured and compared to justify that our IoT based device is as good as the industrial ones. Sidewise, heading to the goal of finding an inexpensive solution, we will be learning more about the advanced air monitoring technology used by AirVisual Pro and explore the reasons why this device is chosen.

In 1963, the history of cleaning air and improvisation of AQI started from the brothers, Manfred and Klaus, who created residential air filters in Switzerland that are now used by more than 70 countries. This device has received applause from customers and air quality experts around the globe. It is known to be used in Olympics because it refines 99.5% of all the ultrafine particles and is proven to deliver medical-grade air using HyperHEPA technology. The 3D ultraseal is designed to eliminate air leakage.

IQAir Earth is the first ever 3D air pollution map. It delivers indoor and outdoor monitoring systems - providing hourly weather and air pollution forecasts and alerts if air becomes unhealthy. The world's first air quality application was introduced by IQAir, which gives real-time data and shows historic air quality information. to be compared with the IoT based device, RefinAir.

5.2 Pre-Prototype

Since RefinAir is the prototype we are making based on our hypothesis, a pre-prototype was made before the prototype as a representation of a design produced before the final solution on an experimental basis.

5.2.1 Objective

The project intends to measure the temperature, humidity, pressure, TVOCs, and multiple toxic gases. Since it is a prototype, we have used very low-cost sensors with a probability of fluctuation in the set of data, along with questionable quality of sensors in case of longevity, as one of the prime reasons why we chose these pairs of sensors for prototyping, for which it serves well, and not for the main project.

5.2.2 Hardware Design

The DHT22 (Temperature & Humidity Sensor), BMP280 (Barometric & Humidity Sensor) are used to measure the amount of humidity, temperature and air pressure simultaneously.MQ2 Gas Sensor will detect CO, LPG, and smoke in the surrounding area. The proposed model relates to a third-party platform called Blynk through a local server. Blynk allows the user to get live streams with the help of the ESP ESP8266 ESP-01 module to connect to Wi-Fi and for communication. If the readings breach the parameter, a warning will be sent to the users' smartphones via email/messages. On the other hand, if the sensors in our device fail to predict the sudden changes in gases around the surroundings, as an alternate, we have used PIR sensors, which is also connected to the device, to inform the user about the upcoming hazard - only when the changes between the initial and data are prominent, which means when the fire will spread to a large scale. Additionally, PIR sensors can also be used to detect illegal entries. Using the Relay module and the Wi-Fi module, the user can also directly turn ON and OFF the electric power supply to prevent any further damages.

However, the following picture is given to demonstrate the proposed system.

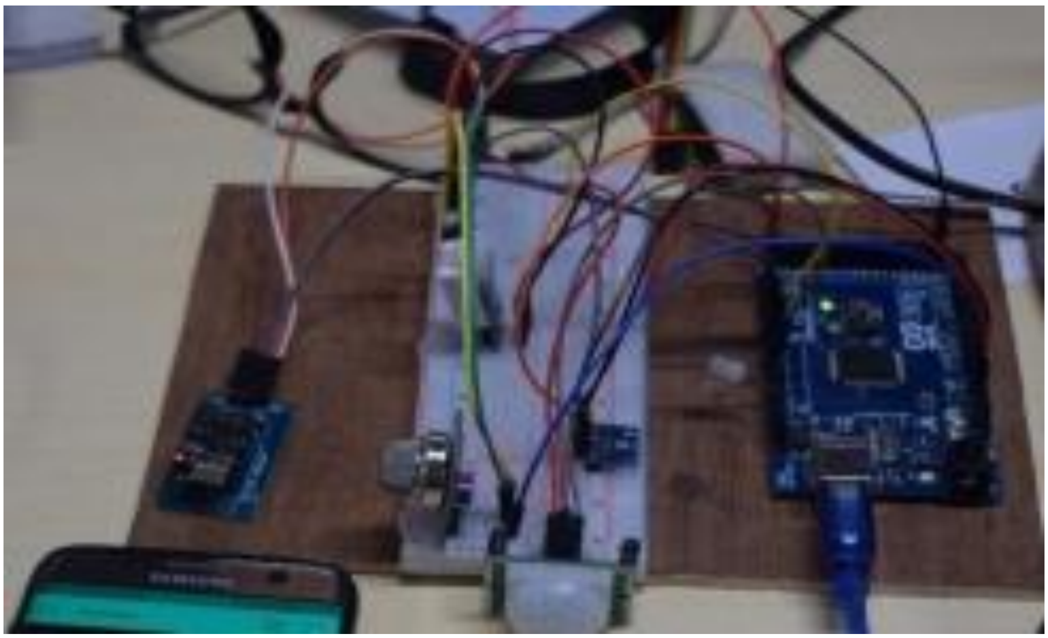


Figure 5.2.2: Proposed hardware system of the prototype

5.2.3 Result Analysis

In this section, the pictures below demonstrate the results on the third-part application called Blynk. The data from the sensors are being uploaded to this platform through a local server and are shown in the Graphical User Interface (GUI). Blynk allows the user to get live streams with the help of the ESP8266 ESP-01 module to connect to Wi-Fi and for communication. If the readings breach the parameter, a warning will be sent to the users' smartphones via email/messages.

