



RESEARCH PAPER ON IOT BASED AIR POLLUTION MONITORING SYSTEM FOR SMART CAMPUS

IoT Based Air Pollution Monitoring System for Smart Campus

¹ Dr.N.N.S.V.Rama Raju , ²Ms.Reddi Sravanthi, ³Mr. Velaga Harish, ⁴Mr. Vechalapu Manoj Kumar, ⁵Mr. Vadditandra Mukesh, ⁶Mr. Muduli Summy Ranjan,

¹Professor, ²Student, ³Student, ⁴Student, ⁵Student, ⁶Student,

¹²³⁴⁵⁶Electronics and communication Engineering,

¹²³⁴⁵⁶Nadimpalli Satyanarayana Raju Institute of Technology, Sontyam, Andhra Pradesh, India

Abstract: Air pollution has become a major environmental and health concern in urban and educational environments due to increasing industrialization, vehicular emissions, and human activities. Monitoring air quality and weather parameters in real time is essential to ensure a safe and healthy atmosphere, especially in smart campus environments. Conventional monitoring systems are often expensive, complex, and lack real-time responsiveness, which limits their effectiveness for continuous environmental monitoring.

This paper presents an IoT-based air pollution and weather monitoring system designed for smart campus applications. The system integrates sensors such as PMS5003 for detecting particulate matter (PM2.5 and PM10), along with DHT11 and SHT21 sensors for measuring temperature and humidity. An Arduino microcontroller is used to process the collected data and compare it with standard Air Quality Index (AQI) thresholds. Based on the analysis, the system provides real-time alerts through LED indicators and automatically activates a DC fan when pollution levels exceed safe limits.

The proposed system enables continuous monitoring and remote data access through IoT technology, ensuring efficient environmental management and timely decision-making. It is a cost-effective, reliable, and scalable solution suitable for smart campuses and other environmental monitoring applications. The results demonstrate that the system effectively detects air quality variations and responds promptly, contributing to improved environmental safety and awareness.

Keywords – Internet of Things (IoT), Air Pollution Monitoring, Smart Campus, Arduino Nano, Air Quality Index (AQI), Embedded System.

INTRODUCTION

Air pollution has become a serious environmental and public health issue due to rapid industrialization, urbanization, and the increasing number of vehicles. Educational campuses are also affected by air pollution caused by transportation, construction activities, and human presence. Poor air quality can lead to various health problems such as respiratory diseases and reduced overall well-being. Therefore, continuous monitoring of air quality and environmental conditions is essential to maintain a safe and healthy campus environment[1].

System Architecture

The proposed IoT-based air pollution and weather monitoring system consists of three main components: **sensing unit, processing unit, and communication & actuation unit**. These components work together to continuously

monitor environmental conditions and provide automated responses.

The **sensing unit** includes sensors such as PMS5003, DHT11, and SHT21. The PMS5003 sensor is used to measure particulate matter concentrations (PM2.5 and PM10) using laser scattering technology. The DHT11 and SHT21

sensors are used to measure temperature and humidity levels in the environment. These sensors continuously collect real-time data from the surroundings.

The **processing unit** consists of an Arduino Nano microcontroller, which acts as the brain of the system. It receives data from the sensors and processes it by comparing the values with predefined Air Quality Index (AQI) thresholds. Based on this analysis, the system determines whether the air quality is safe or hazardous.

