AIR POLLUTION MONITORING SYSTEM

A PROJECT REPORT

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1 Introduction

Air pollution is becoming a serious issue that affects both our health and the environment. It's something that has been growing in importance as cities become more crowded, industries expand, and car traffic increases. We've all experienced days when the air feels heavy or smoggy, and that's not just uncomfortable—it can be dangerous. This project is all about tackling this problem by building a low-cost, real-time air quality monitoring system. Using an ESP32 microcontroller along with SDS011, AHT10, and Prana CO2 sensors, the system tracks important air quality parameters such as PM2.5, PM10, temperature, humidity, and CO2 levels. The data collected from this system can provide valuable insights into pollution trends, helping individuals and policymakers take informed actions for better air quality management.

1.1 Background

Air pollution is more than just a nuisance; it's a public health crisis. Fine particulate matter (PM2.5 and PM10) and greenhouse gases, especially CO2, are linked to a range of serious health problems, including asthma, lung cancer, and heart disease. Beyond health impacts, poor air quality can also contribute to global warming and climate change. Despite these serious consequences, accurate and affordable monitoring systems are still hard to come by. Most existing solutions are either too expensive for widespread use or just don't provide real-time data that can help us take immediate action. That's where this project comes in—our aim is to create an affordable, user-friendly system that provides continuous, real-time air quality data.

1.2 Objectives

The main goals of this project are as follows:

- **Develop a Real-Time Monitoring System:** Build a cost-effective and portable system capable of tracking air quality in real-time using IoT technology.
- **Measure Key Pollutants and Environmental Parameters:** Utilize sensors to monitor PM2.5, PM10, temperature, humidity, and CO2 levels for a comprehensive understanding of air quality.
- **Analyze Trends and Patterns:** Collect data over time to identify trends and spikes in pollution, particularly during events like Diwali when pollution levels may rise.
- **Provide Actionable Insights:** Enable individuals and policymakers to use the collected data to take informed actions to improve air quality.
- **Raise Awareness:** Foster awareness about the importance of air quality and its impact on health and the environment.

1.3 Scope

The project has a few areas that we'll focus on:

- **Deployment Areas:** This system can be used in urban areas, residential neighbourhoods, and even industrial locations to keep tabs on the air quality.
- **Who Can Use It:** This project is aimed at anyone interested in air quality—individuals, local authorities, environmental activists, and policymakers who need accurate and up-to-date information.
- **What It Can Do:** The system tracks real-time data on PM2.5, PM10, temperature, humidity, and CO2 levels. This data can be used to spot trends over time or investigate changes in air quality during special events or high-traffic periods.
- **Event-Specific Analysis:** For example, during festivals like Diwali, we can see how air pollution spikes due to increased firecrackers and traffic.

Limitations: Since we're working with a limited budget and using certain sensors, the system might not be as advanced as professional air monitoring networks. However, it's definitely a step in the right direction.

Applications: The project can be useful in monitoring local air quality, raising awareness about pollution, and even as an educational tool for understanding how pollution impacts us. It could also support larger environmental efforts and help shape policies for better air quality management.

1.4 Contributions

I was solely responsible for the entire project, and my contributions include the following:

- **System Design:** I designed the overall setup for the air quality monitoring system. This involved choosing the right sensors (SDS011 for PM2.5 and PM10, Prana for CO2) and planning how the hardware and software would work together.
- **Building the Hardware:** I built the Zero PCB and connected the sensors to the microcontroller. I also tested the hardware to make sure everything was working properly.
- **Software Development:** I wrote the software needed to collect data from the sensors, calibrate them, and send the data to a server for storage. I also made sure the system could work in real time.
- **Sensor Calibration and Data Collection:** I calibrated the sensors to make sure they provided accurate readings. I collected data during the Diwali festival and also gathered regular data at T-Hub.
- **Deployment:** I deployed the system at T-Hub on the 4th floor, where it ran continuously to monitor the air quality. I also handled any issues that came up during the deployment.
- **Data Analysis:** I analyzed the data collected from both Diwali and T-Hub to identify trends and patterns. I looked at how the air quality changed during busy and calm periods.
- **Writing the Report:** I wrote this report, summarizing the entire project, from design to deployment. I also presented the findings in an easy-to-understand way.

2 Timeline

2.1 September: Hardware Setup and Sensor Integration

In September, the project began with the assembly of the Zero PCB, which served as the foundation for connecting the various sensors. The primary sensors integrated during this phase were the SDS011 for measuring PM2.5 and PM10, and the Prana CO2 sensor for monitoring carbon dioxide levels. This phase involved careful calibration of the hardware, including wiring and ensuring proper communication between the sensors and the microcontroller. The setup also included testing the sensors' response to environmental conditions, ensuring their functionality and accuracy before proceeding with data collection.