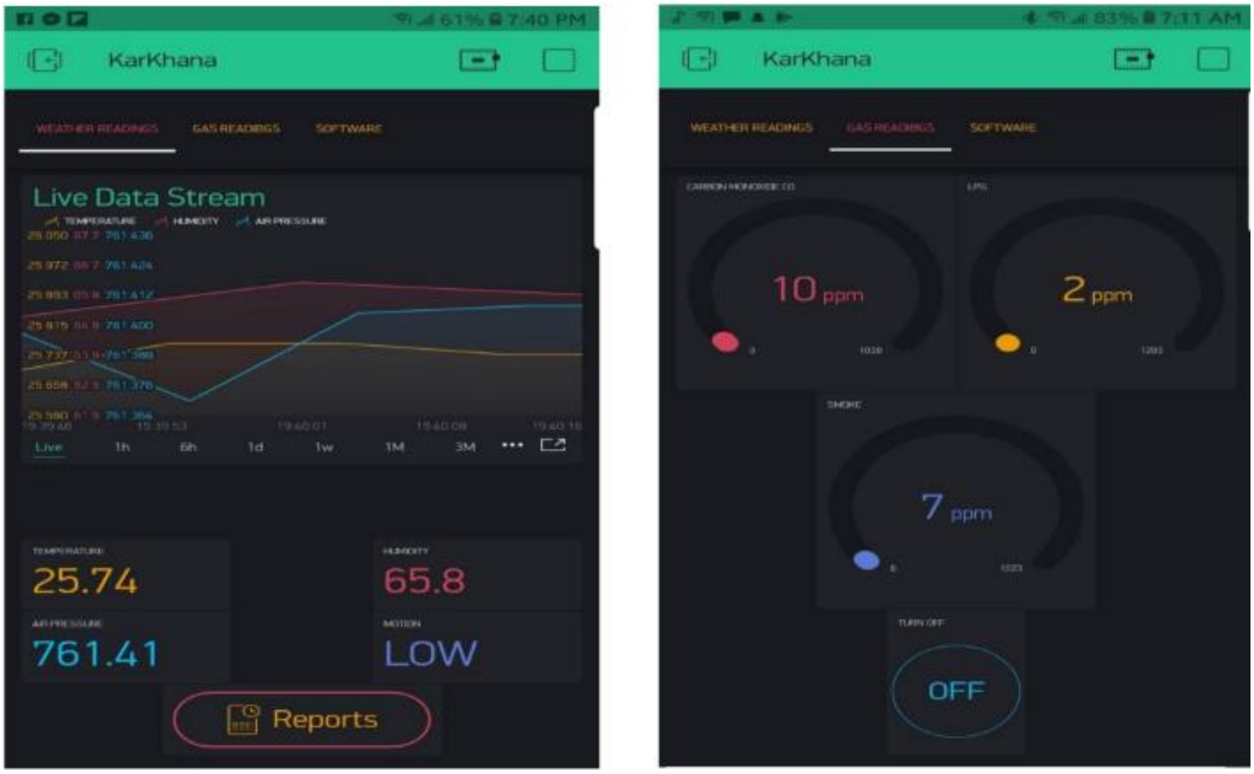
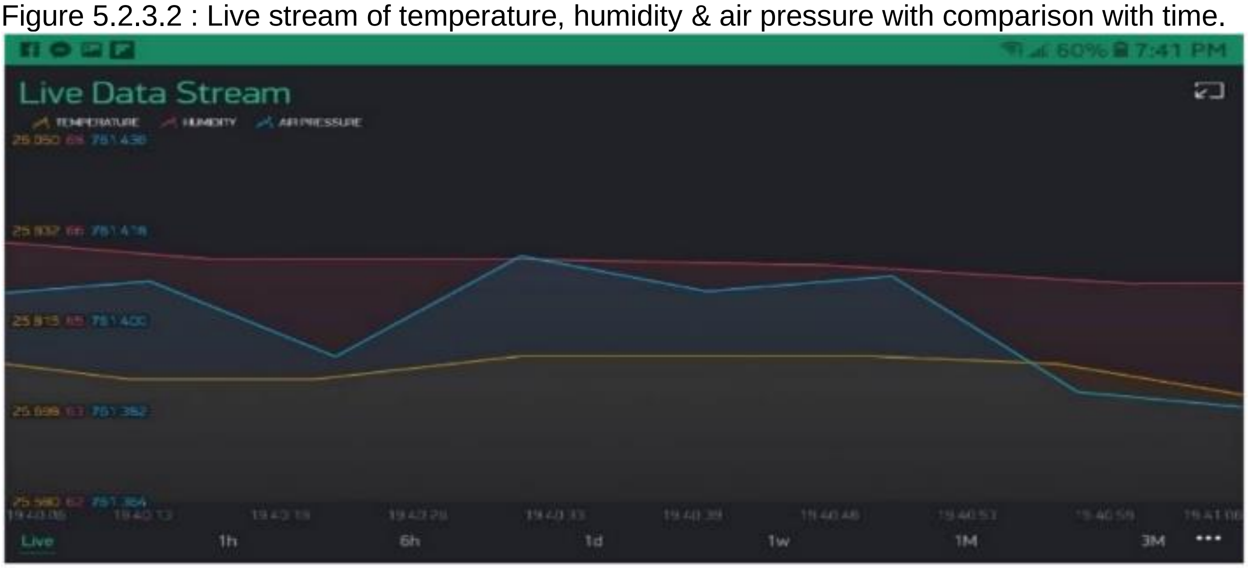


Figure 5.2.3.1: Live data stream and readings of temperature, humidity, air pressure, motion, CO, LPG, Smoke and button to turn on and off electric power supply.

Figure 5.2.3.2 : Live stream of temperature, humidity & air pressure with comparison with time.



5.2 Problem Statement

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To eliminate the climate change crisis, we have chosen a set of sensors with a microcontroller to detect the concentration of pollutants and monitor the data patterns. It will be turned to an IoT based device after the set of sensors are connected to the development board. The data from IoT based devices will then be compared with the industrial-graded device to determine the accuracy level of the experimental device.

Devices for air monitoring are available in the market but they are very expensive and not easily accessible in case of maintenance. The sustainability of these devices are also questionable, even if they attain industrial accommodation. Third world countries like Bangladesh need to attempt serious air monitoring strategies to avoid future catastrophe. Keeping in concern to this matter, our IoT based air monitoring device, RefinAir, is introduced with which we will be comparing the industrially graded device, AirVisual Pro, to distinguish the device compatibility, durability, and sustainability.

5.3 System Description

5.3.1 Component Compatibility Comparison with other Sensor

The purpose of making this IoT based device is to present a cheaper option and easily accessible to the citizens of this country, so that they become alert of the alarming situation which is not being addressed yet. However, we will be discussing about the components that are being used in the device along with the proposed solution.

5.3.1.1 Arduino Mega 2560 WiFi

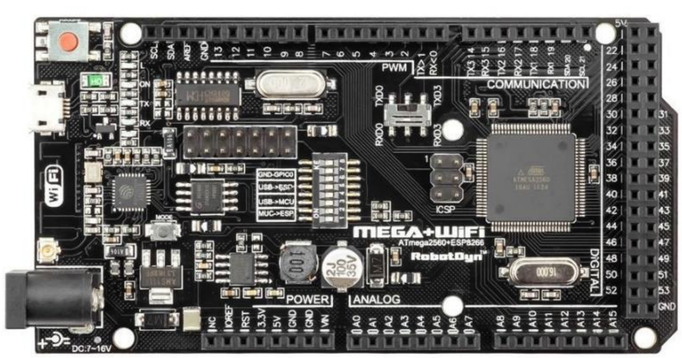

Figure 5.3.1.1: Arduino Mega 2560 WiFi

Arduino Mega 2560 WiFi is the microcontroller of the system and a development board with a facility of inbuilt wifi system, which helps users to transmit data easily and store it to a database for future research purposes. This board also has a selector switch that allows the ESP to interleave the connection between TX0 and TX3, remembering that the ATmega has four serials. A second selector switch is the DIP Switch, and we also have a key recording mode of the ESP8266. All the pinning is completely compatible with the ATmega pinout. It has a memory flash of 32mb and the Esp8266 incorporated into the board has a memory of 8mb. The input voltage for ATmega 2560 are 5V/7-12V. The price for this microcontroller was BDT1,372. NodeMCU was not chosen to work with in this project because it has less voltage, which is of 4.5V-10V, than Arduino Mega 2560 WiFi - making it less efficient. Also, it has a flash memory of 4MB/64kB only.

