IoT Based REAL-TIME AIR QUALITY MONITORING SYSTEM

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MASTER OF SCIENCE

IN

PHYSICS

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ABSTRACT

Air pollution is a critical health and environmental concern, particularly in urban and industrial areas where pollutants like CO_2, nitrogen oxides, and particulate matter impact public health and quality of life. Real-time air quality monitoring is essential to address these risks, enabling timely actions against pollution. This project presents an IoT-based air quality monitoring system designed to provide continuous, accessible, and accurate air quality data.

The system is powered by the ESP8266 microcontroller, which connects the sensors to the internet, enabling real-time data access and storage on a cloud platform. We use the MQ135 gas sensor to detect harmful gases, including CO_2 and ammonia, along with the DHT11 sensor to measure temperature and humidity. Together, these sensors provide a comprehensive view of environmental conditions. Data collected is processed and transmitted to a user-friendly interface accessible via web or mobile, where users can monitor air quality trends over time. Additionally, a buzzer alerts users when pollutant levels exceed safe thresholds, offering instant feedback to mitigate health risks.

Our IoT-based system offers a scalable, low-cost solution suitable for various settings, including urban areas, schools, hospitals, and industrial zones. By providing real-time data and alerts, the system empowers individuals and communities to respond proactively to air pollution. This project demonstrates how accessible IoT technology can support sustainable development goals and contribute to large-scale environmental monitoring, potentially aiding policymakers in data-driven pollution control efforts.

Introduction

Air pollution has become one of the most pressing environmental and health challenges worldwide, especially in densely populated urban areas and industrial zones. Pollutants like carbon dioxide, nitrogen oxides, sulphur dioxide, and particulate matter contribute significantly to respiratory and cardiovascular diseases, impacting human health and quality of life. Real-time air quality monitoring has thus gained importance as an essential tool for tracking and controlling pollution levels, providing timely data to inform public health responses and environmental policy.

Traditional air quality monitoring systems are often managed by government or environmental agencies, utilizing large, expensive, and stationary equipment to measure pollutant levels across specific locations. These conventional systems, while accurate, are limited in scalability due to their high cost and maintenance requirements, resulting in limited spatial resolution. Consequently, numerous researchers and engineers have turned to Internet of Things (IoT) technologies to develop affordable, portable, and scalable air quality monitoring solutions that can offer more flexible coverage and near real-time data.

In recent years, a range of IoT-based air quality monitoring systems has been proposed and developed. These systems typically use microcontrollers or microprocessors, such as Arduino or ESP8266, paired with various sensors to detect harmful gases and particulate matter. The ESP8266, for example, is a low-cost, Wi-Fi-enabled microcontroller widely adopted for IoT projects due to its capability for remote data transmission. Researchers have demonstrated that using ESP8266 with sensors like the MQ135 (for detecting gases like CO2, ammonia, and benzene) and DHT11 (for measuring temperature and humidity) can yield promising results in air quality monitoring.

ESP8266 was used with air quality sensors to collect data on air pollutants in urban environments, which was then transmitted to a cloud platform for visualization and analysis. Similarly, Rani et al. implemented an air quality monitoring device using the MQ135 gas sensor and ESP8266 to detect harmful gases and transfer data to an online platform. Their research demonstrated that compact, low-power solutions can make air quality monitoring feasible for widespread adoption, especially in smart cities where environmental data needs to be accessible and responsive.

Building on this work, our project aims to design and implement an IoT-based real-time air quality monitoring system using the ESP8266 microcontroller, MQ135 gas sensor, DHT11 temperature and humidity sensor, and a buzzer. Our system collects and transmits air quality data, such as temperature, humidity, and concentrations of hazardous gases, to a cloud-based platform where users can monitor air quality in real-time. Additionally, we integrate a buzzer that activates when pollutant levels exceed safe thresholds, providing an immediate local alert to users.

Our approach seeks to address the limitations of traditional air quality monitoring by providing an affordable, real-time, and accessible solution suitable for a variety of environments, from homes to industrial areas. This system serves not only as a practical tool for individuals and communities to monitor and respond to air pollution but also as a scalable model for potential citywide deployments, contributing to a larger network of environmental monitoring solutions.