2.2 October: Calibration and Diwali Data Collection

October was dedicated to calibrating the sensors to fine-tune their readings for accuracy and reliability. Calibration for both the SDS011 and the Prana sensor was done by comparing their readings against known standards or controlled conditions. Following calibration, data collection began during the Diwali festival. This phase was crucial as it allowed us to capture real-time air quality data during a period of significant environmental change due to fireworks and increased human activity. The data collected during Diwali provided insight into how air quality fluctuates during festivals and high-activity periods, allowing for the identification of peak pollution levels and potential sources of contamination, such as firecrackers.

2.3 November: Deployment in T-Hub for Continuous Monitoring

In November, the system was deployed on the 4th floor of T-Hub, an active coworking space, for real-time air quality monitoring. The deployment involved setting up the entire hardware and software system in the building, ensuring continuous data collection. This phase also included the installation of the monitoring dashboard, which allowed stakeholders to view air quality metrics in real time. The T-Hub deployment provided valuable baseline data on air quality under normal conditions, without the influence of special events like Diwali. The data collected during this phase helped track air quality trends, identify areas with higher pollution, and assess the system's effectiveness in providing actionable insights for improving air quality in indoor spaces.

3 System Overview

The system is built to provide comprehensive and real-time monitoring of air quality using an integrated set of hardware components and a software platform. This section details the hardware components and the circuit diagram used in the system.

3.1 Hardware Components

The main hardware components of the system include:

- **ESP32:** The central microcontroller that processes data from sensors and handles wireless communication. It is chosen for its affordability, low power consumption, and Wi-Fi/Bluetooth connectivity.
- **SDS011:** A sensor that measures PM2.5 and PM10 particulate matter in the air. It provides real-time data on the concentration of fine particles that can affect human health.
- **AHT10 Sensor:** Measures temperature and humidity, providing contextual environmental data to assess air quality.
- **Prana CO2 Sensor:** Monitors the levels of carbon dioxide in the air, which is crucial for understanding indoor air quality and potential suffocation risks.

3.2 Circuit Diagram

The circuit diagram provides an overview of how the sensors are connected to the ESP32 microcontroller. This setup ensures that data from each sensor is correctly captured and transmitted for further processing and analysis.

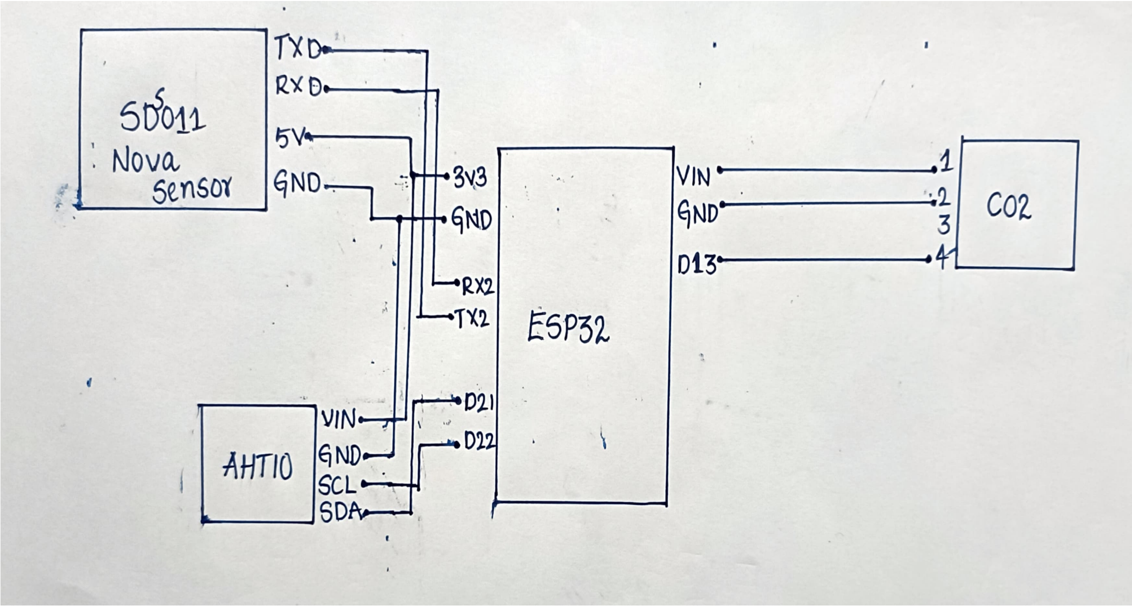

Figure 1: Circuit Diagram for Air Pollution Monitoring System

4 Calibration

Accurate sensor calibration is essential to ensure that the readings from the air quality monitoring system are precise. This section outlines the calibration methods used for the SDS011 PM sensors and the Prana CO2 sensor.

4.1 Calibration Process for SDS011

To calibrate the SDS011 PM sensors, the system used an Aeroqual sensor as a reference device. The following steps outline the calibration procedure:

- **Reference Device:** The Aeroqual sensor, known for its high accuracy, was used as the benchmark for comparison.
- **Setup and Duration:**
  - The SDS011 sensors and the Aeroqual device were placed in the same controlled environment to minimize external influences on the readings.
  - The calibration period lasted for 24 hours to allow the sensors to stabilize and provide consistent data.
  - Data were recorded at one-minute intervals throughout the entire duration.
- **Data Collection:**
  - Both the SDS011 sensors and the Aeroqual sensor collected PM2.5 and PM10 readings every minute.
  - The data were compiled and analyzed using a linear regression approach to derive calibration parameters.
- **Calibration Results:**
  - **PM2.5 Calibration:**
    * **Slope**: 1.15
    * **Intercept**: -0.69
    * This indicates that the SDS011 readings were slightly higher than the reference Aeroqual readings, and the intercept was adjusted accordingly.

