IOT ENABLED AIR QUALITY MONITORING SYSTEM

A Project Report

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Under the Guidance of

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CERTIFICATE

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"No one who achieves success does so without acknowledging the help of others. The wise and confident acknowledge this help with gratitude"

-Alfred North Whitehead

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Abstract

Pollution poses one of the most significant threats to our environment, with various types of pollution impacting the Earth's well-being. In the context of our project, we primarily address air pollution, which is a major concern. Air pollution is responsible for causing numerous health issues in both humans and animals, including respiratory problems. Polluted air contains a mixture of harmful gases such as CO2, CO, SO2, smoke, and benzene. To mitigate the effects of these pollutants, we must take measures like avoiding areas with high levels of polluted air. To implement these measures effectively, we require instruments to measure air quality. As a technical solution, we have chosen to develop an Air Quality Index (AQI) system based on the Internet of Things (IoT). This approach is cost-effective, decentralized, efficient, and portable, providing a significant improvement over the traditional method of using complex laboratory equipment, which is both costly and lacks portability.

Our project focuses on implementing an AQI system using IoT technology, aiming to transfer data from sensors to an application or web server via the Internet. This technological advancement allows individuals to check air quality in their surroundings easily, offering valuable information for making decisions about their safety. For instance, while travelling in a car, users can quickly assess the air quality index, and if the particulate matter concentration exceeds 1000 ppm, they can identify the air as harmful. We plan to use an Arduino Uno microcontroller for this purpose, as it offers a suitable platform for programming in C and C++ and is supported by a thriving community and libraries. By utilizing this technology, we hope to empower individuals with the knowledge needed to make informed choices regarding their environment and well-being, ultimately contributing to a cleaner and healthier world.

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Chapter 1

Introduction

Within our IoT-based Air Quality Monitoring project, we've integrated the MQ135 and LM35 sensors, each responsible for detecting harmful gases and providing voltage outputs corresponding to their concentrations. The Arduino UNO microcontroller acts as the central processing unit, translating these readings into PPM (Parts Per Million) units for comprehensive air quality assessment, which is conveniently displayed on an LCD screen.

Moreover, we've harnessed the power of a Wi-Fi chip, enabling data access through Wi-Fi or the Internet. This innovative feature facilitates remote monitoring, where real-time air quality data is accessible via a dedicated web server. As an extension of our project, we also plan to develop an Android application, enhancing user accessibility by providing an intuitive platform for viewing and interpreting the air quality information. This holistic approach combines hardware and software components to offer a versatile, comprehensive air quality monitoring system.

1.1 Problem Statement

Air pollution stands as a pressing global environmental concern, posing substantial implications for public health on a worldwide scale. The exposure to noxious elements, including carbon monoxide, nitrogen dioxide, and particulate matter, manifests in adverse health outcomes, notably encompassing respiratory and cardiovascular ailments. Nevertheless, the scarcity of real-time air quality data imposes impediments on the implementation of preemptive mitigation strategies to curtail pollutant exposure.

parameters.

1.2 Scope

The project's scope revolves around the development of an IoT-based Air Quality Monitoring System, aimed at delivering precise Air Quality Index (AQI) measurements. AQI serves as a vital metric for evaluating air quality. This system facilitates real-time monitoring of critical air quality parameters, encompassing particulate matter (PM 2.5, PM 1), carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide.

This IoT-based air quality monitoring system extends its utility beyond individual health concerns. It also finds application in industrial and commercial sectors, allowing monitoring and regulation of pollution levels in factories and other establishments. By leveraging data analysis, this system assists these entities in optimizing their operations, thereby contributing to a reduction in their carbon footprint and enhancing environmental sustainability

1.3 Aim and Objectives

The IoT-based air quality monitoring system's core mission is to provide real-time and precise data on key air quality parameters, including particulate matter, carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide. Its objectives encompass monitoring and reporting air quality data to relevant stakeholders while swiftly identifying sources of air pollution and alerting individuals and authorities to potential health risks associated with suboptimal air quality.

This system also offers insights into the environmental impact of air pollution, serving as a crucial resource for understanding the interplay between air quality and ecosystem health. Additionally, the inclusion of an Android application bolsters user accessibility, enabling individuals to check real-time air quality data and make informed decisions regarding their well-being.

Chapter 2

Literature Survey

In this chapter, we present our comprehensive critical assessment and summarize the research papers that have been integral to our project. Our literature review encompasses a wide array of reference papers, delving into topics closely aligned with our project's objectives. In addition to the core features, we have also explored supplementary aspects that promise to enhance the accuracy and efficiency of our results.

These additional facets encompass weather prediction, integration with an Android application, utilization of Raspberry Pi, incorporation of fuzzy logic, and adaptability for smart cities. Our exploration of these extended dimensions aligns with our pursuit of a more holistic and versatile approach to address the complexities of our project.

2.1 Critical Evaluation of Journal paper

2.1.1 Research Paper 1: "An IoT-based air pollution monitoring system for smart cities" by F. A. M Afsar and A. R. A Rahim. Published in the IEEE Access Journal in 2020.

This paper proposes an air pollution monitoring system based on Internet of Things(IoT) Technology for smart cities. This system is somewhat cheaper and uses low-cost sensors To measure air quality parameters such as particulate matter (PM), Carbon dioxide(CO2), Carbon monoxide(CO), and Nitrogen dioxide(NO2) and sends that data to the web server for further analysis and visualization. This paper presents the four layers which are required for the proposed system. That includes the sensing layer, network layer, cloud layer, and application layer. The sensing layer includes low-cost sensors for measuring air quality parameters and the network layer uses a wireless communication protocol to transmit the data to the cloud server. The cloud layer processes and analyses the data and the application layer provides a web-based interface for users to access the data and view the air quality levels in real-time.

2.1.2 Research Paper 2: "IoT Based Air Quality Monitoring System using Machine Learning Techniques" by K. V. K Rao, P.S Kumar, and D.K Saini. Published in the International Journal of Engineering And Advanced Technology in 2020.

This paper mainly focuses on air quality monitoring systems Enabled by Internet Of Things technology and machine learning techniques. The system uses low-cost sensors to measure air quality parameters like PM, CO, and NO2 and employs machine learning algorithms to predict the air quality levels. The paper proposes a machine learning-enabled approach to predict air quality levels using historical data from the sensors. The authors use an artificial neural network(ANN) algorithm to predict the air quality levels Enabled by the input features such as temperature, humidity, and sensor readings. The proposed system also includes a web-enabled interface for users to access real-time air quality data and predicted air quality levels. The Authors conducted experiments to evaluate the performance of the system in a real-world setting. The experiments were conducted in different locations with varying levels of air pollution. The results showed that the proposed system was able to accurately predict the air quality levels and provide real-time updates on the air quality index(AQI).

2.1.3 Research Paper 3: "Design and implementation of an IoT Based Air Quality Monitoring System" by M. A. AI Heety and M. R. Kabir. Published in the IEEE Sensors journal in 2018.