Motivation

- Rising Air Pollution: Increasing pollution levels harm health, making it essential to monitor air quality in real-time.
- Health Benefits: Real-time monitoring can help people avoid exposure to harmful air, protecting them from respiratory diseases.
- Awareness and Prevention: By providing immediate data, the system can raise awareness about air quality and encourage actions to reduce pollution.
- Low-Cost Solution: Using affordable components like the ESP8266, MQ135, and DHT11 allows for a budget-friendly monitoring device.
- Convenient Alerts: A buzzer warns users when air quality worsens, allowing for quick action to improve indoor air quality.
- User-Friendly Interface: The ThingSpeak app allows users to easily monitor air quality on their smartphones, making it accessible and convenient.
- Educational Value: The project demonstrates practical applications of IoT in environmental monitoring, making it a valuable learning experience in technology and environmental science.
- Scalability: The device can be installed in various locations to monitor air quality across larger areas, benefiting communities at large.

Objective

- Accurately Measure Air Quality: Detect and display real-time air quality levels (e.g., CO_2, alcohol, smoke, etc) using the MQ135 sensor.
- Monitor Temperature and Humidity: Collect and display environmental data (temperature and humidity) from the DHT11 sensor for a comprehensive air quality assessment.
- Provide Real-Time Alerts: Use a buzzer to give immediate alerts if air quality drops below safe levels, enabling timely preventive actions.
- Display Data Locally: Show air quality, temperature, and humidity levels on an LCD for easy on-site monitoring.
- Enable Remote Monitoring: Transmit air quality data to the ThingSpeak app, allowing users to check levels from their mobile devices in real-time.
- Graphical Data Visualization on ThingSpeak Server: Display graphs on the ThingSpeak app to show real-time variations in temperature, humidity, and PPM values, making it easier to track trends over time.
- Develop a User-Friendly Interface: Set up a simple, intuitive interface on the ThingSpeak app that displays air quality trends.
- Use LED Indicators for Air Quality Levels: Integrate LEDs that change colour based on different PPM (parts per million) values:
    - Green LED for good air quality (safe levels)
    - Yellow LED for moderate air quality (slightly elevated levels)
    - Red LED for poor air quality (high levels, requiring immediate action)
- Promote Awareness of Air Quality Issues: Educate users about air pollution and its health impacts through accessible, real-time monitoring.

Methodology

This project involves building an IoT-based real-time air quality monitoring system using sensors, modules, and ThingSpeak as the cloud platform. The following details each component, along with the methodology for assembling, configuring, and operating the system.

1. System Components

- ESP8266 Wi-Fi Module: The ESP8266 serves as the central microcontroller, chosen for its low cost and built-in Wi-Fi, enabling remote data transfer. It handles data collection from sensors and communication with the ThingSpeak cloud platform.
- MQ135 Gas Sensor: The MQ135 sensor detects harmful gases, including CO_2, ammonia (NH_3), and alcohol. It outputs an analog signal representing gas concentration, processed by the ESP8266.
- DHT11 Temperature and Humidity Sensor: This sensor measures ambient temperature and humidity, both of which influence gas sensor readings and overall air quality.
- LCD Display: The LCD provides real-time, local air quality data, allowing users to monitor the environment directly from the device.
- Smartphone Access via ThingSpeak App: ThingSpeak's app enables remote monitoring of air quality data, allowing users to view real-time values and trends on their smartphones.
- Buzzer: The buzzer alerts users when harmful gases exceed safe limits, providing an immediate warning signal.
- LED Indicators: LEDs provide a visual cue for pollution levels, with green for safe, yellow for moderate, and red for dangerous air quality.
- Power Source: A USB connection with a power bank or battery powers the entire setup, ensuring stable voltage for all components.

Figure 1: ESP8266 Module

Figure 2: MQ135 Gas Sensor

Figure 3: DHT11 Sensor

Figure 4: LCD with I2C Module

Figure 5: Buzzer

Figure 6: LEDs

Figure 7: Power bank

2. System Assembly

- ESP8266 Connections: The ESP8266 was programmed with Arduino IDE software to handle sensor input and output control, including the LCD, buzzer, and LEDs, and was connected to a power source.
- Sensor Connections:
  - The MQ135 connects via an analog input, and the DHT11 uses a digital pin.
- LCD Display: The LCD connects to the ESP8266 to show air quality values like CO_2 levels, temperature, and humidity locally.
- Buzzer and LED Setup: The buzzer and LEDs are wired to digital pins on the ESP8266, which controls them based on threshold levels set for each pollutant.

