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A Review: Air Quality Monitoring System

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Abstract

High population and urbanization growth rate raises the issue of air pollution in recent years. Air quality monitoring is one of the major concerns due to its influence on human health. With the advancement in sensing and embedded technology, Internet of Things becomes one of the economic alternative to implement air quality monitoring system(AQMS)compared to costly and fixed air quality monitoring stations. In this paper we present the ample review of candidate enabling technology for IoT based AQMS architecture. Specifically, we start with overview of major low cost air pollutant sensors classification, typical error sources and calibration methodologies. Then we present analysis and comparative study of infrastructure protocols and application layer protocols to support IoT based architecture for AQMS. We also review existing system and categorised them based on deployment strategy employed. Finally, challenges involved in building such systems are discussed in detail.

Keywords
Air Quality Monitoring System (AQMS), Air Pollution, Air Quality Sensors, Environmental Monitoring, Smart Cities.

1.Introduction
One of the issues where increased population, urbanization, and industrial activities make it important globally is air quality. It is not an end result as the effects go further by affecting public health, intensifying climate change, and disturbing the ecological balance. The harmful pollutants that now fill the air we breathe include carbon dioxide, carbon monoxide, nitrogen oxides, volatile organic compounds, and particulate matter. They have led to a huge number of respiratory diseases and cardiovascular disorders and even deaths from old age. Therefore, a solution was urgently required, and the technological solution attracted the attention of scientists as well as policymakers. Traditional air quality monitoring systems are powerful but have significant disadvantages. The systems are mainly fixed and, therefore, very resource-intensive and expensive; thus, they can be used in very few places. This forms the major reason they can never be adequate and timely enough to facilitate data about the air quality in underdeveloped regions and densely populated urban areas. With that motivation, there has been a call to explore other alternative methods that are cost-effective and scalable to give real-time data.

It brought into the arena the Internet of Things (IoT), with all of its transformative possibilities in this area.
The IoT-based air quality monitoring system is dynamic and scalable. The number of pollutants being monitored and analyzed in real time can vary with a low-cost sensor with microcontrollers like Arduino, Raspberry Pi, or any similar

platform. These sensors normally gather information at different points simultaneously and are equipped with wireless communication technologies like Wi-Fi, ZigBee, or LoRa to send the information to the cloud-based platforms for further processing or make decisions at that location. This paper addresses a few forms of IoT-based air quality monitoring systems including its structure, technologies, and application in real life.
The major components are MQ135 gas sensor, which identifies dangerous gases such as CO_2 and NH_3. ESP8266 Wi-Fi considerably simplifies the communication. Some of the methodologies related to calibration techniques and error minimization strategies are also presented in order to address the accuracy and reliability issues in deployments with low-cost sensors.

It also covers novel deployment strategies including stationary, mobile, and crowd-sensing approaches specially tailored to the needs of monitoring applications. Stationary systems provide continuous data within localized areas while mobile systems spread coverage to a much larger region through public transport or through wearable devices. Crowd sensing harnesses citizen power, which captures data from publicly owned devices.

Other issues related to IoT-based air quality monitoring systems include calibration of sensors, energy optimization, and accuracy of data. Generally, they are based on power-constrained devices and low-cost sensors, which can create problems due to drift, non-linearity, and cross-sensitivity. So, overcoming these challenges becomes very important for scalability and longevity.

Apart from that, the paper will further go with real-life application cases and studies on matters as broad as monitoring air quality in smart cities to detecting particular pollutants in industrial zones. It further predicts trends in pollution when artificial intelligence and machine learning are integrated into IoT systems and gives actionable insights for policymakers and individuals. This paper reveals the potential of IoT-based air quality monitoring systems as one of the most feasible and accessible solutions to one of the most serious environmental challenges our world faces: air pollution. They will inspire further innovation and cooperation toward a cleaner and healthier future for all.

1.1 Objectives
The objectives of the air quality monitoring system are to develop a low-cost and portable solution using Arduino and IoT technologies to monitor pollutants like CO_2, CO, NO_x, and PM in real time. It aims to integrate wireless communication protocols for seamless data transfer, ensure sensor accuracy through calibration, and provide user-friendly data representation on screens or online platforms. Additionally, the system seeks to support smart city initiatives, encourage public awareness about air quality issues, and enable predictive analysis using advanced data processing techniques. Through real-world deployment and validation, the system aspires to address urban and industrial air quality challenges effectively.