5.3.1.2 MQ 7 sensor

Figure 5.3.1.2: MQ 7 sensor

This Carbon Monoxide (CO) gas sensor detects the concentrations of CO in the air and outputs its reading as an analog voltage. The sensor can measure concentrations of 10 to 10,000 ppm. The sensor can operate at temperatures from -10 to 50°C and consumes less than 150 mA at 5 V. This sensor is highly sensitive to CO and has a stable and long life. Compared to the MQ 7 sensor, the CCS811 also detects CO in the air. But MQ 7 sensor more efficient than CCS811 because of its higher voltage than CCS811 which has a voltage range of 1.8 to 3.3V. In terms of pricing, MQ 7 is still feasible because it costs less than CCS811 which is BDT 180 and BDT1,600 simultaneously.

5.3.1.3 PMS5003 sensor

Figure 5.3.1.3: PMS5003 sensor

The PMS5003 air quality sensor, which is known to detect the concentration of PM2.5 particles, is connected with the Arduino WiFi development board through UART communication. It's TX and RX are connected with the Arduino mega's RX and TX pins. The PMS5003 transmits data of PM2.5 to the Arduino mega.

According to research, the PM-900M sensor of the Temtop M2000C, known to be the leading air quality monitoring system in the world, is used for measuring the concentration of PM2.5. This industrial graded sensor costs $29.99 and the PMS5003 air quality sensor we have used in our project is of $30.83. Both PM-900M and PMS5003 sensors have an accuracy of 10% (100-500 ug/m³), but PM-900M has a maximum concentration range of 0-999 ug/m³ and PMS5003 has more than 1000 μ g/m³.

5.3.1.4 BME280 sensor

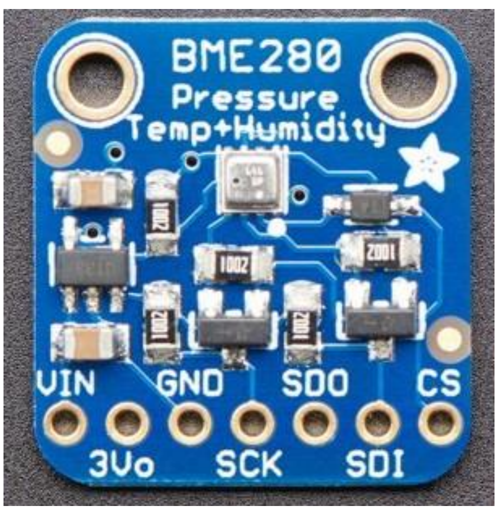

Figure 5.3.1.4 : BME280 sensor

BME280 is a product of BOSCH which is used to provide temperature, humidity and air pressure data to the Arduino mega using I2C communication, it’s SDA and SCL pins are connected to Arduino mega’s SDA and SCL pins.

Similar to BME280, which has an accuracy tolerance of 3% relative humidity , Groove TH02 temperature and humidity has an accuracy of 0.5C. Sidewise, the Groove MPX5700AP sensor has a maximum error of 2.5% and the BME280 has sensitivity error of 0.25%. The BME280 has cost $10.63 and the Groove TH02 has a price of $12.70.

5.3.1.5 MH-Z19B sensor

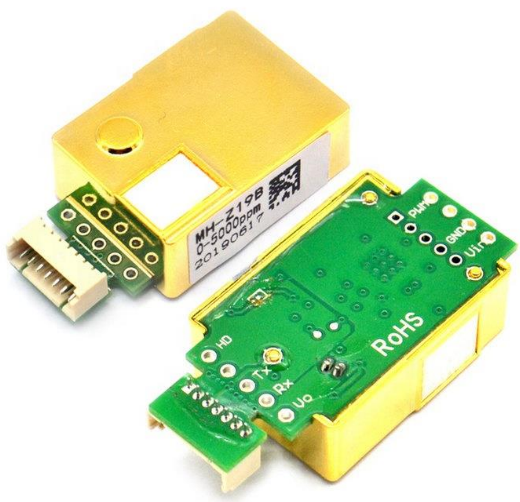

Figure 5.3.1.5: MH-Z19B sensor

The MH-Z19B sensor is a CO_2 detecting sensor, which operates in UART communication, and its RX and TX pins are connected with the Arduino’s TX and RX pins. It has three detection ranges, from 0-2000/5000/10000 ppm and the accuracy for all the three detection ranges is (50ppm+5% reading value), whereas an industrial certified SprintIR6S 100% CO_2 Sensor has an accuracy of (300ppm+5% reading value). With higher accuracy comes less voltage and more current of 3.3 to 5.5V and 33mA simultaneously, leaving the SprintIR6S 100% CO_2 Sensor less efficient in terms of energy loss. However, MH-Z19B sensor has more voltage of 4.5 to 5.5 V which means a decrease in current, which is 20mA, means less energy loss from resistance. The price for MH-Z19B is BDT. 3,500 and for SprintIR6S 100% CO_2 Sensor is BDT 21,083.86. The weight also comes as a plus point for MH-Z19B, which is 5g, making another reason to not choose SprintIR6S 100% CO_2 Sensor which weighs 16g.

5.3.1.6 Grove Multichannel Gas Sensor V2

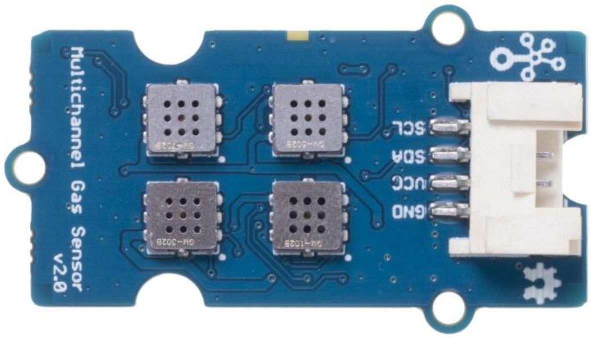

Figure 5.3.1.6: Grove Multichannel Gas Sensor V2

Grove Multichannel Gas Sensor V2 is a sensor with four measuring units, which are sensitive to Carbon monoxide (CO), Nitrogen dioxide (NO2), Ethyl alcohol (C2H5CH), and Volatile Organic Compounds (VOC). This sensor can provide four sets of data at the same time. It operates in I2C communication, it's SDA and SCL pins are connected with the Arduino Mega's SDA and SCL pins. It has a voltage up to 3.3-5v leaving one of its market competitors GC310 portable gas detector by Chicheng, which has a voltage of 3.7V and accuracy of <±3%, behind in case of efficiency. Grove Gas Sensor also has an advantage of being lighter in weight, which is 7g, compared to GC310 which weighs 220g. GC310 costs BDT 30,472 and Grove Gas sensor's price is BDT 3,600, which concludes that GC310 has also lost in case of cost feasibility with Grove Gas Sensor.

For the IoT based air monitoring system, Arduino Mega 2560 Wifi - which is a development board- is used as the microcontroller of the system and incorporated with the set of sensors to detect the concentration of pollutants and monitor the data patterns. It is turned to an IoT based device after the set of sensors are connected to the development board.