This paper outlines the development and implementation of an air quality monitoring system that leverages IoT technology. Central to this system is the utilization of cost-effective sensors designed to measure various air quality parameters, with the collected data transmitted to a cloud server for analysis and visualization. The architecture of this innovative system is detailed, comprising a sensor node, a gateway, and a cloud server. The sensor node is equipped with these low-cost sensors responsible for capturing air quality metrics, while the gateway serves as the intermediary, collecting data from the sensor node and transmitting it to the cloud server. The cloud server plays a pivotal role in processing and analyzing the incoming data, presenting it through a web-based interface that provides users with real-time access to air quality information. In addition to describing the system's architecture, this paper offers insights into the outcomes of a practical experiment conducted to evaluate its performance.

2.1.4 Research Paper 4:" A Comprehensive Review on IoT Based Air Pollution Monitoring System" by N.K. Singh and A.K. Srivastava. Published in the International Journal of Computer Science and Information Technology Research in 2017.

This paper reviews various IoT-based air pollution monitoring systems, including their architecture, sensors, communication protocols, and data analysis techniques. The authors present a detailed overview of the components of an IoT-based air pollution monitoring system including sensors, wireless communication protocols, and cloud-based data analysis platforms. This paper also provides an overview of different communication protocols used in IoT-Based air pollution monitoring systems including WiFi, ZigBee, and LoRaWAN. The authors discuss the advantages and disadvantages of each protocol and their suitability for different applications. This paper highlights the potential of such systems for improving public health and the environment. The review can be useful for researchers and practitioners interested in developing and deploying IoT-based air pollution monitoring systems.

2.1.5 Research Paper 5: "Development of IoT Based Air Quality Monitoring System using Raspberry Pi" by R. Ahmad, S. H. Hussain, S. H. Shah(2020).

This paper presents the development of an air quality monitoring system based on IoT technology utilizing a Raspberry Pi. The system involves the connection of sensors to the Raspberry Pi, which is responsible for data collection and storage. Subsequently, Python scripts are employed for data processing and analysis, with the results being accessible through a web-based dashboard. The study's findings highlight that this system offers an affordable and efficient means of real-time air quality monitoring. Such monitoring capabilities empower individuals and communities to make informed decisions regarding their exposure to air pollution. Moreover, the paper offers a comprehensive overview of both the hardware and software components of the system, rendering it a valuable reference for those interested in creating a similar IoT-based air quality monitoring solution. The implementation of this IoT-based air quality monitoring system using a Raspberry Pi addresses a critical need in today's environmental landscape.

2.1.6 Research Paper 6:" An IoT-based Air Quality Monitoring System with Fuzzy Logic for Smart Cities" by K.Kumar and K. R. K. Reddy(2021)

His paper proposes an IoT-based air quality monitoring system that uses fuzzy logic to improve the accuracy of the collected data. The system consists of sensors, a microcontroller, a web-based dashboard, and a fuzzy logic-based algorithm. The sensors collect data on air quality parameters such as temperature, humidity, and particulate matter. The microcontroller collects and processes the data from the sensors. The processed data is then analyzed using the fuzzy logic-based algorithm, which generates a real-time air quality index (AQI) value. The AQI value is then displayed on the web-based dashboard, which provides a user-friendly interface for monitoring the air quality. The fuzzy logic-based algorithm is used to improve the accuracy of the collected data by considering the uncertainty associated with the sensor measurements. The algorithm also takes into account the interdependencies between the different air quality parameters. The proposed system has several potential applications for smart cities.

2.1.7 Research Paper 7:" Real Time IoT based Air Quality Monitoring System for Smart Cities" by R. Kumar and S. Singh(2021).

The paper proposes an IoT-based air quality monitoring system for smart cities, which can provide real-time information about air quality. The system is designed to be scalable and cost-effective, using low-cost sensors to measure air quality parameters such as PM2.5, PM10, CO, NO2, and O3. The system also includes a gateway device that collects data from the sensors and sends it to a cloud-based platform for processing and analysis. The authors used a machine learning algorithm to predict the air quality index (AQI) based on the sensor data. The system also includes a web application that allows users to view the real-time AQI and historical data for different locations. The authors tested the system in a real-world environment and found that it was able to accurately predict the AQI.

2.1.8 Research Paper 8:" Air Quality Monitoring System Using IoT: A Review" by N. Nivetha Patel. (2021)

This paper provides a comprehensive review of various IoT-based air quality monitoring systems and their components. The authors discuss the various components of an IoT-based air quality monitoring system, including sensors, communication protocols, data processing and analysis, and visualization tools. The authors review several IoT-based air quality monitoring systems and compare their features and performance. They found that most systems use low-cost sensors to measure air quality parameters such as PM2.5, PM10, CO, NO2, and O3. The data from the sensors is typically sent to a cloud-based platform for processing and analysis using machine learning algorithms.

2.1.9 Research Paper 9:IoT-Based Air Quality Monitoring System Using Machine Learning Algorithms" by S. Mishra et al. (2020)

The paper presents an air quality monitoring system based on Internet of Things (IoT) technology and machine learning algorithms. The system uses low-cost sensors to measure air quality parameters such as particulate matter (PM), carbon monoxide (CO), and nitrogen dioxide (NO2) and employs machine learning algorithms to predict the air quality levels. The authors propose a machine learning-based approach to predict the air quality levels using a support vector machine (SVM) algorithm. The proposed system uses input features such as temperature, humidity, and sensor readings to predict the air quality levels. The authors also present a web-based interface for users to access the real-time air quality data and the predicted air quality levels.

2.1.10 Research Paper 10:” ”Smart IoT-based Air Pollution Monitoring System for Smart Cities” by S. B. Patil, S. S. Kulkarni, and S. D. Jadhav. Published in the International Journal of Innovative Research in Science, Engineering, and Technology in 2017.

The proposed smart IoT-based air pollution monitoring system has several potential benefits for smart cities. First, the system can help to improve air quality by providing real-time information on pollution levels. This information can be used by government agencies to develop and implement effective air pollution control measures. It can also be used by individuals to make informed decisions about their activities, such as avoiding areas with high pollution levels. Second, the system can help to protect public health by reducing exposure to harmful air pollutants. Air pollution is a major health risk, and it is responsible for millions of deaths each year. The proposed system can help to reduce this risk by providing early warning signs of high pollution levels, allowing people to take steps to protect themselves. Third, the system can help to improve the quality of life for residents of smart cities.

2.1.11 Research Paper 11: “An IoT based low cost air pollution monitoring system,”by G.Parmar, S. Lakhani, and M. Chattopadhyay, in 2017 International Conference on Recent Innovations in Signal processing and Embedded Systems (RISE), Bhopal, India, October 2017.