- **PM10 Calibration:**
  - **Slope:** 1.05
  - **Intercept:** -1.08
  - The calibration showed a close alignment with the Aeroqual sensor, with minor adjustments made for more precise readings.

- **Error Percentages:**
  - PM2.5: The calibration process resulted in an error percentage of 12.4%, indicating the deviation between the SDS011 and the Aeroqual sensor readings.
  - PM10: The calibration yielded an error percentage of 1.17%, which is relatively lower and suggests a high degree of accuracy.

4.2 Calibration Process for CO2 (Prana Sensor)

The Prana CO2 sensor was calibrated using a zero-point calibration method. This process is essential for establishing a baseline reading for the CO2 sensor and ensuring that the system accurately monitors CO2 levels in various environments:

- **Calibration Method:** Zero-point calibration, where the sensor is exposed to an environment with a known CO2 concentration.
- **Zero-Point Value:** The baseline value was set at 400 ppm, which is considered the average outdoor CO2 concentration.
- **Calibration Duration:** The calibration process was carried out over 96 hours (4 days). This extended period allowed the sensor to acclimate and provide consistent data readings.
- **Initial Sensor Readings:** During the zero-point calibration cycle, the sensor readings were monitored to ensure that they aligned closely with the expected 400 ppm value. Adjustments were made as necessary to refine the sensor's baseline reading.

The combination of the above calibration procedures ensures that the system's sensors provide reliable and accurate data for air quality monitoring. This calibration process laid the groundwork for the subsequent data collection and analysis phases of the project.

5 Software Development

The software development for this project involved configuring the ESP32 microcontroller to read data from connected sensors and transmit it to the cloud for real-time analysis. The development process included setting up the environment, writing the code for data collection, and enabling data transmission.

5.1 Software Stack

The software stack used included:

- **Arduino IDE**: Used for coding and uploading firmware to the ESP32.
- **ThingSpeak**: Initially used for data collection and visualization but due to certain limitations(8000 per entries per day, not so good UI), I discontinued using it.
- **Qubitro Cloud**: Used for data visualization and real-time monitoring. The Qubitro dashboard was integrated to display the collected data and monitor trends over time.

5.2 Sensor Integration

The sensors were connected to the ESP32 GPIO pins, and appropriate libraries were used for data collection. The system read PM2.5 and PM10 levels from the SDS011, temperature and humidity from the AHT sensor, and CO2 levels from the Prana CO2 sensor.

5.3 Data Transmission

Data was transmitted using Wi-Fi via HTTP POST requests to the Qubitro cloud. This setup ensured that data was available for remote monitoring and visualization. Error-handling mechanisms were incorporated to ensure reliable data transfer.

6 Deployment

The air quality monitoring system was deployed on the 4th floor of T-Hub. This location was chosen in response to reports from students who experienced suffocation during extended periods in the enclosed space. The deployment aimed to monitor environmental factors and identify the cause of discomfort.

7 Data Collection and Analysis

7.1 Data Collection

Data collection for this project was performed using the deployed air pollution monitoring system. The sensors continuously monitored air quality parameters such as **PM2.5**, **PM10**, temperature, humidity, and **CO2** levels. The data was collected at one-minute intervals to ensure frequent updates and provide near-real-time information on air quality.

The following sensors were used:

- **SDS011**: Measured PM2.5 and PM10 particulate matter concentrations.
- **AHT10**: Captured temperature and humidity levels.
- **Prana CO2 Sensor**: Monitored carbon dioxide levels.

Data collection was initially done using ThingSpeak for both gathering sensor data and creating the dashboard. However, ThingSpeak presented some challenges, including a daily limit of 8000 entries and limited customization options for the dashboard. As a result, I transitioned to Qubitro, which allowed for better scalability, larger data handling, and more flexible dashboard configurations to meet the project's needs.

The collected data was sent to the **Qubitro** database for storage and further analysis. The system was designed to be scalable and responsive, handling data streams efficiently.

7.2 Data Analysis

The collected data was analyzed to extract meaningful insights and observe trends in air quality. The data analysis involved statistical methods and visualization tools. The **dashboard** provided a visual representation of this data, allowing for a comprehensive view of pollution levels over time.

7.3 Dashboard Integration

The **Qubitro dashboard** was used to visualize real-time data and past trends. It helped present the data in a user-friendly format, making it easy to monitor air quality at a glance.

- **Real-Time Monitoring**: The dashboard displayed live sensor data, including PM2.5, PM10, CO2, temperature, and humidity.
- **Historical Data Analysis**: One can access historical data to analyze trends and fluctuations over time.