5.3.2 Hardware Layout

The Arduino Mega 2560 WiFi is the microcontroller of the system and a development board with a facility of inbuilt wifi system, which helps users to transmit data easily and store it to a database for future research purposes. All the sensors are connected to the development board for transmission of data. The PMS5003 air quality sensor is connected with the Arduino mega development board through UART communication, it's TX and RX are connected with the Arduino mega's RX and TX pins. The PMS5003 transmits data of PM2.5 to the Arduino mega. BME280 provides temperature, humidity and air pressure data to the Arduino mega using I2C communication, it's SDA and SCL pins are connected to Arduino mega's SDA and SCL pins. MH-Z19B is a CO2 detecting sensor, which operates in UART communication, and its RX and TX pins are connected with the Arduino's TX and RX pins. CCS811 detects Carbon Monoxide CO and VOCs level of the air. It operates in I2C communication, it's SDA and SCL pins are connected to Arduino mega's SDA and SCL pins. Grove Multichannel Gas Sensor V2 is a sensor with four measuring units, which are sensitive to Carbon monoxide (CO), Nitrogen dioxide (NO2), Ethyl alcohol (C2H5CH), and Volatile Organic Compounds (VOC). This sensor can provide four sets of data at the same time. It operates in I2C communication, it's SDA and SCL pins are connected with the Arduino Mega's SDA and SCL pins.

Arduino Mega 2560 Wi-Fi takes readings from the sensors. Arduino Mega connected with a PC sends all the sensor data to the PC using Serial Communication. A python application runs on the PC, which opens a serial communication between the Arduino Mega 2560 and the PC. The Python script then adds a timestamp with every single data and posts every single data simultaneously to the google cloud using RestAPIs and GoogleAPIs with very low latency. Then the inbuilt Google Sheet APIs fetches the data from the RestAPIs and adds the data into a google sheet. All the data is dynamically added to the google sheet automatically. Using the google sheet charts all the sensor data are visualized in different linear time series data charts according to the different obtained gas compounds and weather elements.