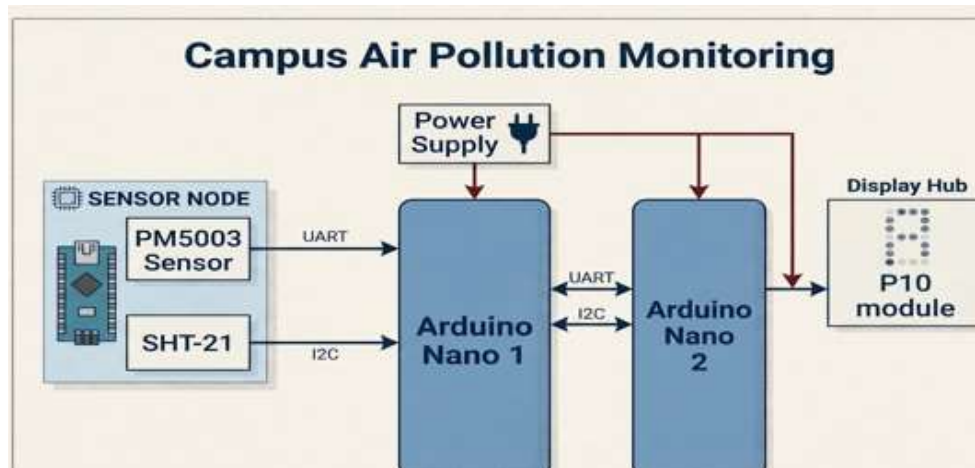


Fig 1 : Architecture

PROBLEM STATEMENT

In spite of the advancements in Internet of Things (IoT) and environmental monitoring technologies, air pollution monitoring systems in smart campus environments still face several challenges that limit their effectiveness in ensuring a safe and healthy atmosphere. The following issues highlight the need for a robust and intelligent monitoring solution:

1. Manual Monitoring:

Conventional air quality monitoring in campuses relies heavily on manual observation and periodic measurements, which are time-consuming, labor-intensive, and prone to human error. This approach often results in delayed detection of harmful pollutants, increasing the risk to human health and reducing the ability to take timely preventive actions.

2. Lack of Real-time Insights:

Traditional systems provide limited real-time data regarding environmental conditions. Without continuous monitoring and instant feedback, it becomes difficult to identify sudden changes in pollution levels or respond quickly to hazardous situations, leading to ineffective environmental management.

3. Insufficient Automation:

Many existing air monitoring systems lack automated response mechanisms. In the absence of intelligent control, actions such as ventilation or alert generation require manual intervention, resulting in inefficiencies and delayed responses to critical pollution levels.

4. Limited Accessibility:

High implementation costs and complex system designs restrict the adoption of advanced air quality monitoring systems, especially in small-scale institutions and campuses. This creates a gap where many environments remain unmonitored or poorly managed.

5. Fragmented Systems:

Current monitoring solutions often operate as isolated units with limited integration capabilities. The lack of

interoperability between sensors, controllers, and communication platforms makes it difficult to build a unified and scalable smart monitoring system.

OBJECTIVES

The essential objective of this proposition is to plan, create, and assess a comprehensive air pollution monitoring system for smart campus utilizing Arduino Nano and different sensors. To realize this overarching objective, the taking after particular targets have been recognized:

1. Plan a flexible and versatile engineering for the air pollution monitoring framework:

This includes conceptualizing the in general framework design, counting the selection and integration of hardware components such as sensors, Arduino Nano, communication modules, and data processing techniques. The point is to create a scalable and extensible system capable of supporting multiple environmental parameters and future enhancements.

2. Select and coordinated fitting components for sensor information procurement:

Distinguish and utilize suitable sensors such as PMS5003 for particulate matter (PM2.5 and PM10), DHT11 for temperature and humidity, and SHT21 for environmental sensing. Coordinated these sensors with Arduino Nano microcontroller to empower real-time information procurement and continuous monitoring.

3. Create real-time observing and investigation component:

This includes developing a system that continuously collects, processes, and analyzes environmental data. The point is to compare sensor values with standard Air Quality Index (AQI) levels to identify pollution conditions effectively.

4. Execute robotized control and caution framework:

Plan a system that can naturally react to harmful air quality levels by activating alerts such as LEDs and controlling devices like DC fan without human intervention, ensuring quick response to environmental changes.

5. Empower IoT-based remote checking and information get to:

Incorporate IoT innovation to transmit data remotely, permitting clients to screen air quality in real-time and make informed decisions based on current environmental conditions.

6. Create a cost-effective and user-friendly arrangement:

The point is to design a system that is simple to install, economical, and accessible for smart campuses and similar environments, encouraging widespread adoption.

LITERATURE SURVEY

Air pollution has ended up a major concern in urban and educational environments due to the increment in vehicular emissions, industrial activities, and human exercises. In spite of the accessibility of conventional air quality checking frameworks, numerous of them are costly, complex, and not reasonable for small-scale or campus-level sending. Subsequently, IoT-based air pollution monitoring frameworks have been proposed as an effective arrangement to supply real-time information collection, investigation, and control. These frameworks utilize different sensors and microcontrollers to screen natural parameters and give opportune cautions to guarantee a secure and sound environment [1].