7.4 Dashboard Snapshot

Below is a snapshot of the dashboard that shows the real-time data display:

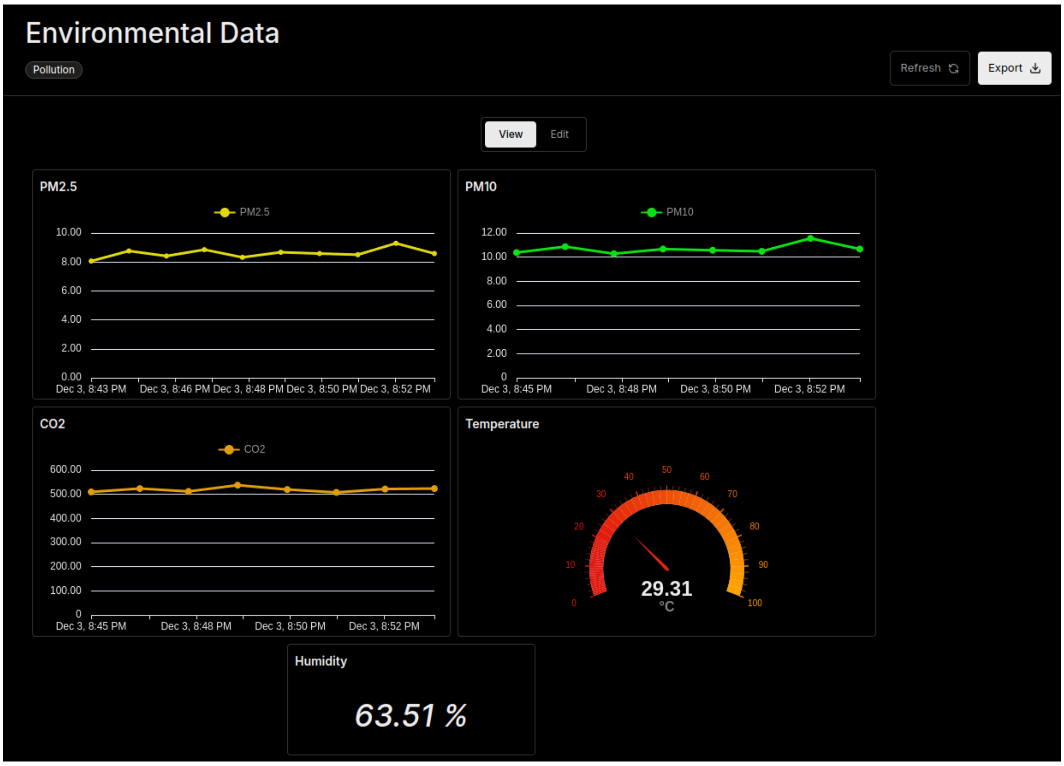

Figure 2: Snapshot of the Qubitro Dashboard Showing Real-Time Air Quality Data

The dashboard allowed us to identify patterns and potential issues, such as the effects of the Diwali festival, which saw an increase in PM levels and CO2 concentrations due to heightened activity and the use of air conditioning in the T-Hub building.

7.5 Analysis

Data analysis was performed to identify trends and make meaningful comparisons. Graphs and plots were generated to observe pollutant levels during different times and events. The following observations were made:

- **PM Levels**: PM2.5 and PM10 levels showed variations depending on the time of day and the number of people in the building.
- **CO2 Concentrations**: CO2 levels remained high, which correlated with reports of suffocation and discomfort among students.
- **Temperature and Humidity**: These parameters were also monitored as they contribute to overall indoor air quality and comfort.

The analysis provided valuable insights that can help in future improvements and actions to maintain a safe and healthy indoor environment.

7.6 Correlations

Correlations were analyzed to understand the relationships between different air quality parameters and their effects on the indoor environment:

- **PM2.5 and PM10 Correlation**: There was a positive correlation between PM2.5 and PM10 levels, indicating that both particulate matter concentrations tended to increase simultaneously during periods of high occupancy and activity.
- **CO2 and PM Levels**: A strong correlation was observed between CO2 levels and PM concentrations. Higher CO2 levels often coincided with higher PM levels, suggesting that poor ventilation and high occupancy contributed to increased particle pollution.

- **CO2 and Temperature**: The correlation between CO2 and temperature indicated that CO2 concentrations were higher when the temperature increased, possibly due to the increased use of air conditioning and other cooling systems that can impact air circulation and contribute to CO2 buildup.

These correlations provided deeper insights into the interactions between different factors affecting indoor air quality, emphasizing the importance of monitoring multiple parameters simultaneously to ensure a healthy environment.

8 Observations

8.1 Overview of Data Collection

Data collection was carried out during two main periods: during the Diwali festival and during regular operations at the T-Hub. The sensors captured various air quality parameters including PM2.5, PM10, combined PM2.5 PM10, and CO2 levels, measured at one-minute intervals and stored in the Qubitro database for analysis.