3. Data Collection and Processing

- Sensor Data Acquisition: The ESP8266 collects data from the MQ135 and DHT11 at one-second time intervals. This data includes concentrations of CO_2, alcohol, and acetone along with temperature and humidity.

4. Threshold Setting and Alert Mechanism

- Threshold Levels: Defined thresholds allow the system to assess air quality. For instance, a CO_2 threshold of 450 ppm. Under 450 ppm, the air quality is fresh. Within 450-750, air quality is moderate. Above 750 ppm, air quality is poor and triggers alerts.
- Alert Activation: When levels exceed these limits, the ESP8266 activates the buzzer and LEDs, and the LCD shows the warning.

5. Data Transmission with ThingSpeak

- Wi-Fi and ThingSpeak Integration: The ESP8266 connects to ThingSpeak's cloud via Wi-Fi, allowing data to be sent to ThingSpeak 's cloud platform in real time.
- Real-Time Monitoring via ThingSpeak App: Data is accessible in the ThingSpeak app on smartphones, where users can monitor live air quality trends, view data history, and receive notifications.

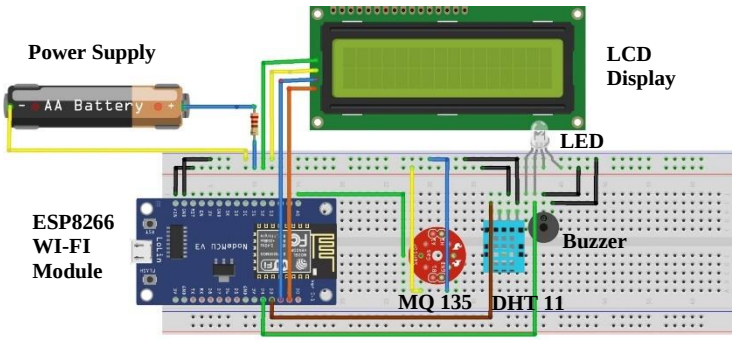

Figure 8: Circuit Diagram of the System

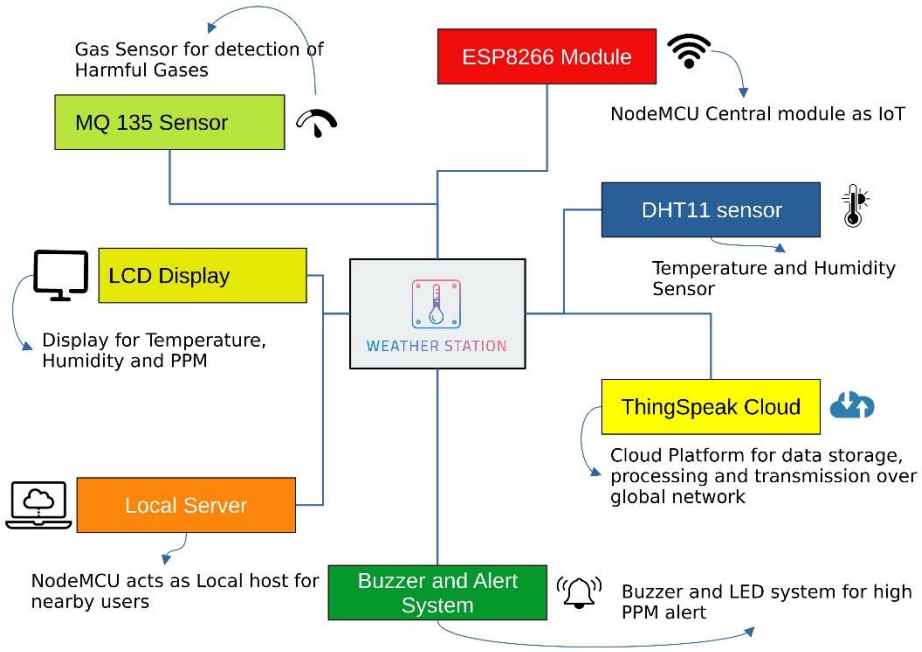

Figure 9: Block Diagram of the System

Figure 10: The Actual Image of the System

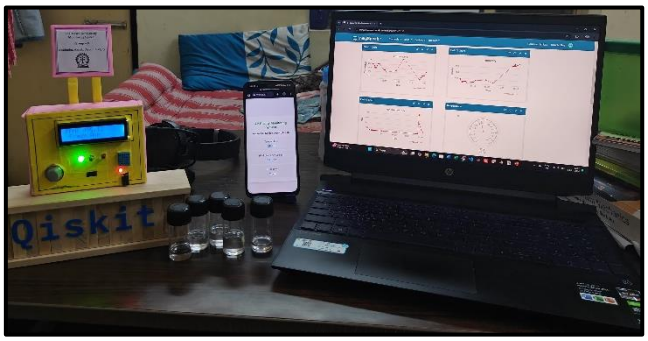

Figure 11: Full Setup of the System

Results

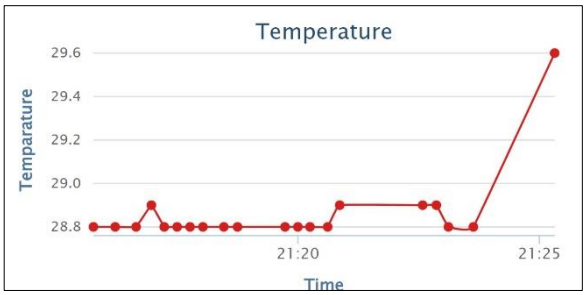

Figure 12: Variation of Temperature with time

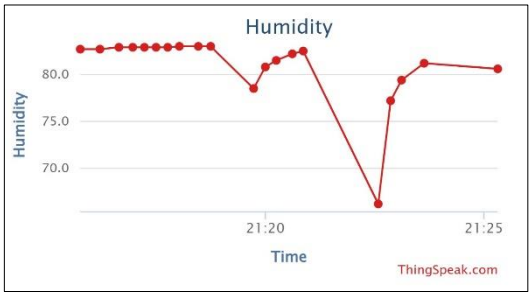

Figure 13: Variation of Humidity with time

Figure 14: Variation of Air Quality Index with time

Figure 15: Real-Time Data

Links & QR Codes

[1] Link for the video of the system: Air Quality Monitoring System

[2] Link for Arduino IDE Code of the System: Air Quality Monitoring System

QR Codes to Connect the System

Scan it to connect **Air Quality Monitoring** Wi-Fi network

Wi-Fi Network: Air Quality Monitoring
Password: 87654321