The proposed IoT-based air pollution monitoring framework is planned to back smart campus applications by persistently checking air quality parameters such as particulate matter (PM2.5 and PM10), temperature, and humidity. Arduino Nano and Node MCU controllers are utilized within the framework to handle sensor information and empower communication. Wi-Fi network is utilized to transmit real-time information to portable applications or cloud stages for remote observing. Sensors such as PMS5003, DHT11, and SHT21 are coordinates to gather exact environmental information, whereas LED indicators and DC fans are utilized as actuators to supply programmed reaction when pollution levels surpass secure limits [2].

In later a long time, numerous IoT-based air quality observing frameworks have been created to move forward environmental observing and administration. These frameworks commonly center on real-time information collection and cloud-based observing utilizing Wi-Fi or GSM communication. A few frameworks give portable applications for observing air quality, but they need programmed control instruments to reply to basic circumstances. Other arrangements present low-cost convenient gadgets, but they regularly center on restricted parameters and do not give a total environmental checking framework with both observing and control capabilities [3].

Air pollution monitoring frameworks depend on different components to degree and analyze environmental parameters successfully. Sensors play a key part in identifying particulate matter, temperature, and humidity levels. Microcontrollers such as Arduino Nano act as the brain of the framework by handling information and controlling yield gadgets. Actuators like fans and alert frameworks are utilized to reply to destructive conditions. Show modules such as LCD screens or portable applications give real-time information to clients, empowering superior decision-making and environmental mindfulness [4].

Node MCU plays an imperative part in IoT-based frameworks due to its built-in Wi-Fi capability and ease of integration. It permits real-time information transmission, remote checking, and control of gadgets through portable applications. With GPIO pins, Node MCU can interface with numerous sensors and actuators, making it appropriate for keen environmental observing frameworks. The utilize of IoT innovation improves effectiveness, decreases manual exertion, and bolsters the improvement of smart campus frameworks aligned with Industry 4.0 concepts [5].

Sensors utilized in air pollution monitoring frameworks incorporate PMS5003 for measuring particulate matter (PM2.5 and PM10), DHT11 for temperature and humidity, and SHT21 for more precise environmental estimations. These sensors give continuous information approximately air quality conditions, making a difference in early location of pollution levels. Keeping up air quality inside secure limits is basic for human wellbeing, as tall levels of particulate matter can cause respiratory issues and other wellbeing issues. Subsequently, real-time observing and control frameworks are fundamental for keeping up a solid environment in smart campuses [6].

METHODOLOGY

The framework engineering of the angle tank checking framework is the establishment upon which the complete venture is built. It envelops the course of action and interaction of equipment components, software modules, and communication conventions to attain the specified usefulness and execution. The framework design serves as a outline for the improvement, usage, and integration of different framework components. Here's an outline of the framework engineering for the angle tank checking framework:

1. NodeMCU (ESP8266) Microcontroller:

The NodeMCU serves as the central handling unit of the checking framework. It is mindful for meddle with sensors, collecting information, executing control calculations, and communicating with outside gadgets. The NodeMCU coordinating Wi-Fi network, permitting for remote communication with the web and farther checking capabilities.

2. Sensors:

Different sensors are associated to the NodeMCU to degree key parameters of the angle tank environment. These sensors incorporate pH sensors, temperature sensors, broken down oxygen sensors, alkali sensors, turbidity sensors, and conceivably others depending on the specific requirements of the aquaculture framework. Sensor information is obtained by the NodeMCU and handled to supply genuine time bits of knowledge into water quality.

3. Actuators:

Actuators such as transfer modules may be utilized to control natural parameters inside the angle tank. For illustration, a relay module can be utilized to switch on/off pumps, radiators, aerators, or other hardware based on sensor readings and predefined control logic. Actuators empower computerized control of water parameters to preserve ideal conditions for angle wellbeing and development.

4. Display Module:

A display module, such as an LCD screen or OLED display, may be consolidated to supply a client neighborly interface for checking framework status and sensor readings. The show module can show real-time information in a outwardly instinctive organize, empowering water culturists to rapidly evaluate the wellbeing of their angle tank environment.

5. Communication Protocols:

The angle tank observing framework utilizes communication conventions to trade information with outside gadgets and administrations. Wi-Fi network given by the NodeMCU empowers communication with web servers, cloud-based stages, or portable applications for inaccessible observing and information logging. Furthermore, MQTT (Message Lining Telemetry Transport) or HTTP (Hypertext Exchange Convention) conventions may be utilized for data transmission and integration with IoT stages.