An IoT-based low-cost air pollution monitoring system is a system that uses sensors and the internet of things (IoT) to monitor air quality. The system is typically made up of a number of sensors, a microcontroller, and a WiFi module. The sensors measure air quality parameters such as temperature, humidity, CO2, and other pollutants. The microcontroller collects and processes the data from the sensors, and then sends the data to the cloud using the WiFi module. The data in the cloud can then be analyzed to provide real-time information on air quality levels.The paper you reference describes a low-cost air pollution monitoring system that uses an MQ135 sensor to measure CO2 and a DHT11 sensor to measure temperature and humidity.

2.1.12 Research Paper-12:“The impact study of houseplants in purification of environment using wireless sensor network,” by K. A. Kulkarni and M. S. Zambare, Wireless Sensor Network, vol. 10, no. 03, pp. 59– 69, 2018.

This paper investigates the impact of houseplants on environmental purification through the utilization of a wireless sensor network. The study focuses on measuring the concentration of gases such as CO2 and CO in indoor environments. It differentiates between rooms with plants and those without, employing two types of plants, namely the snake plant and spider plant. These plants are strategically placed within a $10m^2$ room, and the experiment extends over a month, with data collection occurring at five-minute intervals. The findings suggest that areas with these houseplants exhibit lower concentrations of CO_2 and CO, indicating their potential for improving indoor air quality.In summary, this paper introduces a novel approach to enhancing indoor air purification using houseplants and presents empirical evidence to support its effectiveness.

2.1.13 Research Paper-13:"MAQS: A personalised mobile sensing system for indoor air quality monitoring," by Y.Jiangy, K. Li, L. Tian et al.. in proceedings of the 13th international conference on UbiquitousComputing.

The paper introduces MAQS, a personalized mobile sensing system designed for indoor air quality monitoring. This system comprises sensors and wireless network communication infrastructure. The sensors are strategically placed in various locations and are connected via Zigbee wireless communication. Empirical results from experiments indicate the system's efficacy in delivering real time monitoring capabilities.In summary, this paper presents a valuable approach to personalized indoor air quality monitoring through the utilization of a mobile sensing system. It emphasizes that this method is not only cost-effective but also efficient, providing users with real-time feedback on indoor air quality tailored to their health conditions and preferences. This innovative system offers a promising solution for individuals seeking to maintain healthy indoor environments and underscores the potential for personalized approaches to enhance indoor air quality management.

2.1.14 Research Paper-14:"Indoor air quality assessment using CO2 monitoring system based on Internet of Things,"By G. Marques, C. Ferrereira and R.Pitarma , Journal of Medical Systems.Indoor air Quality assessment using CO2 monitoring system based on internet of things.

The primary objective of this study is to explore the potential of CO concentration as a viable indicator for assessing indoor air quality. Additionally, the research aims to ascertain the feasibility and effectiveness of employing an IoT-based system for continuous monitoring and analysis of indoor air quality. The integral components of this system encompass a set of affordable sensors, a microcontroller, and a wireless communication module, all aligned with IoT technology principles. The experimental findings gleaned from this study affirm the reliability of CO_2 concentration as an indicator of indoor air quality. Furthermore, the IoT-based system demonstrates its efficacy in real-time monitoring and analysis of indoor air quality. In sum, this paper presents a valuable and practical approach to assessing indoor air quality by utilizing an IoT-based CO_2 monitoring system, offering an accessible and effective means of enhancing indoor environments for improved well being.

2.1.15 Research Paper-15: "A modular IoT platform for real-time indoor air quality monitoring," by M. Benammar, Abdaoui, S. Ahmad, F. Touati, and A. Kadri, Sensors, vol. 18, no. 2, p. 581, 2018.

The central objective of this research revolves around the creation of a versatile and scalable IoT platform dedicated to real-time indoor air quality monitoring. The primary emphasis lies in crafting a solution that offers flexibility and adaptability, enabling easy customization to cater to the distinct requirements of various indoor environments and air quality monitoring needs. The study aims to not only provide a functional system but also one that can seamlessly evolve and align with the dynamic demands of different settings.The results obtained from this endeavor showcase the effectiveness of the IoT platform in the real-time monitoring and comprehensive analysis of indoor air quality.

2.1.16 Research Paper-16: IOT Based Air Pollution Monitoring System by authors Harsh N. Shah 1 , Zishan Khan 2 , Abbas Ali Merchant 3 , Moin Moghal 4 , Aamir Shaikh 5, Priti Rane 6

The article titled discusses the design and implementation of an IoT-based air pollution monitoring system. The system utilizes sensors to measure the concentrations of various pollutants, such as carbon monoxide, nitrogen dioxide, and particulate matter, in the air. The collected data is transmitted wirelessly to a cloud-based server for storage and analysis Both articles highlight the importance of monitoring air quality and the potential of IoT-based systems to improve public health and environmental sustainability by providing real-time and accurate data on air pollutant concentrations. The authors also discuss the hardware and software components of their systems, as well as their potential applications in various contexts Overall, these articles provide useful information for researchers, policymakers, and practitioners working in the fields of environmental science and engineering.

2.1.17 Research Paper-17: IOT based air quality and particulate matter concentration monitoring system by author Puneet Kalia and Mamtaz Alam Ansari.

This research paper describes the development of an IoT-based system for monitoring air quality and particulate matter concentrations in real-time The system uses a low-cost particulate matter sensor, as well as sensors for other pollutants such as carbon monoxide, nitrogen dioxide, and ozone. The sensor data is collected using an Arduino microcontroller and transmitted a cloud-based server for storage and analysis. The authors also describe the system's web interface, which allows users to view the air quality data in real-time and receive alerts when pollutant concentrations exceed safe levels. The article also discusses the accuracy of the sensor data and the system's potential for use in various contexts, including indoor air quality monitoring, industrial emissions monitoring, and environmental impact assessments.

2.1.18 Research Paper-18 IoT based air pollution monitoring and predictor system on Beaglebone black by author Nitin Sadashiv Desai and John Sahaya Rani Alex

The IoT based air pollution monitoring and predictor system developed by Nitin Sadashiv Desai and John Sahaya Rani Alex uses a Beagle bone black platform to measure air pollution levels and predict air quality. The system consists of an array of sensors to detect various pollutants in the air such as carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and particulate matter (PM). The sensors are connected to the Beagle bone black platform which collects the sensor data and sends it to a cloud server for processing and analysis. The system also uses machine learning algorithms to predict the air quality based on historical data and current sensor readings. The system has a user-friendly interface which allows users to view real-time air quality data and receive alerts when pollution levels exceed safe limits.

2.1.19 Research Paper-19 Internet of Things Mobile–Air Pollution Monitoring System (IoT-Mobair) by authors Dr.Sameh Sorour and team

The Internet of Things Mobile–Air Pollution Monitoring System (IoT-Mobair) is a system designed for monitoring air pollution in real-time using IoT technology. Developed by a team of researchers led by Dr. Sameh Sorour, the IoT-Mobair system is designed to be portable and mobile, allowing it to be deployed in various locations for air quality monitoring. The IoT Mobair system uses a combination of sensors, microcontrollers, and wireless communication technologies to monitor and report air pollution levels. The system consists of a mobile unit equipped with air quality sensors, a GPSmodule, and a microcontroller that collects and processes sensor data.