5.3.2.1 Block Diagram

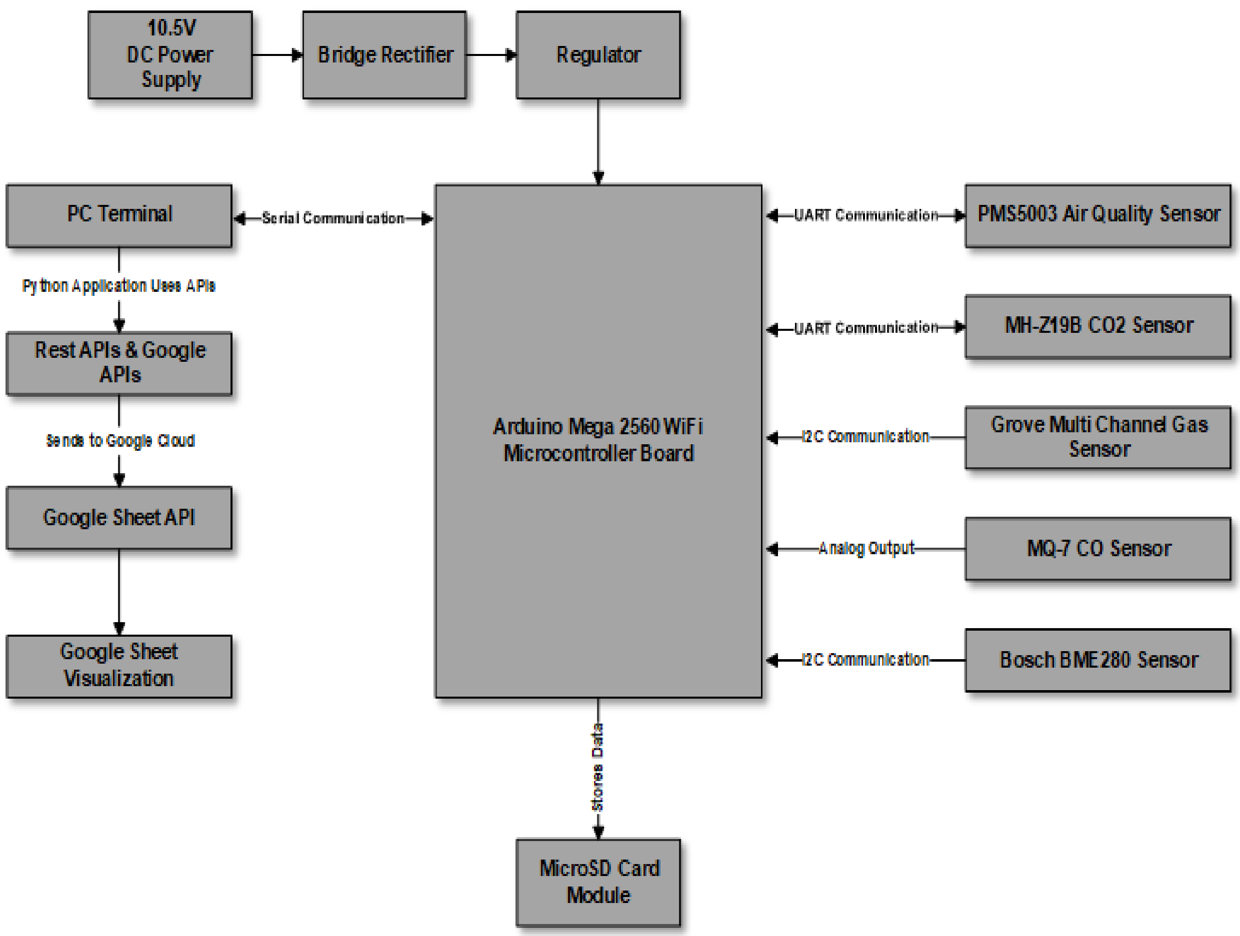

Figure 5.3.2.1: Block Diagram of the proposed system

5.3.2.2 Schematic Diagram

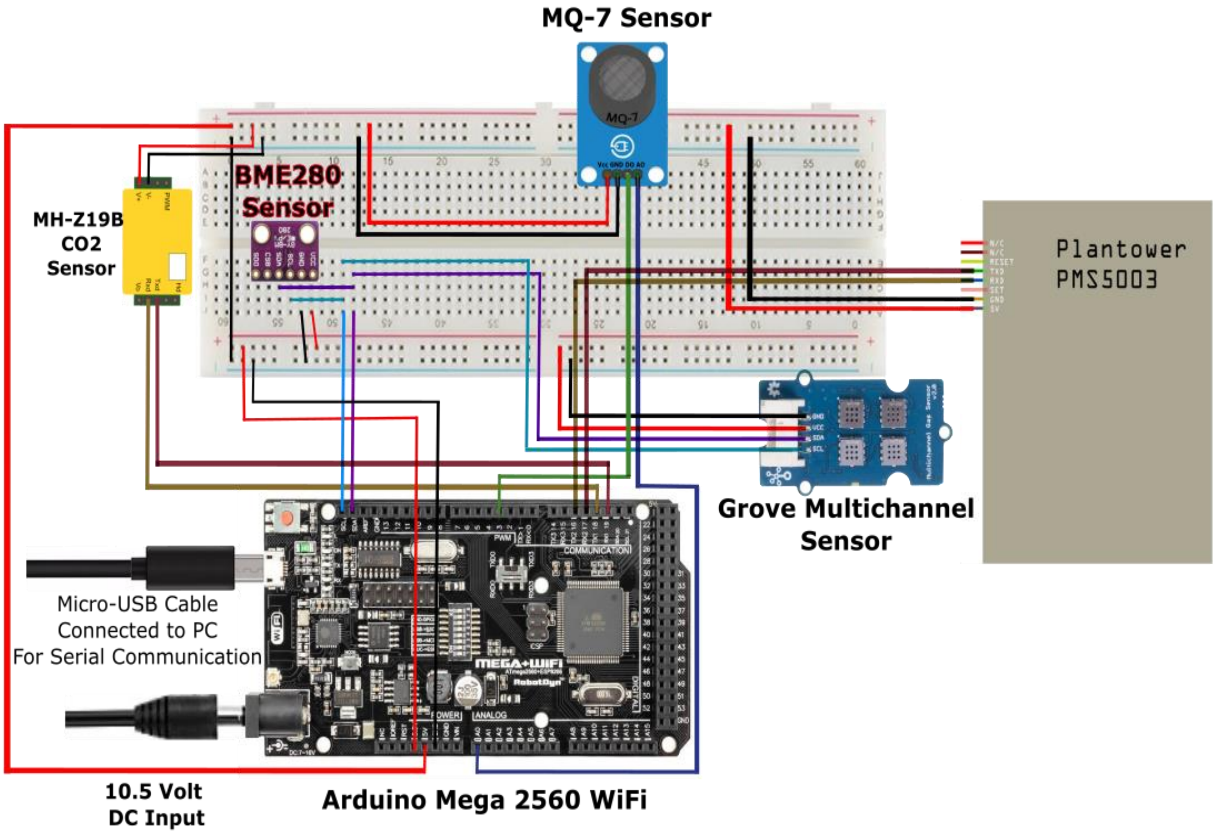

Figure 5.3.2.2: Schematic Diagram of the proposed system

5.3.2.3 Hardware implementation of IoT air quality monitoring system

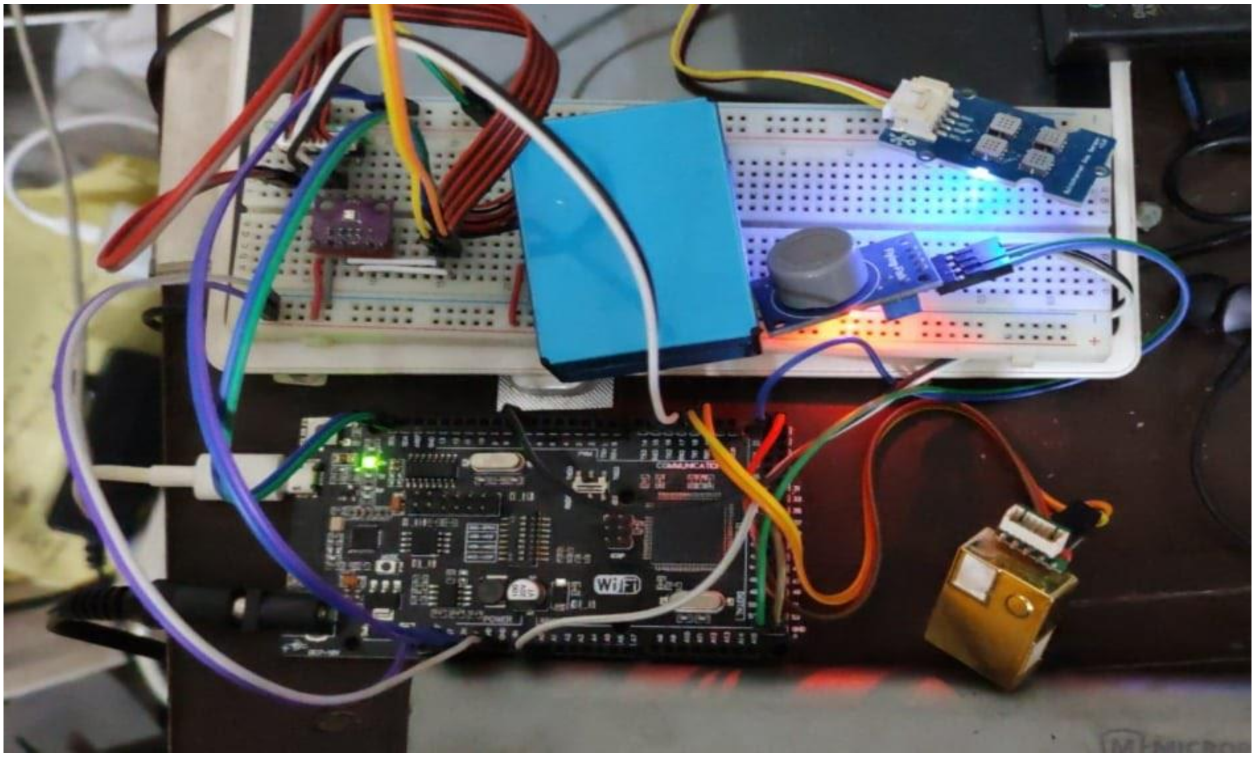

Figure 5.3.2.3: Hardware implementation of the proposed system

5.4 Performance Analysis

This part of the report will determine the device compatibility with the help of the data that has been found from the IoT based device. The data taken from IoT based device, is generated by the sensors connected to a microcontroller. The microcontroller sends the data to the PC and through the PC the data is updated into Google Cloud. The inbuilt Google Sheet APIs fetches the data and adds data to the Google Sheet with timestamps.

On the other hand, the purchased device - AirVisual Pro- stores their data to a text file. The text file is then stored into Microsoft Excel. The data is then uploaded to the Google Cloud and the inbuilt Google Sheet APIs fetches the data and adds data to the Google Sheet.

5.4.1 Graphical Data Patterns

In this performance analysis, the collection of data of different polluting compounds are compared between the IoT based device and AirVisual Pro. Please note that all the data were collected for 8 hours after proper calibration of both AQI Air Visual Pro and our Air monitoring system device. Within the 8-hour timeline, after every 5-minute data was fetched from both the devices automatically. Between the two devices, data difference is shown under the same category of sensors. Percentage error is done between temperature, humidity, and **CO_2**. Particle concentration difference is between PM1.0, PM2.5 and PM10.0.