8.2 Analysis of Diwali Data

The analysis of data collected during Diwali revealed significant fluctuations in indoor air quality, which can be attributed to the festivities and the increased number of people present in the area. The following figures illustrate the key findings:

8.2.1 PM2.5 Levels During Diwali

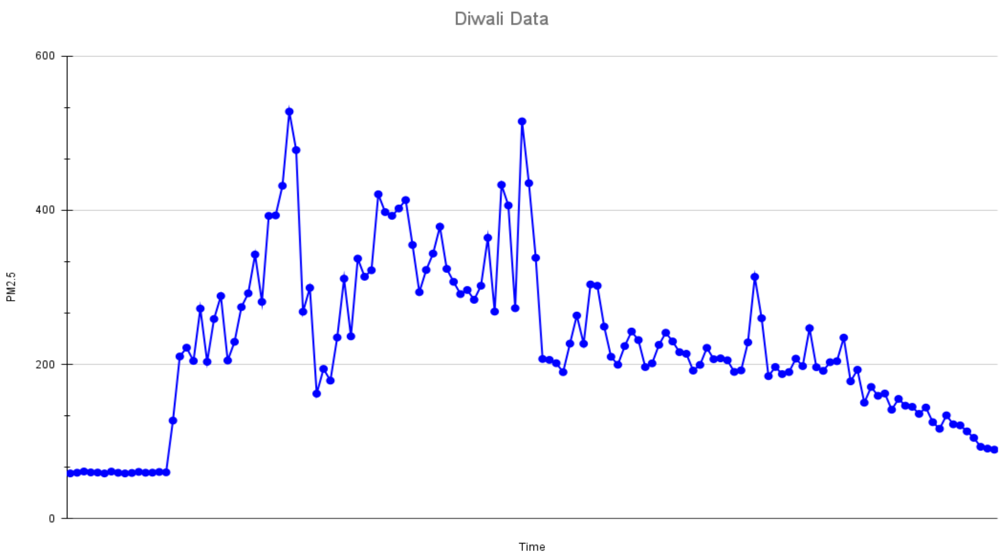

Figure 3: PM2.5 Levels During Diwali

Observation: PM2.5 levels showed a marked increase, especially during peak times of celebration, indicating a higher level of fine particulate matter in the air due to fireworks and increased activity.

8.2.2 PM10 Levels During Diwali

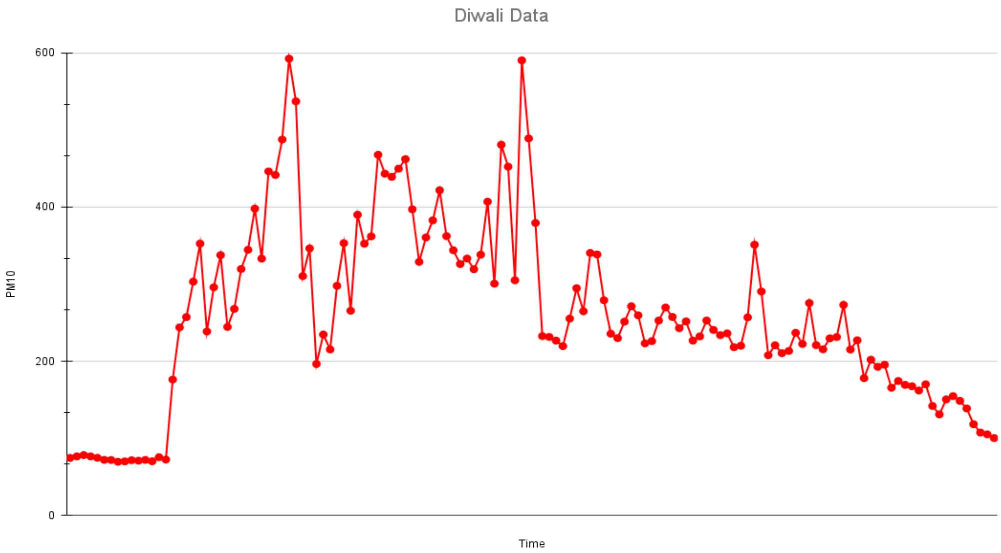

Figure 4: PM10 Levels During Diwali

Observation: PM10 levels also showed an increase, following a similar trend as PM2.5, suggesting a combination of airborne dust and particulate matter from external sources like firecrackers.