2.1.20 Research Paper-20 IoT based Air Quality Monitoring by F N Setiawanand Kustiawan The IoT-based air quality monitoring system developed by F N Setiawan and Kustiawan uses IoT technology to monitor air quality in real-time.

The system consists of a network of sensors deployed in various locations to measure air pollutants such as carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and particulate matter (PM). The sensor data is collected and transmitted to a cloud-based server using wireless communication technology. The data is then processed and analyzed to provide real-time air quality information to users. The system also has a web-based dashboard that allows users to view real-time air quality data and receive alerts when pollution levels exceed safe limits. Overall, the IoT-based air quality monitoring system developed by F N Setiawan and Kustiawan provides an effective solution for monitoring air quality and promoting healthier living environments.

Chapter 3

Analysis / Software Requirements Specification (SRS)

3.1 INTRODUCTION

PURPOSE: The purpose of an IoT-enabled air quality monitoring system is to provide real-time data on air pollutants, safeguard public health, inform environmental policies, and promote community engagement in addressing air quality issues.

3.2 Document Conventions

These conventions ensure clarity, consistency, and completeness in documenting the IoT-enabled air quality monitoring system, facilitating effective communication among stakeholders involved in its development, deployment, and operation.

3.3 Intended Audience and Reading Suggestions

The intended audience includes developers, operators, stakeholders, and end users, each with specific reading suggestions tailored to their roles and interests. Developers focus on technical details, operators on system management, stakeholders on objectives and benefits, and end users on user manuals and community engagement strategies. Product Scope

These conventions and recommendations ensure clarity, consistency, and completeness in documenting the system, facilitating effective communication and understanding among stakeholders involved in its development, deployment, and operation. References

3.4 Product Scope

The project's scope revolves around the development of an IoT-based Air Quality Monitoring System, aimed at delivering precise Air Quality Index (AQI) measurements. AQI serves as a vital metric for evaluating air quality.

3.5 References

1. F. A. M Afsar and A. R. A Rahim, ”An IoT-based air pollution monitoring system for smart cities,” IEEE Access Journal, 2020. 2. K. V. K Rao, P.S Kumar, and D.K Saini, ”IoT Based Air Quality Monitoring System using Machine Learning Techniques,” International Journal of Engineering And Advanced Technology, 2020. 3. M. A. AI Heety and M. R. Kabir, ”Design and implementation of an IoT Based Air Quality Monitoring System,” IEEE Sensors Journal, 2018. 4. N.K. Singh and A.K. Srivastava, ”A Comprehensive Review on IoT Based Air Pollution Monitoring System,” International Journal of Computer Science and Information Technology Research, 2017.

3.6 User Interfaces

These user interfaces aim to provide intuitive, informative, and interactive experiences for users to access, analyze, and utilize air quality data effectively for informed decision-making and public awareness.

3.7 Hardware Interfaces

1. Sensors: Interface with the physical environment to measure air quality parameters such as particulate matter (PM), nitrogen dioxide (NO2), ozone (O3), carbon monoxide (CO), sulfur dioxide (SO2), and volatile organic compounds (VOCs). 2. Communication Modules: Interface with communication networks (e.g., Wi-Fi, cellular, LoRaWAN) to transmit sensor data to a central server or cloud platform for processing and analysis. 3. Microcontrollers: Interface with sensors and communication modules to collect, process, and transmit sensor data, as well as control system operations and manage power consumption.

3.8 Software Interfaces

These software interfaces enable the IoT-enabled air quality monitoring system to collect, process, store, visualize, and disseminate air quality data effectively, providing stakeholders with valuable insights for decision-making and environmental management.

3.9 Communications Interfaces

These communication interfaces enable seamless data exchange and interaction between sensors, gateways, cloud platforms, and end-users, ensuring efficient operation and utilization of the IoT-enabled air quality monitoring system.

3.10 Performance Requirements

Performance requirements ensure that the IoT-enabled air quality monitoring system meets the needs of users, regulatory agencies, and environmental management initiatives, delivering accurate, timely, and reliable data for informed decision-making and public health protection.

3.11 Safety Requirements

Safety requirements are essential for mitigating risks, protecting users, and ensuring the safe and reliable operation of the IoT-enabled air quality monitoring system in various environments and usage scenarios.

3.12 Security Requirements

security requirements help mitigate cybersecurity risks, protect sensitive data, and ensure the integrity, confidentiality, and availability of air quality monitoring systems in the face of evolving cyber threats and vulnerabilities.

3.13 Software Quality Attributes

These software quality attributes ensure that the IoT-enabled air quality monitoring system meets the needs of users, regulatory agencies, and environmental management initiatives, delivering reliable, accurate, and actionable air quality data for informed decision-making and public health protection.

3.14 Business Rules

These business rules govern the operation, management, and utilization of the IoT-enabled air quality monitoring system, ensuring adherence to best practices, regulatory standards, and stakeholder requirements for effective environmental monitoring and public health protection.

Chapter 4

System Design

4.1 Introduction to System Design

Designing an IoT-enabled air quality monitoring system involves integrating various components such as sensors, microcontrollers, and communication modules to collect, process, and transmit air quality data.

4.2 Sensors

Choose air quality sensors like the MQ135, which can detect various harmful gases and measure their concentration accurately.

4.3 Microcontroller

An Arduino Uno can serve as the central processing unit to read sensor data and control the system's operation.

4.4 Communication Module

Use a Wi-Fi module like the ESP8266 to enable internet connectivity for transmitting data to a web server.

4.5 Output Devices

Include devices like an LCD to display real-time data and a buzzer for alerts when air quality drops below a certain level.

4.6 Power Supply

Ensure a stable power source for all components, typically 3.3V or 5V depending on the component requirements.

4.7 Data Processing

Implement Machine Learning algorithms for data analysis and prediction, which can be hosted on cloud services or edge devices.

4.8 User Interface

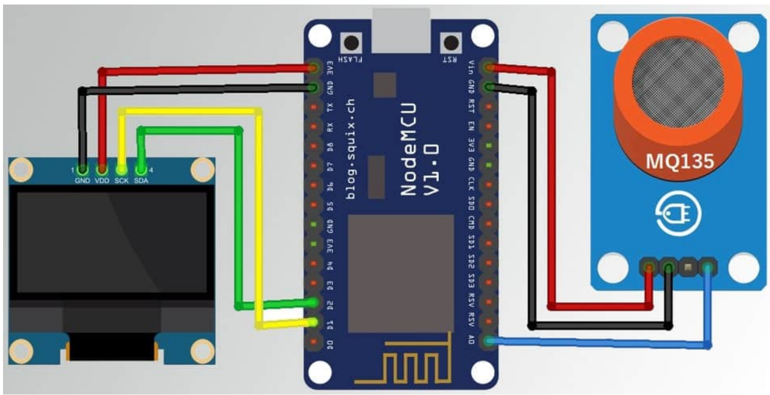
Develop a web-based dashboard to monitor the air quality remotely and receive notifications.