Scan it to access real-time data on our local web server

The IP address of the local server: **192.168.4.1**

Scan it to access real-time data on the Thingspeak web server

Discussion

- **Effective IoT-Based Monitoring**: Successfully implemented a real-time monitoring system for air quality, temperature, and humidity, demonstrating the reliability and practicality of IoT technology in environmental tracking.
- **Real-Time Data Visualization with ThingSpeak**: Utilized the ThingSpeak platform for live data streaming, enabling continuous and accessible visualization of environmental data.
- **Cost-Effective and Scalable Solution**: Validated a low-cost, easily deployable system with the potential for scalability, making it suitable for both personal and broader community applications in air quality management.
- **Identified Limitations and Solutions**: Acknowledged minor issues, such as sensor accuracy and occasional data delays, with recommendations for improved calibration and potential hardware upgrades.
- **Future Enhancements for Broader Impact**: Outlined plans for integrating more sensitive sensors, additional pollutant detection, and predictive data analytics to provide a more comprehensive air quality solution.
- **Environmental and Public Health Implications**: Highlighted the project's significance in supporting environmental health and public awareness, offering a proactive tool for pollution monitoring and response strategies.

Acknowledgment

We would like to express our sincere gratitude to everyone who contributed to the successful completion of this project on Real-time Air Quality Monitoring using IoT.

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This project would not have been possible without the contributions of each of these individuals and groups, and we are deeply appreciative of their help in bringing our vision to life.

References

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