6. Power Supply:

A steady and solid control supply is fundamental to guarantee continuous operation of the checking framework. The framework may be fueled by mains power, batteries, or a combination of both, depending on the sending situation and control prerequisites of the components. Voltage controllers such as the 7805 regulator may be utilized to direct and ensure the electrical components from variances or overvoltage conditions.

- **Testing and Validation Procedures:**

Testing and approval are significant stages within the improvement of a fish tank checking framework, guaranteeing that the framework meets its expecting targets, capacities dependably, and gives exact information. These methods include methodically assessing the execution, precision, and vigor of the framework beneath different working conditions. Here's an outline of the testing and approval strategies for a single tank observing framework:

1. Functional Testing:

Useful testing confirms that the framework components perform their aiming capacities accurately. Each sensor, actuator, and communication interface is tried separately to guarantee legitimate operation. For case, pH sensors are tried by drenching them in calibration arrangements of known pH values and confirming that they give exact readings. Actuators are tested by enacting them and watching their reaction. Communication interfacing are tried by sending and getting information bundles to confirm network.

2. System Integration Testing:

System integration testing assesses the interaction and compatibility of framework components when coordinates into the total checking framework. This includes interfacing sensors, actuators, microcontrollers, and communication modules as per the framework design and confirming that they communicate successfully. Integration testing guarantees that information streams easily between components which control commands are executed accurately.

3. Accuracy Testing:

Accuracy testing assesses the exactness and rightness of sensor estimations beneath real-world conditions. Sensors are uncovered to a extend of natural conditions experienced in single tank situations, such as temperature variances, changing pH levels, and turbidity changes. The exactness of sensor readings is compared against reference measures or calibrated rebellious to decide the degree of deviation.

4. Reliability Testing:

Reliability testing assesses the strength and strength of the checking framework over amplified periods of operation. The framework is subjected to persistent observing beneath mimicked or genuine single tank conditions to recognize and potential disappointments or glitches. Unwavering quality testing may incorporate push testing, where the system is uncovered to extraordinary conditions to survey its flexibility and disappointment focuses.

5. Performance Testing:

Performance testing measures the system's reaction time, throughput, and asset utilization beneath commonplace working scenarios. This includes mimicking distinctive client intelligent, sensor inputs, and control activities to assess framework performance.

Components Used:

The air pollution monitoring system depends on a assortment of equipment components to degree, process, and analyze environmental parameters successfully. These components play a vital part in guaranteeing precise information collection, real-time monitoring, and automated response. A few of the essential components utilized within the framework are as follows:

1. Sensors:

Sensors are the core components of the monitoring system, dependable for measuring different environmental parameters. PMS5003 sensor is utilized to detect particulate matter (PM2.5 and PM10), DHT11 sensor is utilized to degree temperature and humidity, and SHT21 sensor gives more exact environmental readings.



Fig 2. PMS5003 sensor.

2. Microcontrollers:

Microcontrollers serve as the brain of the framework, processing sensor information and controlling operations. Arduino Nano is utilized for data processing and system control, whereas NodeMCU (ESP8266) is utilized for Wi-Fi communication and IoT integration.