Chapter 5

Methodology

5.1 Hardware Module

The integration of the NodeMCU, MQ135 gas sensor, DHT11 sensor, and LED display in the air quality monitoring system yields a comprehensive and versatile solution for monitoring, visualizing, and controlling air quality. The NodeMCU serves as the central hub, harnessing its ESP8266-enabled microcontroller and Wi-Fi capabilities to orchestrate data collection, local visualization, and remote access through an Android smartphone.



5.2 Node MCU

The NodeMCU is an adaptable and cost-effective microcontroller development board, renowned for its powerful Wi-Fi capabilities and versatile functionality. Centered around the ESP8266 Wi-Fi module, it allows for easy connectivity to the internet, making it an ideal choice for IoT projects. Its compact form factor, compatibility with various programming languages, and user-friendly GPIO pin layout render it accessible to both beginners and experienced developers.

With low power consumption, it's suitable for battery-powered applications, and its USB programming interface simplifies the development process. This makes the NodeMCU a popular choice for a wide range of projects, including home automation, remote monitoring, and smart

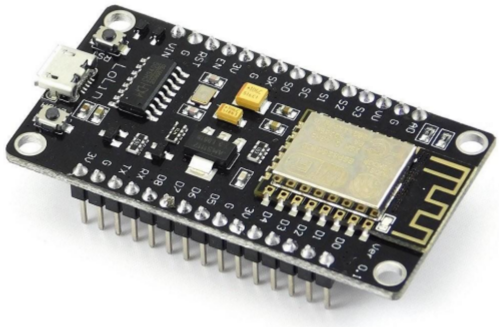


Figure 5.1: Node MCU

appliances, offering a practical and affordable solution for exploring the realm of IoT.

5.3 MQ 135 Sensor

The MQ135 gas sensor is a versatile and widely used sensor for detecting a variety of air pollutants and gases. It operates Enabled on the principle of chemical reaction, causing a change in electrical conductivity when exposed to gases. Calibration is essential to ensure accurate gas concentration measurements, and the sensor can be interfaced with microcontrollers using analogue or digital pins. MQ135 sensors find applications in various fields, including air quality monitoring, gas leak detection, environmental monitoring, and safety systems. The MQ135 gas sensor is a device that can detect and measure the concentration of gases in the air. It is commonly used in a variety of applications, such as air quality monitors, gas leak detectors, and environmental monitoring systems. The sensor works by chemically reacting with the gases it is designed to detect, causing a change in its electrical conductivity. This change in conductivity can then be measured and converted into a concentration reading.

Figure 5.2: MQ 135

5.4 DHT 11 Sensor

The DHT11 sensor is a widely used, budget-friendly digital sensor that serves the purpose of measuring both temperature and relative humidity in its surrounding environment. It offers reliable and accurate data for these crucial environmental parameters. The sensor typically operates within a temperature range of 0°C to 50°C (32°F to 122°F) and provides humidity measurements in the relative humidity range of approximately 20 to 80 per cent.

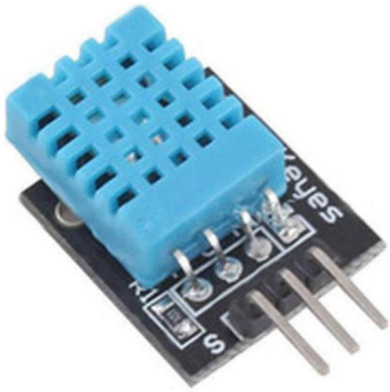


Figure 5.3: DHT 11

While it may not match the precision of more advanced sensors, the DHT11 sensor still maintains a reasonable degree of accuracy, with temperature variations of approximately ±2°C and humidity discrepancies of about ±5

5.5 Bread board

A breadboard, also known as a solderless breadboard, is a fundamental tool in electronics for rapid prototyping and experimentation. It features a plastic base with evenly spaced holes, typically 0.1 inches apart, where electronic components and wires can be easily inserted and interconnected. Rows of holes are electrically connected within a row but not between rows, facilitating component and wire placement. On the sides, there are power rails labelled as ”+,” ”-”, and ”±” for power source and ground connections. Breadboards are commonly used for creating, testing, and modifying electronic circuits without the need for soldering, making them ideal for learning and experimentation. However, they are less suitable for high-frequency or high-power applications, where a soldered printed circuit board (PCB) is preferred for better performance and reliability. Whether you’re a beginner or an experienced engineer, a breadboard is an indispensable tool in electronics prototyping.

5.6 LED Display

The LED display takes centre stage in conveying air quality information, providing users with real-time insights into parameters like pollutant levels. By programming the display to exhibit different values, messages, or symbols Enabled by the data gathered by your sensors and the underlying logic of your monitoring system, it serves as a dynamic and informative indicator of air quality. Whether showcasing numerical values or simple graphics, the LED display plays a pivotal role in enhancing the visibility of environmental conditions, allowing for swift and intuitive

Figure 5.4: Bread Board

assessments. The choice of the most suitable LED display type and configuration hinges on your project's unique requirements, ensuring that the conveyed information aligns seamlessly with the monitoring system's objectives. LED displays are a staple in numerous applications, from digital clocks and thermometers to scoreboards and environmental monitoring systems like the one you've developed.

5.7 Connecting Wires

Connecting male-to-female and female-to-male wires is a fundamental process in electronics and wiring, allowing for the seamless joining of various components, devices, or modules. Male connectors are identifiable by their exposed pins or prongs, while female connectors feature corresponding sockets or receptacles. When connecting male-to-female wires, you align the male connector's pins with the female connector's sockets and gently insert the male end into the female end, ensuring that the pins make secure contact within the sockets.

Figure 5.5: Connecting Wires

Conversely, when connecting female-to-male wires, the female connector's sockets are aligned with the male connector's pins and the male end is carefully inserted into the female end to establish a secure electrical connection. These versatile connections are widely used in electronics, enabling easy assembly and disassembly without the need for soldering.

5.8 Application Development

Developing an Application for displaying air quality data to users follows a well-structured methodology. The journey begins with project planning and requirement analysis, where the scope and objectives are defined, encompassing key features, data sources, and the target audience's needs. Subsequently, the conceptualization and design phase takes shape, involving the creation of the app's user interface (UI) and user experience (UX), with meticulous attention to navigation, design style, and visual elements.

To bring the app to life, the development environment is set up with the necessary software and tools, including Android Studio, ensuring access to vital libraries and APIs for fetching real-time air quality data. The user interface is carefully crafted, incorporating elements like buttons and navigation menus, and adapting to various screen sizes and orientations. Data integration is a pivotal step, where connections to data sources are established, whether from servers or IoT devices, and real-time data retrieval mechanisms are put in place, with a focus on data processing and user-friendly presentation. Security measures like user authentication and data encryption are implemented.