2. Literature Review
We review some of the past works in processing and understanding of Air Quality Monitoring system. Air quality monitoring has gathered a lot of attention and many researchers have developed several microcontroller-based systems. People in Delhi were able to inhale fresh air only 38 days in the last six years, revealed by the Central Pollution Control Board at Delhi India. Analysing six years of data on the air quality index in January CPCB found the average air pollution of level increased 9.8% in 2021 compared to 2020.

1. **Virendra Barot , Viral Kapadia, "Air Quality Monitoring Systems using IoT" :**
   Researchers are doing efforts to avail such systems for benefit of people across the globe. IoT plays crucial role in building next generation systems In this paper we analysed most appropriate technology and protocol to suit IoT based architecture for air quality monitoring system over various technical parameters.

2. **Mr.D.Tilak Raju, K.Shivani, T. Sahitya Bharathi, "Air Quality Monitoring System Using Arduino" :**
   Here the Air Quality is measured in terms of ppm (parts per million). If the ppm is greater than the threshold value that we have fixed, then the LED blinks, and Buzzer turns on and prints "AQ LEVEL HIGH" If its high particulate matter is high and the air is impure and needs to be purified. The circuit for the air quality management system has been designed using Arduino Uno, MQ135 messenger and other components through and Arduino software is such a way that it shows that particular concentration in PPM.

3. **Patricia Arroyo, Jesús Lozano*, José Ignacio Suárez, "Wireless Sensor Network for Air Quality Monitoring and Control" :**
The prototype uses headspace as the sampling system: the headspace of samples stored in 15 ml vials is carried to the sensor cell by using an integrated pump. The measurement setup includes cycles of 60 s of adsorption and 540 s of desorption. Gas sensors were operating at different temperatures between 400 and 500ºC. At least 20 measurements were taken from the samples prepared as solutions of several compounds in water: blank water (W), acetone (Ac), toluene (To), ammonia (Am), formaldehyde (Fo), ethanol (Et), benzene (Be), dichloromethane (Dc), acetic acid (AA), xylene (Xy) and dimethylacetamide (Da). The average response of each sensor to the measured samples is shown in It can be observed that a different profile is obtained for each sample.

4. **Shazia Afroze, Md. Istiak Hossain Paran, Rakibul Hasan Roki, "IoT Based Air Quality Monitoring System Using Arduino":**
In this work, Internet of Things (IoT) system has been devised to monitor in real time the basic pollutants like Carbon dioxide, Carbon monoxide, Particulate matter, Temperature, Humidity, Pressure. The Primary focus of this paper is to monitor air quality at indoor and outdoor level of residential and industrial sectors by using in total of five sensors, ESP8266 Wi-Fi module and Arduino Uno. The emission from vehicle modeling and vehicle's other emissions can be monitored easily through the internet. A real time air quality monitoring system is essential for Bangladesh especially in Dhaka City because, here the pure air is getting denser and polluted day by day.

5. **Meghana P Gowda, Harshitha G Y, Jyothi K N, Srushti, Padma R, "Air Quality Monitoring System"**
This paper discusses a monitoring system that gives information about environmental conditions and briefly touches the technological advancements in monitoring the environment and bringing out the new scope in monitoring the current environmental problems. The system is developed using Arduino, Raspberry Pi3, and Zigbee which proves to be cost-ineffective and having low power consumption. The sensors will gather the data of various environmental parameters and provide that data to Raspberry Pi via Zigbee from the Arduino. The sensors will gather the data of various environmental parameters and provide it to the raspberry pi which acts as a base station. Realization of data gathered by sensors is displayed on Raspberry pi 3 based Webserver. Experimental results demonstrated that the system can accurately measure the concentrations of carbon monoxide, carbon dioxide, combustible gases, smoke and air quality.

6. **T Dineshkumar, V Suresh Babu, Pachaivannan Partheeban, "Air Quality Monitoring System Based on IoT" :**
The system presented in this paper is an advanced real-time air quality reporting system supported by the Internet of Things (IoT) architecture. Air quality in an environment heavily affected by the community's state in a region may affect human, animal, and plant safety. Therefore, air quality levels in a region should be tracked regularly. This study aimed to build an IoT-based air quality system to evaluate air quality conditions in a given region. The device can track the air rates of different substances including O3, CO and particulate matter using sensors.