8.2.3 Combined PM2.5 and PM10 Levels During Diwali

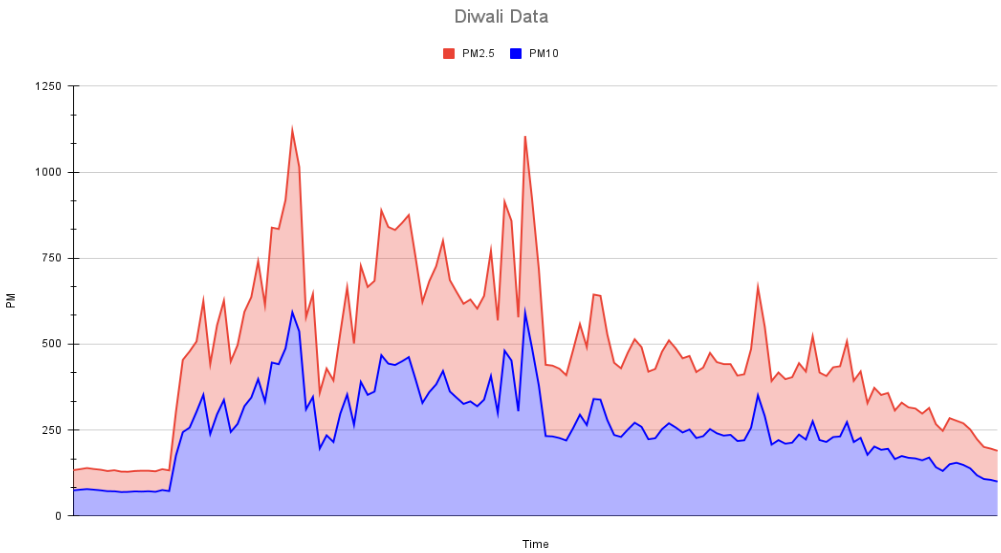

Figure 5: Combined PM2.5 and PM10 Levels During Diwali

Note: In Figure 5: PM2.5 is shown as Blue and PM10 is shown as Red.

Observation: The combined PM2.5 and PM10 data highlighted the cumulative particulate exposure, showcasing peak periods where the air quality dropped significantly.

8.2.4 CO2 Levels During Diwali

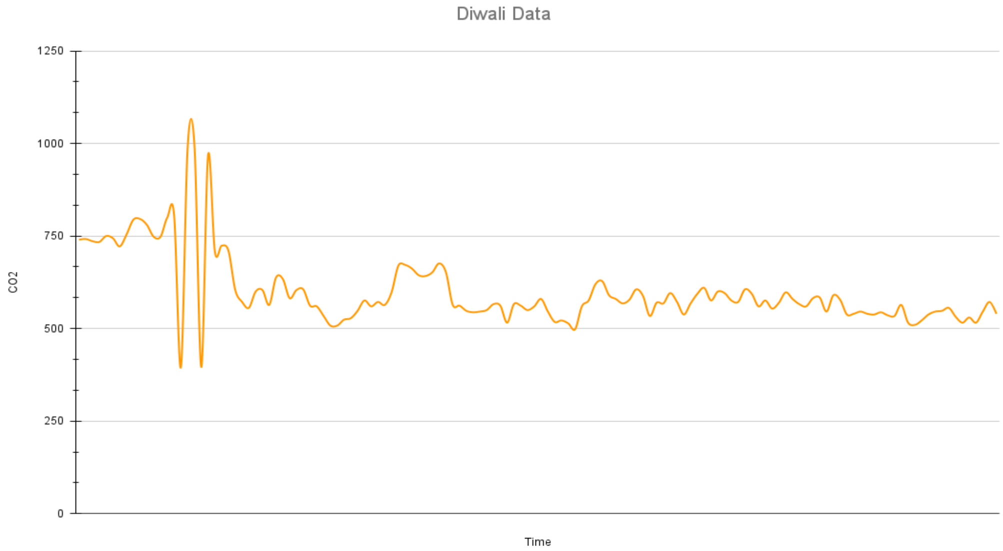

Figure 6: CO2 Levels During Diwali

Observation: CO2 levels during Diwali were higher than average, which can be attributed to the higher occupancy and the prolonged use of air conditioning, leading to reduced air circulation and elevated CO2 concentrations.

8.3 Analysis of T-Hub Data

The analysis of data collected at T-Hub during regular operations helped establish baseline air quality metrics and identify trends over time. The following figures present the key insights:

8.3.1 PM2.5 Levels in T-Hub

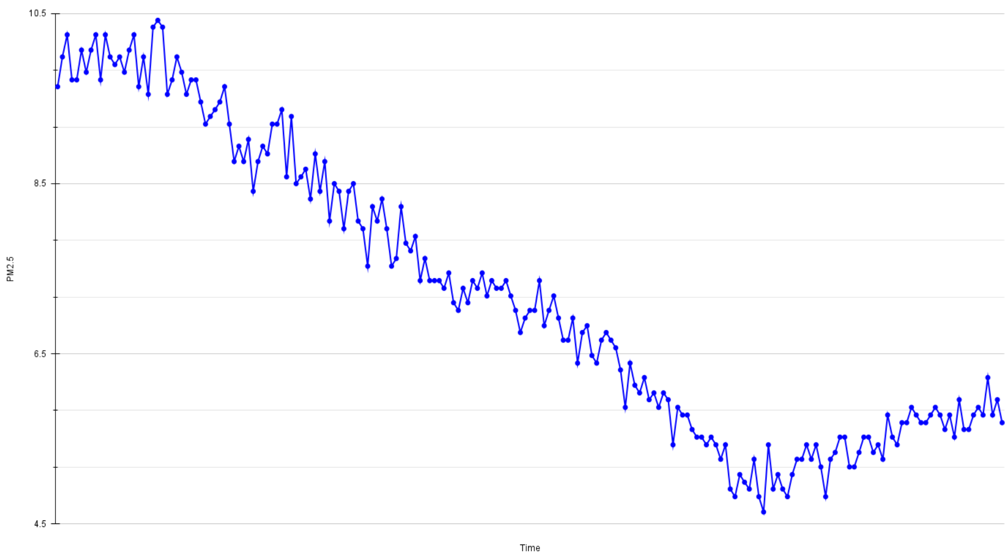

Figure 7: PM2.5 Levels in T-Hub

Observation: PM2.5 levels at T-Hub remained within acceptable limits but showed slight increases during peak hours when more people were present.