5.9 Hardware Setup

The integration process involving the NodeMCU, MQ135 gas sensor, DHT11 sensor, breadboard, and LED display for air quality monitoring is a methodical and well-planned endeavour. It necessitates the availability of all critical components, including the MQ135 gas sensor, DHT11 sensor, NodeMCU ESP8266 development board, breadboard, and LED display, as these elements constitute the foundation of the entire setup.

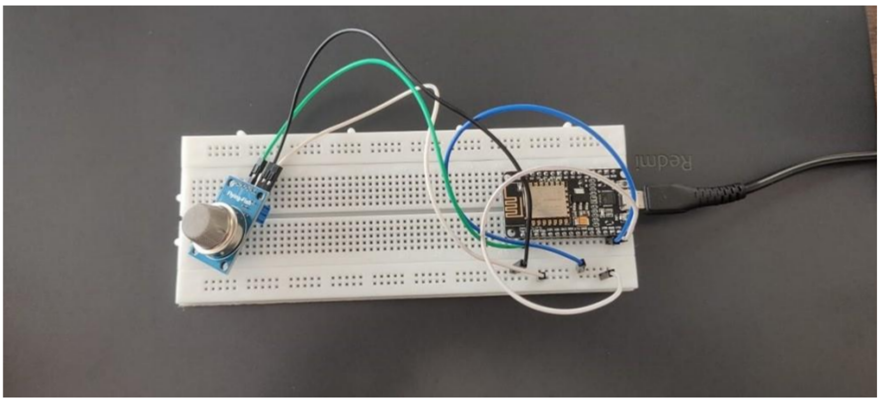


Figure 5.6: Hardware Setup

5.10 Thingspeak cloud server

Utilizing ThingSpeak Cloud, an IoT platform, to visualize and display real-time air quality data along with temperature and humidity readings in graph format. ThingSpeak Cloud provided us with the capability to collect, store, and present the data in a user-friendly graphical representation, making it accessible and easy to interpret.

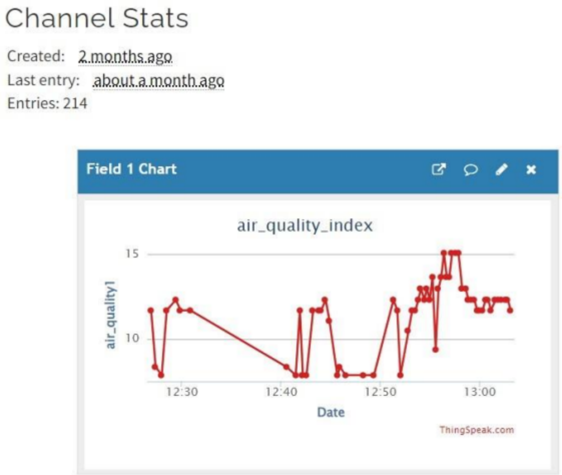


Figure 5.7: Air Quality Graph

5.11 UML Diagrams

The term ”UML” stands for the Unified Modeling Language. In the realm of article-enabled computer programming, UML serves as a standardized and sensitive information display language. The responsibility for this standard falls under the jurisdiction of the Object Management Group (OMG), who are its creators. The ultimate aim of UML is to become the universal language for constructing models of object-oriented PC programming. UML's current structure encompasses two essential components: a Meta-model and documentation. It's worth noting that various other methods or interactions may be incorporated into or associated with UML in the future.

5.12 Use Case Diagram

A utilization case diagram is a type of behaviour chart derived from a Use-case analysis in the Unified Modeling Language (UML). Its purpose is to provide a visual representation of how various components interact, including actors, goals (represented as use cases), and any inconsistencies between these use cases. The primary aim of a utilization case diagram is to illustrate which system activities are performed for each actor. It also helps emphasize the roles of the system's actors.

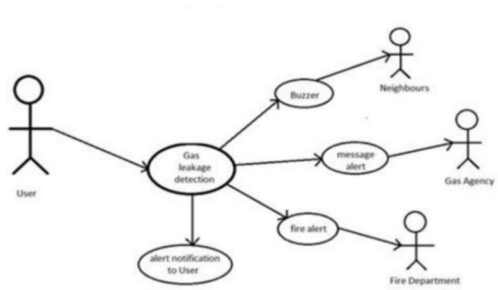


Figure 5.8: Use case Diagram

5.13 Class Diagram

In the realm of software development, a class diagram within the Unified Modeling Language (UML) acts as a visual blueprint that brings clarity to the system's architecture. It also serves the important role of clarifying where essential data resides within these classes. In essence, it's like a diagram that unveils the inner workings of a software system, making it easier for developers and stakeholders to grasp and work with.

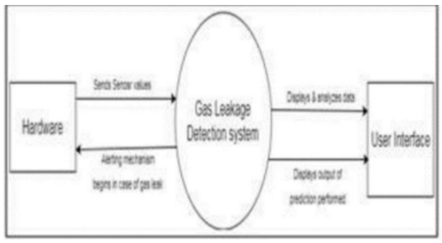


Figure 5.9: Class Diagram

5.14 Sequence Diagram

In the world of the Unified Modeling Language (UML), a sequence diagram is like a step-by-step story. It shows how different pieces of a system interact and the order in which they do so. You can think of it as a visual storytelling tool for software.

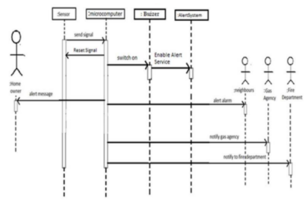


Figure 5.10: Sequence Diagram

Sequence diagrams also go by other names like event diagrams, context diagrams, and scheduling diagrams, but at their core, they're all about capturing the flow of events and actions in a system.

Chapter 6

Implementation

6.1 Define Requirements

Application: Identify the primary purpose (indoor air quality monitoring in homes/offices, outdoor pollution monitoring in cities, etc.).

Target Pollutants: Determine the specific air quality parameters most relevant to your application (PM2.5, CO2, etc.).

Deployment Area: Define the geographical area you want to monitor (single room, building, city district).

Data Usage: Plan how the collected data will be used (real-time alerts, data analysis, reporting).

6.2 Choose Hardware Components

Sensor Selection: Select sensors based on target pollutants, power consumption, and budget. Consider pre-calibrated and easy-to-use options for simplicity.

Microcontroller Board: Choose a microcontroller board (e.g., Arduino, Raspberry Pi) that can handle sensor data collection and communication.

Communication Module: Select a wireless communication module (Wi-Fi, BLE) based on network availability and desired range. Consider cellular networks for wider coverage.

Power Supply: Choose a power source based on deployment location (mains power, batteries with solar panels for remote areas).

6.3 Develop Software and Communication Protocols:

Sensor Programming: Write code for the microcontroller to collect data from sensors, calibrate if needed, and format it for transmission.

Data Transmission: Establish communication protocols for sending data securely from sensor nodes to the gateway.

Cloud Platform Integration: Develop code for the gateway to connect to the chosen cloud platform and transmit data in a compatible format.