7. **E. U. Oyo-Ita, U. J. Ekah, P. Ana, I. O. Ewona, "Development of a Smart Air Quality Monitoring System Using Wireless Sensors" :**
A smart air quality monitoring system has been developed for the measurement of Air quality index, as well as relative humidity and temperature. The air quality monitoring system is based on ESP8266 embedded WIFI Module that runs on a 5V DC source. The device takes readings from the MQ135 and DHT11 sensors and sends the data to an android device via Wi-Fi in every 5 seconds, using a third-party mobile App, Blynk. The device sensor detects and measures the air quality index, temperature and relative humidity and communicates with the ESP WIFI module via internet to access the Blynk server so as to display the air quality information.

8. **Ramik Rawal, "Air Quality Monitoring System" :**
This paper deals with measuring Air Quality using MQ135 sensor along with Carbon Monoxide CO using MQ7 sensor. Measuring Air Quality is an important element for bringing lot of awareness in the people to take care of the future generations a healthier life. Based on this, Government of India has already taken

certain measures to ban 'Single Stroke' and 'Two Stroke' Engine based motorcycles which are emitting high pollutions comparatively.

9. **Aneessha Acharya K, Sucheta V. Kolekar, "Air Quality Monitoring System Development using IoT for Indoor Applications" :**
The proposed system provides an indoor air quality monitoring setup using Raspberry Pi, along with gas and dust sensors that can give accurate and reliable readings, as shown by the results. It uses the Internet of Things and Cloud concepts to facilitate low power consumption on the device node.

10. **Jen-Hao Liu, Yu-Fan Chen, Tzu-Shiang Lin, and Da-Wei Lai, "Developed Urban Air Quality Monitoring System Based on Wireless Sensor Networks" :**
This study uses wireless sensor network technologies to receive and record monitoring data to complete a fully automatic air quality monitoring task. On the hardware side, we integrate different types of sensors and WSNs to conduct wireless communication under the ZigBee protocol. The back-end platform, controlled by the LabVIEW program, successfully communicates with users through sending them SMS messages. It also stores a large amount of data into the database via the MySQL program, so that experts can establish a prediction model of pollution diffusion based on the data.

3. Methodology

i) Module Choice -
Starting with the right choice of components for the system, such as the Arduino Uno microcontroller, sensors like MQ135 to detect the presence of gas, particulate matter by GP2Y1014AU0F, temperature and humidity sensor DHT11, and wireless communication ESP8266, all these ensure that we have good air quality data.

ii) System Design -
Then we design how the components will connect. We draw a schematic and pay special attention to the fitting of all the pieces, taking care in which power supply and wiring will be used. This step may require the use of breadboards or PCBs for a more stable basis in setting up everything.

iii) Sensor Calibration -
Calibration helps significantly to ensure high accuracy in sensor reading. In this case, we compare reference values with sensor outputs and adjust for errors such as drift or non-linearity, ensuring data reliability.

iv) Data Collection -
Arduino gathers the real-time data flowing in through. All this information continuously extracted from the source, gets prepared for the analysis and thereby helps understand air qualities in different places.

v) Data Processing -
We process the data when we collect. We take a reading from the sensor and convert it to standard units, like parts per million (PPM). Cleanliness of data is maintained through filters, and what we put out there would be as accurate as possible.

vi) Wireless Communication -
We transfer the data we collected using the ESP8266 Wi-Fi module to a cloud-based platform so that we can access it from any place. It gives the facility to check air quality from anywhere with MQTT or HTTP protocols to enable communication in a secure and efficient way.

vii) Real-time Monitoring -
We set real-time displays of the air quality data on an LCD screen as well as push this information to a web or mobile app. This allows users real-time access to air quality data from anywhere, making it easier for them to be informed.

viii) Alert Mechanism -
Further, to ensure that the users are informed about the unsafe air quality levels, we include alert systems for example through buzzers or LEDs that light up once the pollutant levels surpass a given threshold. The application can also send alerts remotely to the user at all times.

ix) Field Deployment -
The system is then put to the test in real environment locations: houses, towns and cities, and industrial sites. Sensors are located in the best positions to collect useful data to give accurate readings in these many settings.

x) Data Analysis -
We analyze methods, such as PCA and machine learning algorithms on the data collected to work out the trends in the levels of pollution. In this manner, such methods will offer valuable information about air quality in different areas.

xi) Power Optimization -
Since the areas where the system is to be used have limited power resources, our primary focus is on making the system energy-efficient. This is achieved by using low-power components and putting sensors into sleep modes when they are not actively collecting data in order to have long-lasting performance without draining battery life.

xii) Feed-Back and Consciousness -
We involve the community in our efforts to seek opinions on improving the system. Having accessible applications and dashboards, we will share the output with the public in order to increase their consciousness towards the problems regarding air quality and motivate proactive measures in the improvement of environmental health. This will bring together the latest in IoT and sensor technology to provide an accessible, real-time solution in the monitoring of air quality for the improvement of public awareness and health.