We have taken data from daytime, nighttime and have done a collation between the series of compounds to determine the sensitivity of the sensors.

5.4.1.1 Daytime Reading

Still in process.

5.4.1.2 Nighttime Reading

The data were collected within an 8-hour period, and the device delivered data every 5 minutes to the Google Sheet using Google APIs.

5.4.1.2.1 Temperature Difference in Percentage

Average Difference: 1.474%

Minimum Difference: 0.748%

Maximum Difference: 1.902%

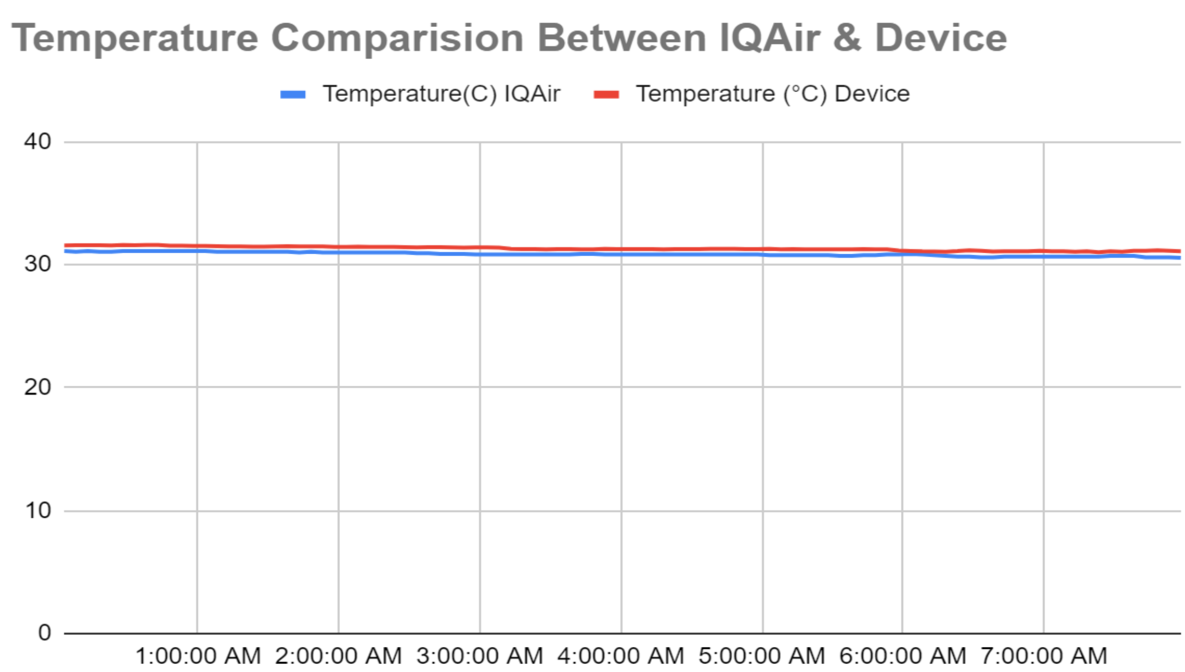

Figure 5.4.1.2.1: Temperature Comparison.

5.4.1.2.2 Humidity Difference in Percentage

Average Difference: 0.979%

Minimum Difference: 0.973%

Maximum Difference: 0.989%

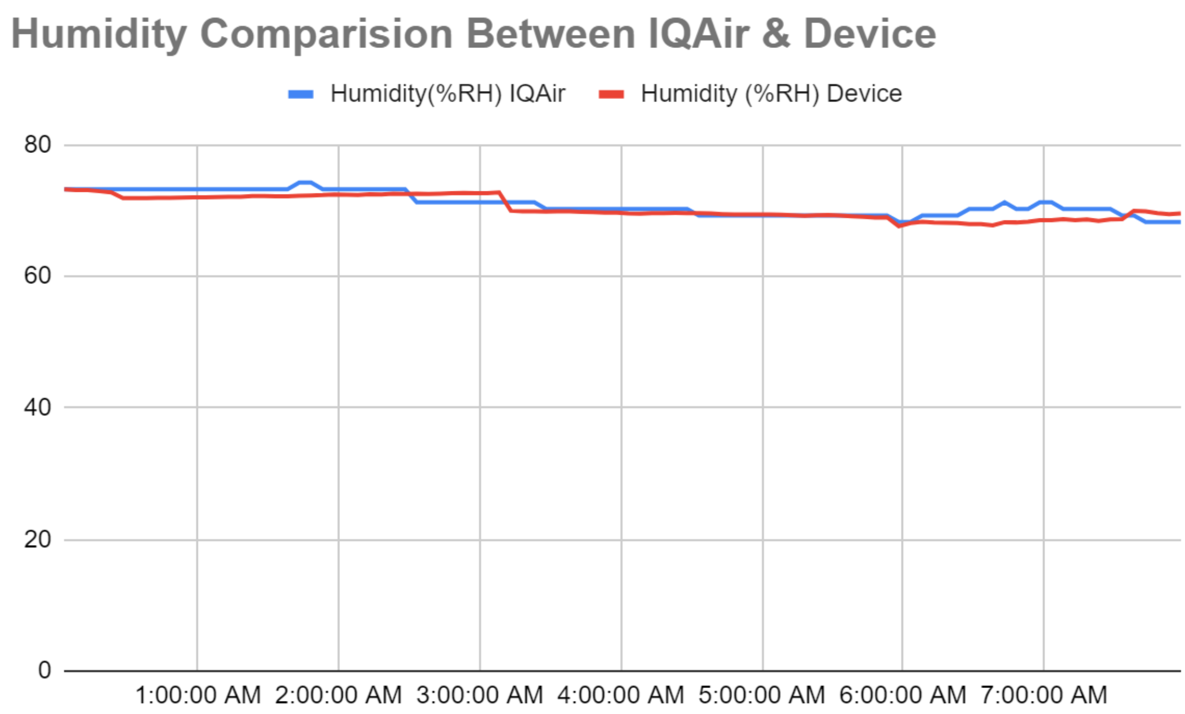

Figure 5.4.1.2.2: Humidity Comparison.