8.3.2 PM10 Levels in T-Hub

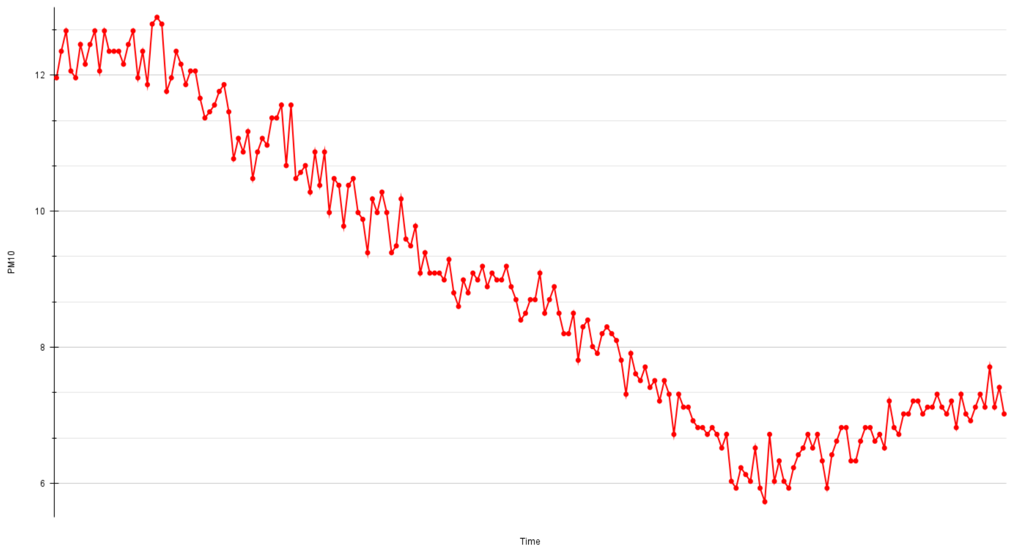

Figure 8: PM10 Levels in T-Hub

Observation: Similar to PM2.5, PM10 levels were relatively stable, with small spikes corresponding to periods of higher activity.

8.3.3 Combined PM2.5 and PM10 Levels in T-Hub

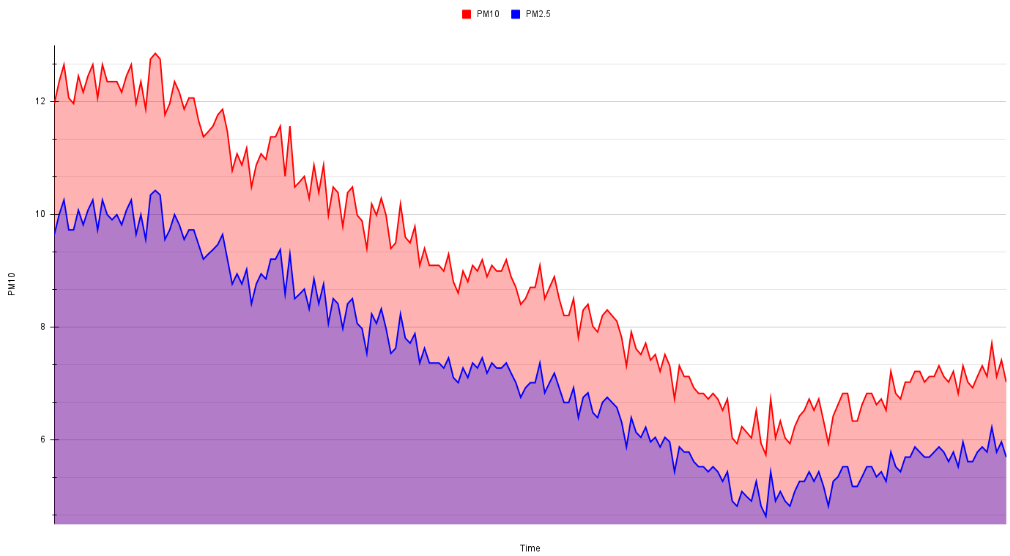

Figure 9: Combined PM2.5 and PM10 Levels in T-Hub

Observation: The combined levels provided a comprehensive view of the air quality, showing steady readings during non-peak hours and slight variations during the day.