3.1 System Architecture and Design

The paper aims at designing an air quality monitoring system using Arduino which can be installed in a specific locality. The project uses Arduino integrated with individual gas sensors like carbon monoxide, carbon dioxide along with particulate matter, humidity, temperature and pressure which measures the concentration of substances separately from air. We propose a cluster of Air Quality Monitoring system which uses the sensors: DHT11, MQ07, MQ135, BMP280 and GPY2Y1014AU0F Dust Sensor. These sensors are directly connected to Arduino uno (Figure 1).

3.2 Block Diagram –

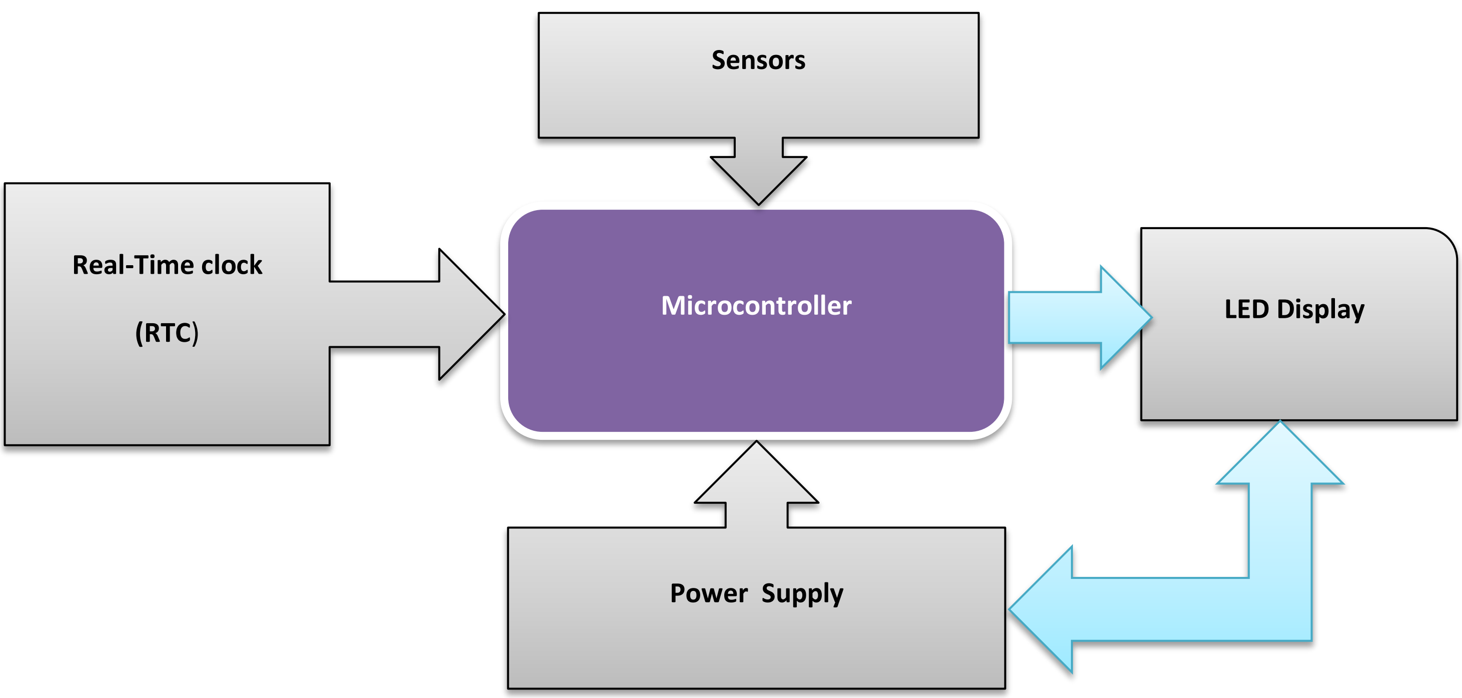

Figure 1. System block diagram.

