"Smart Air Quality Monitoring Station Using loT Sensors and Centralized Web Platform"

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Abstract

Owing to rapid urbanization and growing industries, there has been a considerable degradation in air quality, which affects both human health and the environment. Conventional air quality monitoring systems may involve high expenditure and may not be location-specific. Moreover, they may not provide real-time access to air quality data for all. To overcome these limitations, this proposed project focuses on developing an IoT-based air quality monitoring system with a Java-based web application .The designed system has the capability to continuously monitor important air-quality factors such a s particulate matter (PM2.5), carbon dioxide (CO2), and other dangerous gases with the help of low-cost sensors and a microcontroller interface. The sensor information is sent to a centralized server on a wireless platform. A Java server is designed to manage and monitor the received data, with a web interface to track the data online. This will provide a reliable and efficient solution to monitor the air quality in the urban area, campus, and public spaces. Therefore, through the real-time access to the air quality data provided by the proposed solution, the decision to enhance the air quality and health of the public can be made. The project shows how the combination of loT platforms with Java-based software platforms could be used for smarter and more sustainable environments monitoring systems useful for campus / urban areas available.

Keywords—IoT, Air Quality Monitoring, Environmental Monitoring, Java-Based Web Application, Real-Time Data Acquisition, Pollution Analysis, Smart Monitoring System

I. INTRODUCTION

Air pollution has become a major environmental and public health issue, especially in rapidly growing cities and school campuses where many people live and work closely together. Pollutants like fine particulate matter (PM2.5) and high levels of carbon dioxide (CO_2) are connected to respiratory problems, heart diseases, and poorer overall health. Despite these dangers, many campuses and urban areas do not have continuous air quality monitoring systems. This lack of monitoring leaves people unaware of real-time pollution levels and potential health risks.

Traditional air quality monitoring systems are usually centralized, costly, and cover limited areas. They provide accurate city-level data, but often fail to capture local pollution differences in smaller places like campuses, indoor environments, or neighborhood's.Furthermore, delays in reporting data make it harder to issue timely warnings during dangerous air quality events. These challenges show that there is a need for a distributed, affordable solution that can deliver real-time air quality information and instant alerts.

Recent progress in the Internet of Things (IoT) has made it possible to create small, low-cost sensor networks for ongoing environmental monitoring. This paper introduces an IoT-based system for real-time air quality monitoring and alerts that connects air quality sensors to a centralized web platform. The system continuously measures key pollution levels, sends data wirelessly to a backend server for processing and storage, and provides real-time visualizations and alerts through a web application. By offering local monitoring and immediate notifications, the system aims to improve environmental awareness and support quick preventive actions in urban and campus settings.

II. LITERATURE REVIEW

Air Quality Monitoring has emerged as an important area of research work because of growing concerns about air pollution and its adverse affects on human health and sustainable environments. Conventional methods of air pollution monitoring involve using air quality monitoring stations consisting of highly precise instruments used to monitor particulate and dangerous gases. Although these methods offer very precise and controlled measures of air pollution, there have been observations about these methods implying that their installation and maintenance charges are quite high and limit their applicability and usability in areas like academic or residential zones which might have varied levels of pollution even within a small geographical region.

With the improvements in the area of embedded systems and wireless communications, there have been attempts to apply Internet of Things (IoT) technology in environment monitoring. IoT-based air quality monitoring networks require low-cost sensors and microcontrollers that measure air contaminants and then send them to servers and cloud environments. It has been shown in numerous studies that such systems can efficiently decrease the cost associated with deployment as well. Nevertheless sensor accuracy and difficulties in calibrating them as well as processing power at the edge device have remained issues.

There has been recent research on improving the use of IoT systems using web-based platforms and data visualization tools. Perhaps the most exciting innovation has been the use of dashboards or mobile apps for the display of air quality in real-time systems. While these systems provide easier accessibility and awareness of the data, a major flaw has been the absence of appropriate IoT system architecture that is able to handle efficient processing and analysis of the data in a structured format in many of these systems. Moreover, the real-time notification feature is either absent in these systems or has not been given adequate importance in the context of air quality hazards.