8.3.4 CO2 Levels in T-Hub

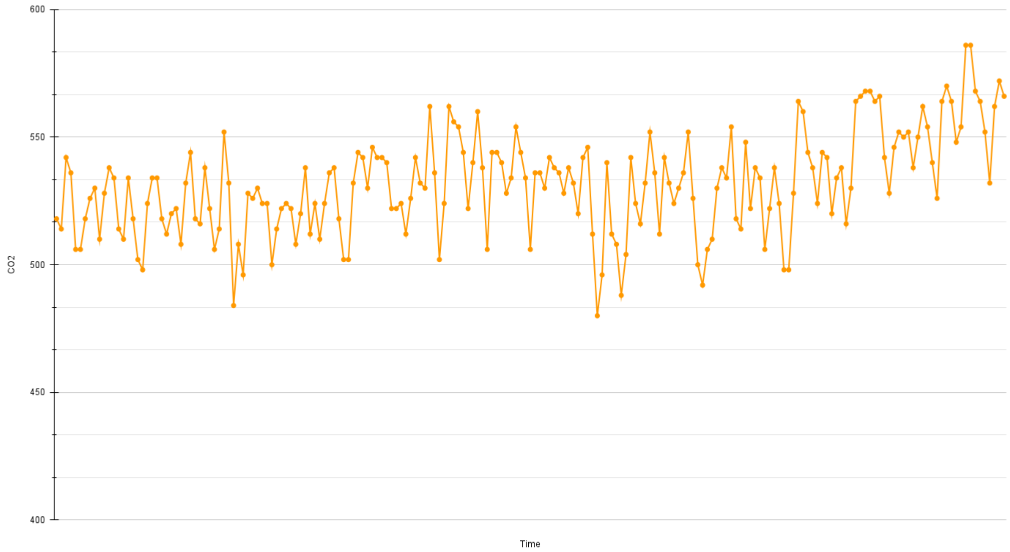

Figure 10: CO2 Levels in T-Hub

Observation: CO2 levels were relatively consistent but showed an upward trend during busy periods, which aligned with increased occupancy and reduced ventilation.

8.4 Comparison: Diwali vs. T-Hub Analysis

To compare air quality during the Diwali festival with regular T-Hub operations, the following insights were observed:

- **PM2.5 Levels:** Diwali witnessed a substantial increase in PM2.5 levels (Figure 3), whereas T-Hub maintained consistent levels within acceptable limits (Figure 7).
- **PM10 Levels:** The PM10 levels during Diwali (Figure 4) were significantly higher compared to the T-Hub baseline (Figure 8).
- **Combined PM2.5 and PM10 Levels:** The cumulative particulate exposure was notably higher during Diwali (Figure 5), showing sharp spikes, while T-Hub data (Figure 9) remained stable.
- **CO2 Levels:** Diwali resulted in elevated CO2 levels (Figure 6), likely due to increased activity and reduced ventilation, whereas T-Hub operations displayed a steady upward trend during busy periods (Figure 10).

Summary: The Diwali period demonstrated the adverse effects of festive activities on air quality, with significant deviations in PM2.5, PM10, and CO2 levels. In contrast, T-Hub's air quality remained relatively stable, reflecting the impact of controlled indoor environments.

9 Challenges Faced

Throughout the project, I faced several challenges that required problem-solving and adaptability:

- **Soldering:** This was my first time doing soldering, and I faced difficulties in ensuring clean and strong connections on the PCB. However, after some practice and learning from online tutorials, I was able to get the components properly soldered and connected.
- **Finding a Good Deployment Spot:** Identifying the ideal location to deploy the sensors was challenging. I had to ensure that the sensors were placed in an area with good air circulation, representative of the whole environment, and free from interference. After considering different spots, I chose the 4th floor of T-Hub as it provided a suitable environment for monitoring.

- **Platform Switching (ThingSpeak to Qubitro):** Initially, I had used ThingSpeak for data collection and visualization, but I faced difficulties with the platform's presentation and usability. I then decided to switch to Qubitro, which provided a more suitable and user-friendly interface for managing the data.

10 Conclusion

This project successfully developed and deployed an air quality monitoring system using various environmental sensors, including the SDS011 for particulate matter, the Prana CO2 sensor, and other related components. The system was designed to collect real-time air quality data and display it on an interactive dashboard, offering valuable insights into the environmental conditions at the deployed location.

During the project, I faced several challenges, including learning to solder components for the first time, selecting an appropriate deployment location to ensure comprehensive data collection, and transitioning from ThingSpeak to Qubitro for data storage and visualization due to the limitations of the former platform. Despite these challenges, the project progressed smoothly and achieved its primary objectives.

The results of the system's deployment during the Diwali festival and regular operations at T-Hub revealed significant fluctuations in air quality, with increased particulate matter and CO2 levels during peak activity periods. These findings highlight the importance of continuous air quality monitoring in both residential and commercial environments.

Overall, this project not only enhanced my technical skills in hardware integration, sensor calibration, and data visualization but also provided me with insights into the practical challenges of real-world system deployments. The system is scalable and can be expanded for broader usage in environmental monitoring and smart city applications.

For further details on the system's design and implementation, the complete project code is available on my GitHub repository: `https://github.com/Arman-03/Air-Pollution-Monitor`.