3.4 Components

1. Arduino Uno R3

   The Arduino Uno R3 is a popular microcontroller board used for prototyping and automation projects. Paired with various sensors, it enables efficient data collection and monitoring. The MQ135 gas sensor measures air quality by detecting harmful gases. Similarly, the MQ7 sensor specializes in detecting carbon monoxide, a toxic gas. The GP2Y1014AU0F dust sensor monitors particulate matter like smoke and dust for air quality assessments. Together, these components provide a comprehensive solution for environmental monitoring systems (Figure 2).

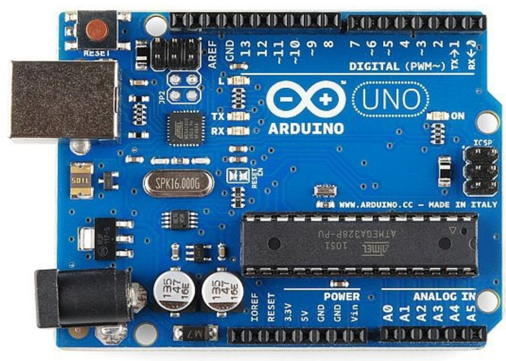

Figure 2. Arduino Uno R3

2. MQ135 gas sensor
   The MQ135 gas sensor is a versatile and widely used air quality sensor capable of detecting gases like ammonia, carbon dioxide, nitrogen oxides, alcohol, and smoke. It operates on a metal oxide semiconductor (MOS) principle, where the sensor's resistance changes in response to gas concentrations. Featuring a broad detection range, it is ideal for monitoring air quality in both indoor and outdoor environments. The sensor requires a working voltage of 5V and provides an analog output proportional to the gas concentration. It is commonly used in environmental monitoring, industrial safety, and smart home systems. Calibration is necessary to ensure accuracy, as external factors like humidity can affect its performance. The MQ135 is affordable, easy to integrate, and suitable for hobbyists and professionals alike (Figure 3).

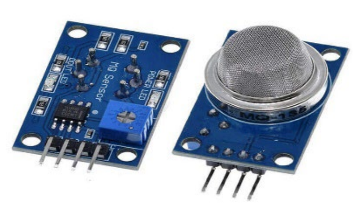

Figure 3. MQ135 gas sensor

3. MQ7 carbon monoxide sensor
   The MQ7 is a carbon monoxide (CO) sensor designed to detect CO concentrations in the air. It operates on a metal oxide semiconductor (MOS) principle, where its resistance changes in the presence of CO. The sensor has a high sensitivity range (10–500 ppm) and provides an analog output proportional to the CO level. It

requires a heating and cooling cycle for accurate operation, powered by a 5V supply. The MQ7 is commonly used in air quality monitoring, automotive safety, and industrial applications. Its affordability and ease of integration make it ideal for both professional and DIY projects (Figure 4).

Figure 4. MQ7 carbon monoxide sensor

4. GP2Y1014AU0F dust sensor (Figure 4)
   The GP2Y1014AU0F is an optical dust sensor designed to detect airborne particulate matter, such as dust, smoke, and allergens. It uses an infrared LED and a photodiode to measure the scattering of light caused by particles in the air. The sensor outputs an analog voltage that corresponds to the dust concentration. Operating at a voltage of 5V, it provides real-time monitoring of air quality. It is compact, energy-efficient, and highly sensitive, making it suitable for various applications like air purifiers and HVAC systems. The GP2Y1014AU0F is commonly used in both consumer and industrial environments.

4. Results and Discussions

The device that has been presented can show data on LCD (Figure 5).We reviewed 7 days of data from South and North City of Delhi. Using their device.
In this review we have found that this device only measure and display Air quality:

- To check air quality every time we need to press button.
- This is static device.
- This device is not future ready to integrate wireless feature in future.

Figure 5. GP2Y1014AU0F dust sensor

5. Conclusion

We will replace Arduino Uno with ESP32 microcontroller which is more powerful and advance as compare to Arduino Uno.

- The ESP32 is dynamic and thus eliminate the process of checking Air quality by pressing button.
- This microcontroller will check Air quality in real time and show the data in display.
- If required this device will send data automatically to remote device.

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