Moreover, there are various existing solutions that are more focused on being hardware-based solutions or software-based solutions. This results in less flexibility and scalability for the overall system. Consequently, there are no existing solutions that have equally presented the balance between sensor networks, edge components, and the overall centralized system. This problem, therefore, throws light on the need for an appropriate IoT-based system that has the potential for sound sensor data retrieval along with the benefit of overall system scalability, along with the further benefit of having an overall friendly user web application. The system designed for this problem is presented below.

III. PROBLEM STATEMENT

Air pollution has become a major environmental and public health issue, especially in rapidly growing urban areas and crowded educational campuses. Pollutants like fine particulate matter (PM2.5) and harmful gases such as carbon dioxide (CO_2) are linked to respiratory illnesses, heart problems, and lower overall well-being. Despite these dangers, many campuses and local urban areas do not have continuous air quality monitoring systems. This leads to limited awareness of real-time pollution levels and potential health risks among people living in these places.

Most current air quality monitoring systems are centralized, costly, and provide data at the city or regional level. While these systems deliver accurate large-scale measurements, they do not account for the local differences in air quality created by factors like traffic, indoor activities, construction, and other environmental conditions in smaller spaces such as classrooms, labs, and campus areas. Moreover, delays in data reporting and the lack of real-time alerts make it hard for individuals and administrators to take prompt action during poor air quality events.

Additionally, many existing monitoring solutions do not integrate well with easy-to-use web platforms that allow for ongoing visualization, historical data review, and immediate notifications. The lack of scalable, affordable, and easy-to-install monitoring systems hinders their widespread use in schools and small urban areas. Therefore, a clear need exists for an IoT-based real-time air quality monitoring system that can gather local environmental data, process it effectively using a central software platform, and provide timely alerts and insights through a web application to help people make informed decisions and raise public health awareness.

IV. OBJECTIVES OF THE PROPOSED SYSYTEM

The main purpose of the proposed system is to develop and execute a trustworthy, real-time air quality monitoring system using the internet of things solution. This internet of things solution aims to monitor important parameters of the ambient air continuously, efficiently transmit and process the data, and produce useful data insights using a central software interface. The main purpose of developing such a solution using low-cost sensing hardware, Java technology, and a web interface is to increase awareness and produce informed decisions using timely alerts.

Objectives of the proposed system are as follows:

A. To continuously monitor air quality in real time using Internet of Things (IoT) technology.

B. To accurately measure important air quality parameters such as PM2.5 and carbon dioxide (CO_2) using air-quality sensors.

C. To collect sensor data and transmit it wirelessly through an ESP32 microcontroller.

D. To efficiently process and store air quality data using a Java-based backend system.

E. To present real-time air quality information and trends through a user-friendly web application.

F. To generate instant alerts when air pollution levels exceed safe limits, enabling timely action.

G. To design a cost-effective and scalable system suitable for long-term monitoring and future expansion.

V. PROPOSED SYSTEM AND METHODOLOGY

The proposed system is a real-time air quality monitoring and alert solution based on Internet of Things (IoT) technology, developed to provide localized air quality information for urban areas and educational campuses. The system is made up of air quality sensors, an IoT edge device, a centralized backend server, and a web-based application. The sensors continuously measure important air quality parameters, including particulate matter (PM2.5) and carbon dioxide (CO_2).

These sensors are connected to an ESP32 microcontroller, which acts as the IoT node responsible for collecting sensor data and transmitting it wirelessly to a centralized server. The backend system, developed using Java, receives the incoming data through RESTful APIs. It then processes the data by comparing the measured values with predefined safety thresholds and stores the results in a relational database for future use.

A web-based application retrieves the processed data from the backend and presents it in an easy-to-understand format, showing real-time air quality conditions, historical trends, and alert notifications. Whenever pollution levels exceed safe limits, the system automatically generates alerts to warn users about potentially hazardous air conditions. Overall, the proposed system is designed to be cost-effective, scalable, and reliable, making it suitable for continuous air quality monitoring and future smart campus or urban applications.

The methodology adopted in this work is organized into a series of sequential stages to ensure accurate data collection, reliable processing, and effective visualization of air quality information.

A. Data Acquisition:

Air quality sensors are deployed in the target environment to measure key parameters such as PM2.5 and CO_2. These sensors continuously collect real-time data from the surrounding air.

B. IoT Device Processing:

The ESP32 microcontroller reads the sensor outputs and performs basic data formatting. It also establishes a Wi-Fi connection, enabling seamless communication with the backend server.