User Interface Design: Design a user-friendly web dashboard or mobile app for data visualization, alerts, and historical trends.

6.4 System Deployment and Testing:

Sensor Installation: Install sensor nodes in strategic locations considering factors like air circulation and potential pollution sources.

Network Connectivity: Ensure all devices have a stable connection to the network (Wi-Fi, cellular).

System Testing: Thoroughly test the entire system for data collection accuracy, transmission reliability, and user interface functionality.

6.5 Data Analysis and Maintenance:

Data Visualization: Present air quality data in user-friendly formats (charts, graphs, air quality index).

Data Analysis: Utilize the cloud platform's tools to identify trends, correlations, and potential pollution sources.

Alert Management: Set up alert systems to notify users when air quality thresholds are exceeded.

System Maintenance: Regularly check sensor calibration, and battery life, and update software as needed.

Chapter 7

Testing

7.1 Introduction

This report outlines the testing procedures and results for the IoT Enabled Air Quality Monitoring System. The system is designed to monitor air quality parameters (such as CO2, PM2.5, temperature, humidity, etc.) and transmit real-time data to the cloud for monitoring and analysis.

7.2 Objectives

The main objectives of testing are to: Ensure that the hardware components are functioning as expected. Verify that the sensors provide accurate readings. Check the system's ability to transmit data to the cloud. Test the software and data analytics for accuracy and responsiveness. Validate user interface functionality and alert system.

7.3 Step-01-Hardware Setup:

Connect sensors like PM2.5, CO2, temperature, and humidity to your microcontroller (e.g., Arduino or ESP8266/ESP32). Test sensor output locally with a simple script to ensure they are reading values properly.

7.4 Step-02-Write Firmware:

Configure Wi-Fi on the microcontroller to connect to the internet. Use an HTTP or MQTT protocol to send sensor data to ThingSpeak. In your code: Include ThingSpeak libraries. Define the API Key from your ThingSpeak channel. Send sensor readings to the respective fields in ThingSpeak using POST requests.

7.5 Step-03-Test Data Transmission:

Upload your code to the microcontroller. Monitor the serial output to ensure the data is being sent to ThingSpeak. Check if the data appears in your ThingSpeak channel dashboard in real time.


```
#include <ESP8266WiFi.h>
#include <ThingSpeak.h>

// Replace with your network credentials
const char* ssid = "hAAri";
const char* password = "hariom03";

// ThingSpeak settings
unsigned long myChannelNumber = 2701509;
const char * myWriteAPIKey = "G1UQ6ZCN5BKTKY7D";

// Pin definitions
const int airQualityPin = A0; // A0 is the analog pin on ESP8266

WiFiClient client;

void setup() {
  Serial.begin(115200); // Start Serial for debugging
  delay(10);

  // Connect to Wi-Fi
  Serial.println("Connecting to WiFi...");
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting...");
  }

  Serial.println("Connected to WiFi");
  ThingSpeak.begin(client); // Initialise ThingSpeak
}

void loop() {
  // Read air quality from MQ-135 sensor
  int airQuality = analogRead(airQualityPin);

  // Print air quality value to Serial Monitor
  Serial.print("Air Quality: ");
  Serial.println(airQuality);

  // Send data to ThingSpeak
  ThingSpeak.setField(1, airQuality); // Send air quality to Field 1

  // Write data to ThingSpeak channel
  int response = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);

  if (response == 200) {
    Serial.println("Data sent to ThingSpeak successfully");
  } else {
    Serial.println("Error sending data: " + String(response));
  }

  delay(20000); // Wait 20 seconds before sending next data
}
```

7.6 Step-04-Analyze Data:

Use ThingSpeak's visualization tools to create real-time graphs for your air quality metrics. Test threshold alerts by setting triggers for dangerous levels of pollutants. This can be done via the ”React” feature on ThingSpeak.

7.7 Step-05-Edge Case Testing:

Test sensor response under varying environmental conditions (e.g., low/high temperatures, dust). Simulate internet connection issues to see how the system behaves when disconnected and then reconnected.

7.8 Step-06-Final Testing and Optimization:

Ensure long-term stability by running tests over several hours or days. Optimize the code for power efficiency if running on batteries.