5.4.1.2.3 PM1.0 (ug/m3) Difference in raw concentration

Average Difference: 0.791 ug/m3

Minimum Difference: 0 ug/m3

Maximum Difference: 3 ug/m3

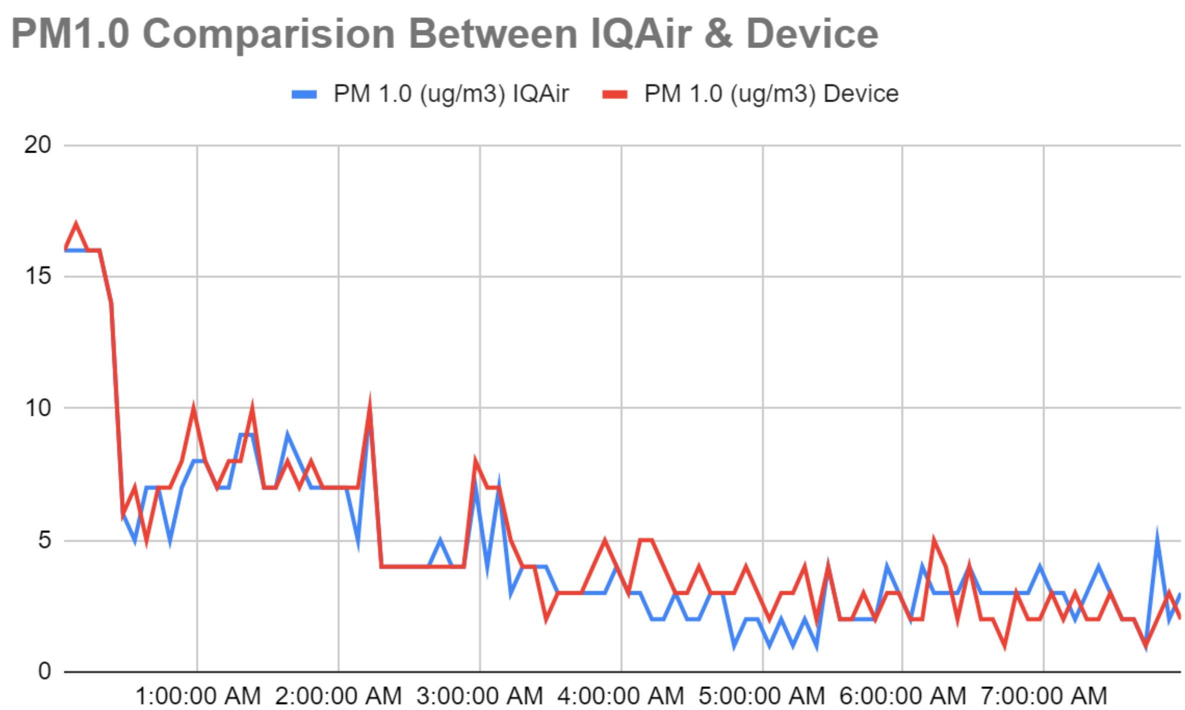

Figure 5.4.1.2.3: PM1.0 Comparison.

5.4.1.2.4 PM2.5 (ug/m3) Difference in raw concentration

Average Difference: 0.604 ug/m3

Minimum Difference: 0 ug/m3

Maximum Difference: 2 ug/m3

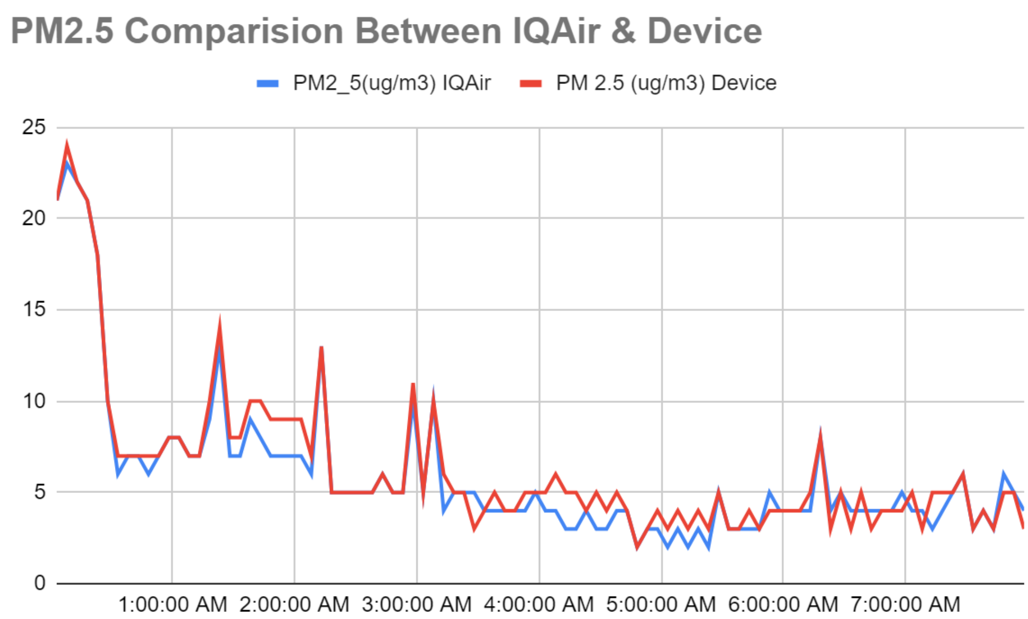

Figure 5.4.1.2.4: PM2.5 Comparison.

5.4.1.2.5 PM10.0 (ug/m3) Difference in raw concentration

Average Difference: 0.646 ug/m3

Minimum Difference: 0 ug/m3

Maximum Difference: 3 ug/m3

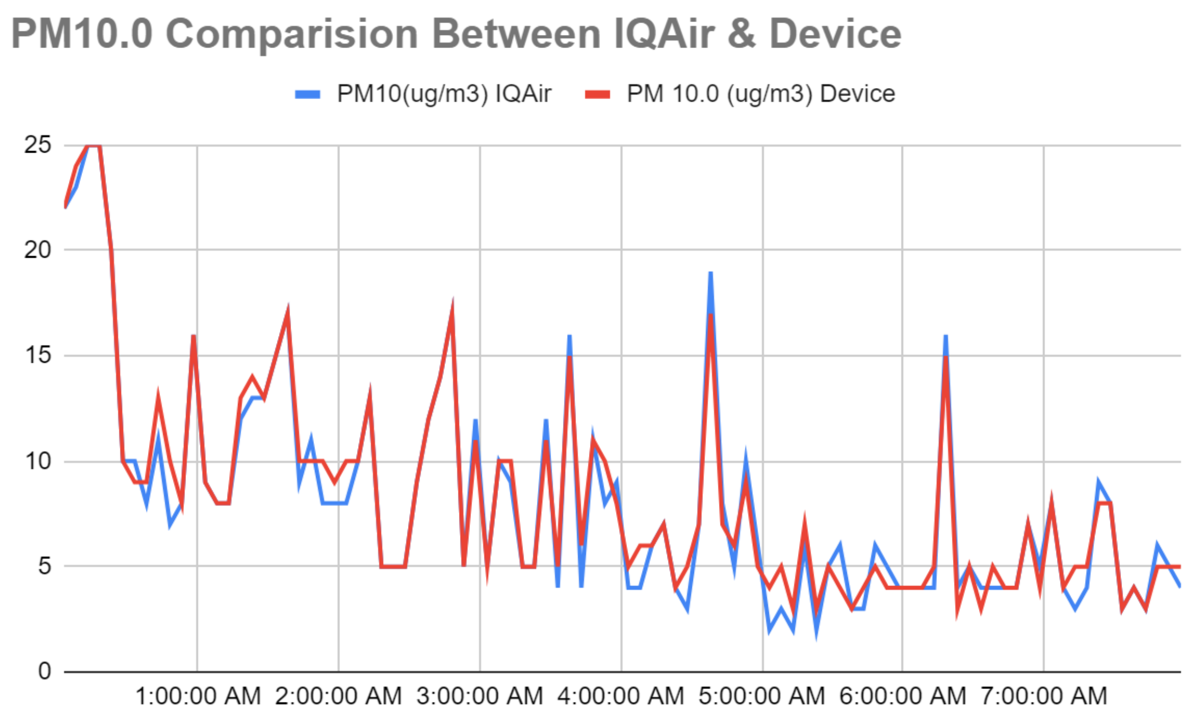

Figure 5.4.1.2.5: PM2.5 Comparison.