C. Data Transmission:

The collected sensor data is transmitted from the ESP32 to the backend system using HTTP-based REST APIs. The data is sent in JSON format to ensure compatibility and structured communication.

D. Backend Processing:

The Java-based backend receives the incoming data and validates the sensor readings. It then compares the values with predefined air quality thresholds to assess current air quality conditions and determine the overall status.

E. Data Storage:

The processed data, along with timestamps and air quality status information, is stored in a relational database. This allows for efficient data management, future analysis, and historical trend evaluation.

F. Visualization and Alerts:

A web-based application retrieves both real-time and historical data from the backend and presents it through interactive dashboards. When pollution levels exceed safe limits, the system automatically generates alerts to notify users and support timely preventive actions.

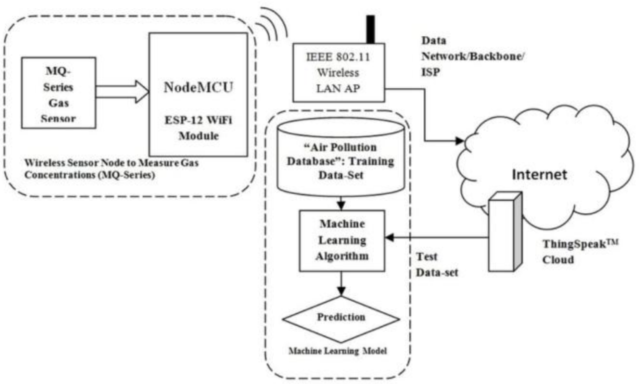

Fig. 1. IoT-Based Air Quality Monitoring System Architecture.

Explanation of Fig.1:
Fig. 1 illustrates the overall architecture of the proposed IoT-based air quality monitoring system. Air-quality sensors measure parameters such as PM2.5 and CO_2 and transmit the data to an ESP32 microcontroller, which sends the readings wirelessly to a Java-based backend server. The backend processes and stores the data and provides real-time visualization and alerts through a web application.

The modular design of the system allows easy hardware replacement and software updates without affecting overall performance. Sensor calibrations and timely validation ensure reliable data collection under varying environmental conditions.

VI. RESULTS AND POSSIBLE OUTCOMES

A. RESULT:

The proposed system successfully monitors PM2.5 and CO_2 levels in real time using IoT sensors connected to an ESP32 microcontroller. The collected sensor data is transmitted wirelessly to a Java-based backend system, where it is processed, securely stored, and displayed through a web-based dashboard. The system accurately identifies changes in air quality and generates alerts whenever pollution levels exceed predefined safety thresholds. Real-time visualizations, along with historical data trends, demonstrate the reliability and consistent performance of the monitoring system.

B. POSSIBLE OUTCOME:

The system enables localized air quality monitoring, helping users better understand environmental conditions in urban and campus settings. By providing instant alerts during poor air quality conditions, it supports timely preventive actions and promotes healthier environments. Additionally, the proposed solution offers a cost-effective and scalable approach, making it suitable for continuous monitoring and future integration into smart campus and smart city applications.

VII. CONCLUSION

This paper presented a real-time air quality monitoring and alert system based on Internet of Things (IoT) technology, specifically designed for use in urban areas and educational campuses. By combining air quality sensors with an ESP32 microcontroller and a Java-based backend platform, the system allows continuous monitoring, efficient data handling, and clear visualization of key air quality parameters such as PM2.5 and CO_2.

The results show that affordable IoT hardware, when integrated with a web-based application, can successfully deliver accurate, localized air quality information along with timely alerts during unsafe conditions. The proposed system is not only cost-effective but also scalable, making it suitable for long-term and continuous environmental monitoring. Overall, this solution offers a practical and reliable approach for improving air quality awareness and supporting smart campus and urban environmental management.

The proposed system has shown feasibility in terms of combining sensing hardware technology using IoT and a centralized platform to monitor air quality in localized setups. The effectiveness of real-time data acquisition and warning generation has been established to increase awareness regarding air quality in an urban and campus setting.

VIII. FUTURE SCOPE

The system can be improved by the inclusion of other sensors such as NO_2, SO_2, and VOCs. Moreover, machine learning algorithms may also be used to forecast air quality patterns based on past data. Also, cloud storage may be used to enhance scalability. Moreover, the future improvements may consist of the integration of mobile apps and alert systems to engage users on a public scale.

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