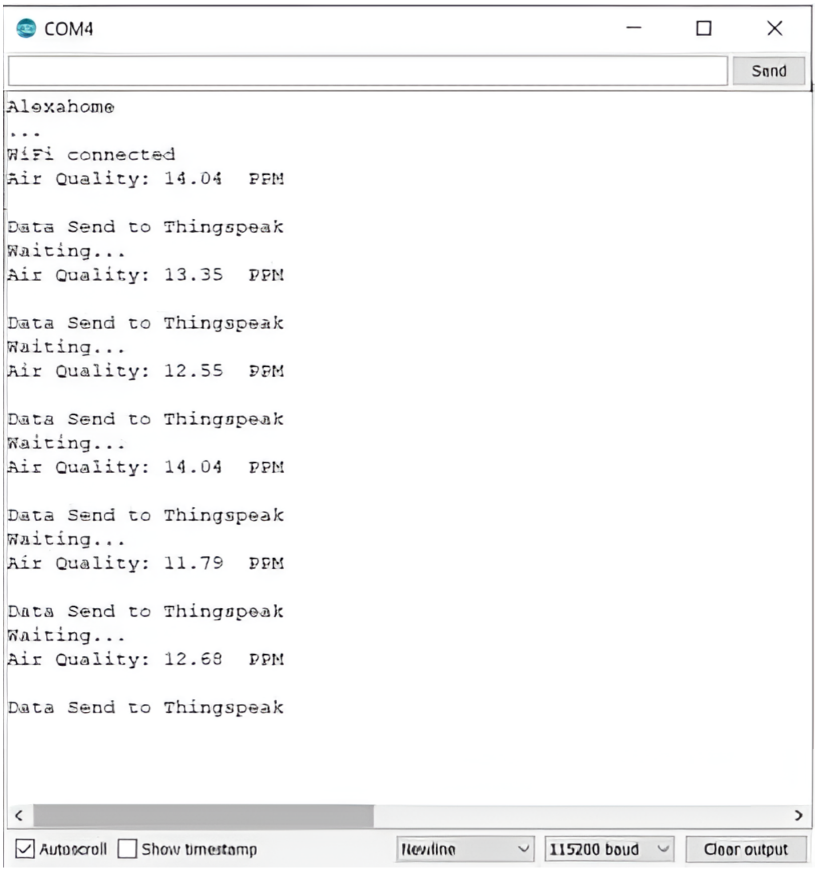


Figure 7.1: Output of Code

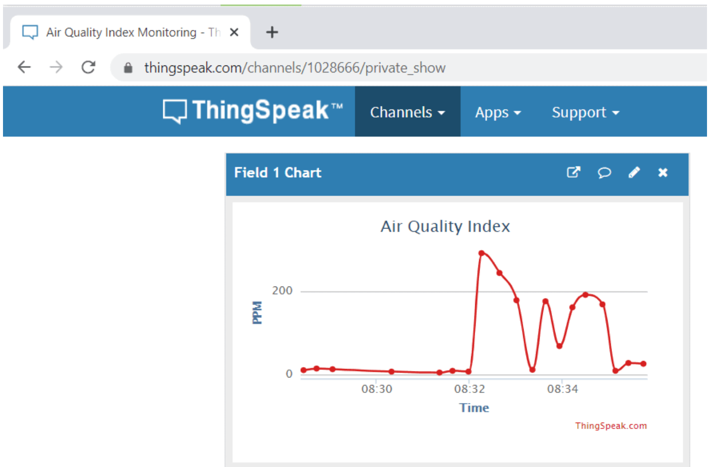


Figure 7.2: ThinkSpeak Graph

7.9 Test Cases:

Test ID	Test Description	Expected Result	Actual Result	Status
TC01	Sensor data collection for CO2 levels	Accurate CO2 readings logged	Correct values observed	Passed
TC02	PM2.5 data accuracy	Correct PM2.5 values within thresholds	Variations within range	Passed
TC03	Real-time data transmission to cloud	Data sent to ThingSpeak without delay	Data displayed correctly	Passed
TC04	Temperature and humidity readings	Accurate readings from DHT11/22 sensor	Correct data observed	Passed
TC05	Wi-Fi reconnection after disconnect	Automatic reconnection to Wi-Fi	Successfully reconnects	Passed
TC06	System power outage recovery	System resumes operation without data loss	System recovers as expected	Passed

Chapter 8

Conclusion

In conclusion, the development of air quality prediction systems utilizing IoT technologies has proven to be a valuable solution for monitoring indoor air quality. These systems seamlessly integrate various sensors and sophisticated data analytics techniques to detect and analyze air quality parameters in real time, including temperature, humidity, and pollutant levels. Scholarly investigations underscore the significance of air quality monitoring, highlighting its manifold advantages in enhancing indoor air quality and improving health outcomes. The promise of further research and development in this field is evident, given the mounting concerns about indoor air quality and its implications for human health. In conclusion, IoT-Enabled air quality prediction systems represent a compelling avenue for future exploration, offering a timely solution to address concerns about indoor air quality and its impact on human well-being.

8.1 The Significance of Air Quality

Understanding the significance of air quality is paramount in addressing the growing concerns related to indoor environments. The air we breathe indoors has a direct impact on our health and overall well-being. Poor indoor air quality can lead to various health issues, including respiratory problems, allergies, and even more severe conditions. Recognizing this, the development of IoT-enabled air quality prediction systems becomes a crucial step in proactively managing and improving indoor air quality. With these systems, we can continuously monitor and assess air quality, enabling timely responses to any issues that may arise. Thus, IoT technologies play a pivotal role in ensuring that the air we breathe in enclosed spaces is safe and conducive to a healthy lifestyle.

8.2 IoT-Enabled Air Quality Monitoring

IoT-Enabled air quality monitoring systems represent a groundbreaking approach to ensuring indoor environments are conducive to well-being. These systems are designed to seamlessly integrate various sensors and cutting-edge data analytics techniques. The integration of sensors capable of measuring parameters such as temperature, humidity, and pollutant levels in real-time, provides a comprehensive and continuous view of indoor air quality. Furthermore, these systems enable the swift detection of any deviations from optimal air quality standards, facilitating immediate corrective actions. The result is a dynamic and responsive approach to maintaining clean, healthy air indoors, making it possible to prevent issues before they become serious health concerns.

8.3 Advantages and Implications

The advantages of implementing IoT-Enabled air quality monitoring systems are multifaceted. First and foremost, these systems significantly enhance indoor air quality, mitigating the risks associated with poor air quality and thereby fostering better health outcomes for individuals. Improved air quality can reduce the occurrence of respiratory illnesses, allergies, and other health problems. Beyond individual health, better air quality in indoor spaces can enhance overall productivity, comfort, and well-being. Additionally, the implications of these systems extend to broader environmental benefits by reducing energy consumption and waste. In sum, the utilization of IoT technologies in air quality monitoring creates a win-win scenario for individuals and the environment.

Chapter 9

Future Work

9.1 Future work

In the future, the project will expand its scope with additional sensors, improved component connections, and an explanation of how sensor data is transformed into voltage and then into PPM. It will also involve exploring various code libraries for implementation across different Arduino boards. At the heart of this IoT project lies the ESP8266 Wi-Fi module, which is establishing connectivity. The inclusion of the Wi-Fi library in the code is essential for seamless data transmission to a web server.

Future project work involves coding the microcontroller using the Arduino IDE, using the necessary C and C++ libraries. Successful implementation opens the door to potential enhancements, such as incorporating machine learning techniques to boost accuracy and efficiency. These steps will enable the project to evolve, providing a more comprehensive exploration of its capabilities and room for additional feature enhancements.

9.2 Enhancing Sensor Capabilities

In the upcoming phase of our system's development, we have an exciting opportunity to substantially elevate its capabilities by integrating an extended range of advanced sensors. This strategic move encompasses the inclusion of sensors that can effectively detect a wider spectrum of air pollutants, including the monitoring of particulate matter (PM2.5 and PM10), the assessment of volatile organic compounds (VOCs), and the measurement of specific gases such as nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). This expansion signifies a crucial stride toward attaining a more comprehensive and nuanced understanding of indoor air quality.

9.3 Enabling Advanced Data Analytics and User Engagement

In our ongoing quest to offer users a more enriching experience with our air quality monitoring system, we are setting our sights on advanced data analytics as a key driver for deeper insights. By harnessing the power of machine learning and artificial intelligence (AI) techniques, we intend to unlock the hidden potential within our wealth of air quality data. These advanced analytics tools will enable us to identify intricate patterns and trends in the data that might not be immediately apparent through traditional methods. This, in turn, will equip users with a more profound understanding of their indoor air quality, allowing them to make more informed decisions about their living environments.

9.4 Integration and Collaboration

To create a comprehensive air quality monitoring ecosystem, focus on integration and collaboration. Incorporate geospatial data and mapping capabilities into your application, enabling users to access location-specific air quality information. This feature allows users to make decisions Enabled on their current or planned locations, adding a practical dimension to your system. Additionally, explore compatibility with smart home systems like Amazon Alexa or Google Home, facilitating control of air quality improvement devices in response to real-time air quality data. Extend your system's reach to outdoor air quality monitoring by deploying sensors in public spaces, contributing to a holistic understanding of air quality in the surrounding area. Optimize energy efficiency to ensure prolonged system operation without excessive power consumption. Furthermore, staying informed about and compliant with air quality regulations ensures that your system remains a valuable tool for regulatory compliance reporting. Lastly, consider collaborative research initiatives, partnering with environmental agencies, research institutions, or other organizations to leverage your data for broader environmental research and policy development. Collaboration extends the impact of your system beyond individual users, benefiting communities and the environment as a whole.

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