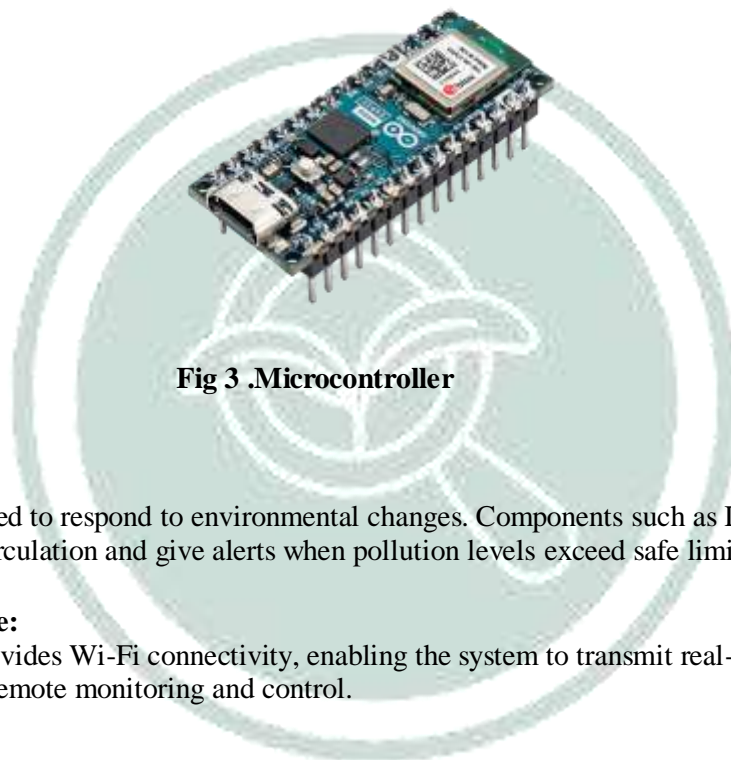


Fig 3 .Microcontroller

3. Actuators:

Actuators are devices utilized to respond to environmental changes. Components such as DC fan and LED indicators are utilized to control air circulation and give alerts when pollution levels exceed safe limits.

4. Communication Module:

The NodeMCU module provides Wi-Fi connectivity, enabling the system to transmit real-time data to cloud platforms or mobile applications for remote monitoring and control.

5. Display Module:

Display modules such as LCD screens are utilized to show real-time sensor readings and system status, providing a user-friendly interface for monitoring.

6. Power Supply:

A stable power supply is required to operate all components efficiently. Voltage regulators and DC power sources are utilized to ensure proper voltage levels and continuous system operation.

7. Supporting Components:

Additional components such as connecting wires, breadboard, resistors, and sensor modules are utilized to integrate the system and ensure proper functionality.

RESULT AND DISCUSSION

The proposed IoT-based air pollution monitoring system was successfully designed and implemented to monitor environmental parameters such as particulate matter (PM2.5 and PM10), temperature, and humidity in real time. The system effectively collected data using sensors like PMS5003, DHT11, and SHT21, and processed it through the Arduino Nano microcontroller. The NodeMCU module enabled real-time data transmission, allowing remote monitoring of air quality conditions. The results demonstrate that the system is capable of accurately detecting variations in environmental parameters and providing continuous monitoring.

During the experimental analysis, it was observed that PM2.5 levels showed significant fluctuations depending on surrounding activities such as vehicle movement and human presence. PM10 levels were comparatively stable but increased in dusty conditions. Temperature and humidity readings were found to influence the dispersion of pollutants, affecting overall air quality. The system successfully compared sensor values with standard Air Quality Index (AQI) thresholds and identified whether the environment was safe or hazardous.

The automated response mechanism performed efficiently, where the DC fan was activated when pollution levels exceeded predefined limits, helping to improve air circulation. LED indicators provided immediate visual alerts, enhancing user awareness. The response time of the system was found to be quick, ensuring timely action in critical situations. The integration of IoT technology enabled real-time data access, which is beneficial for continuous monitoring and decision-making.

The system demonstrated high reliability during continuous operation, with minimal errors in data acquisition and transmission. Accuracy testing showed that the sensor readings were within acceptable limits when compared to standard values. However, minor deviations were observed due to environmental factors and sensor limitations. Overall, the system proved to be cost-effective, efficient, and suitable for smart campus applications.

In comparison with existing systems, the proposed model provides both monitoring and automated control features, making it more effective for real-time environmental management. The system can be further enhanced by integrating cloud storage, advanced analytics, and mobile application interfaces for better usability and scalability. Thus, the results confirm that the developed system is a reliable solution for air pollution monitoring and contributes to maintaining a healthy and safe campus environment.

Conclusion and Future Work

The proposed IoT-based air pollution and weather monitoring system provides an efficient and cost-effective solution for real-time environmental monitoring in smart campus environments. By integrating sensors such as PMS5003, DHT11, and SHT21 with an Arduino microcontroller, the system successfully monitors particulate matter, temperature, and humidity while providing automated responses through LED indicators and DC fan activation. The inclusion of IoT technology enables remote monitoring and enhances system usability and effectiveness. The system demonstrated reliable performance, accurate sensing, and timely response during testing. Future work can focus on integrating mobile applications for real-time alerts, incorporating artificial intelligence for pollution prediction, utilizing renewable energy sources like solar power, and expanding the system for large-scale smart city and industrial applications.

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