5.4.1.2.6 CO2 Difference in Percentage

Average Difference: 0.76%

Minimum Difference: 0.00%

Maximum Difference: 2.70%

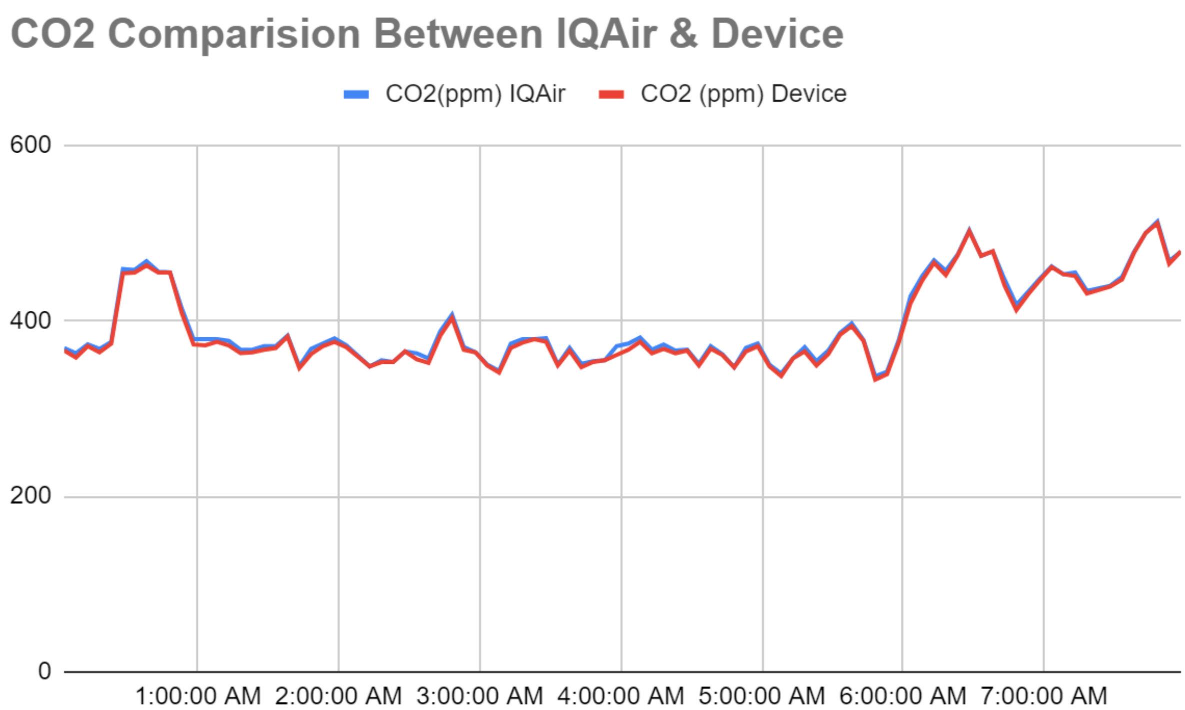

Figure 5.4.1.2.6: **CO2** Comparison.

5.4.2 Discussion on Graphical Patterns

There are two graphs of the same polluting components shown for determining the collection between RefinAir and AirVisual Pro. Please note that all the data were collected for 8 hours after proper calibration of both the air monitoring system devices. Within the 8-hour timeframe, data was fetched within every 5 minutes from both the devices automatically. Between the two devices, data difference is shown under the same category of sensors. Percentage error is done between temperature, humidity, and **CO2**. Particle concentration difference is between PM1.0, PM2.5 and PM10.0.

An observation is shown on the graph above and we can conclude by saying that, both the devices have a very slim difference in data among all the sensors, proving our goal to diminish the worldwide crisis by introducing a low-cost and cheap solution.

5.5 Application of RefinAir

Around 3.8 million people die due to indoor air pollution because of the presence of Particulate Matter and increasing levels of toxic gases. Severe respiratory diseases have been reported which could lead to cancer. It is vital to keep the emission of toxins around the atmosphere in control, which is why the following places should be using our device, RefinAir.

- Indoor Air Quality Monitoring System or Gas Detection System

Monitoring indoor air can ensure a good working environment. It can be used in hospitals, homes, shops, or any other indoor areas. The gas detection system can alert the people about the rising levels of pollutants and become health conscious.

- Outdoor Monitoring System

We will be able to fetch data from the most polluting outdoor sources like industries, untreated sewage, lead-acid battery recycling, metal smelting and processing, etc.. Data from transportation routes and surface areas of water bodies can also be collected by mounting our devices on the transportations.

- Atmospheric Map

An Atmospheric Map can be generated with the help of satellite data using MLAs, and this can help the citizens to determine the most polluting areas and take precautions accordingly. The industrialists will get alarmed about the situation and control the pollution in favorable conditions.

On Process

5.6 Comparison between RefinAir and AirVisual Pro

Properties	RefinAir	AirVisual Pro
Industrial Grade Sensors	✓	✓
Sensor Durability	✓	✗
Air Quality Forecasting	✓	✓
Device Maintenance Facility	✓	✗
Cost Feasibility	✓	✗
Real Time Monitoring	✓	✗
Indoor Air Monitoring System	✓	✓
Outdoor Air Monitoring System	✓	✗
Toxic Data Collection for extensive research	✓	✗

Table 5.6.1: Comparison table for RefinAir and AirVisual Pro

7.1 Challenges face

The following section is to give an insight of the boundaries that have been faced during the one-year timespan of the ongoing research period. I believe, with every good thing, comes difficulty. However, the problems are mentioned below.

7.1.1 Air Quality Monitor

- Difficulty to distinguish the work breakdown structure.
- Listing out all the initiatives that can be done in the project.
- Determining the start date, due date of the initiatives done in the project in Gantt Chart.

7.1.2 RefinAir

- Finding a proper library for all the sensors.
- Calibrating all the sensors.
- Establishing smooth UART communication between PMS5003 and MH-Z19B sensors.
- Troubleshooting the python application to decrease errors in serial communication.
- Unavailability of components due to pandemic situation.
- Sudden increase of cost and shipping charge due to lockdown and pandemic.
- Unable to go to the lab and do the project together.
- Virtual screening of the project.