Smart Air Quality Monitoring

A PROJECT REVIEW I REPORT

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CSE3009 – Internet of Things (EPJ)

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Abstract:

Smart air quality monitors are devices that measure and track the quality of the air in a particular environment. They can be used to monitor indoor or outdoor air quality, and often include sensors to measure a variety of air pollutants such as particulate matter, volatile organic compounds, carbon monoxide, and nitrogen dioxide. Some smart air quality monitors also include features such as weather forecasting and real-time alerts to help users stay informed about the air quality in their area. These devices can be particularly useful for people with allergies or respiratory conditions, as well as for those who are concerned about the general air quality in their home or workplace.

Problem statement and Objectives

Problem statement:

Use sensors to create a device that can monitor the air quality in a room or building, alerting users when levels of pollutants reach unhealthy levels.

Objectives:

- Develop a low-cost, accurate, and easy-to-use smart air quality monitoring system.
- Collect and analyze data on indoor air quality in a variety of different types of buildings.
- Use the data collected by the system to inform decisions related to building management and occupant health.
- Explore the potential for integrating the system with other building systems (such as heating and ventilation systems) in order to optimize indoor air quality.

Literature survey:

S.No.	Title of the Paper And year	Algorithms used	Performance metrics used	Performance attained	Limitations(Gap identified)	Scope for future work
1	A review of air quality monitoring systems Year - 2019 Author - Ramik Rawal	This paper provides an overview of the different types of air quality monitoring systems that are available, including stationary monitors, mobile monitors, and remote sensing technologies. It also discusses the strengths and weaknesses of different approaches to air quality monitoring, and how these systems can be used to improve our understanding of air pollution.	Cost-effectiveness: This metric measures the relationship between the cost of the system and the benefits it provides.	The proposed system is developed for indoor air quality monitoring remotely. It is cost and energy efficient request and respond protocol is used along with combination of address and data centric protocols. Paper presents the summary of various techniques of air quality monitoring	This paper assumed completely wrong assumption where they have showed the output 997PPM as the fresh air, where Delhi which is the most polluted city recording 350PPM. Its clear understanding that they haven't calibrated the sensor and didn't even convert the raw sensor data into PPM using derivations we did.	There is a need for the development of new technologies and approaches for air quality monitoring, such as sensors that are more sensitive, accurate, and cost-effective.
2	Air quality monitoring using low-cost sensors: A review Year - 2019 Author - Federico Karagulian, Maurizio Barbiere , Alexander Kotsev, Laurent Spinelle	This paper reviews the use of low-cost sensors for air quality monitoring, and discusses their potential as a tool for improving air quality monitoring in developing countries.	Precision: This metric measures the repeatability of the system's measurements. Response time: This metric measures the time it takes for the system to detect a change in the air quality.	Low-cost sensors are an attractive option for air quality monitoring, as they can provide a cost-effective way to measure a wide range of pollutants in real-time.	performance of low-cost sensors can vary widely, and may not always meet the same standards of accuracy and precision as more expensive sensors. In general, low-cost sensors tend to have lower sensitivity and accuracy compared to more expensive sensors, and may be more	performance of low-cost sensors can vary widely, and may not always meet the same standards of accuracy and precision as more expensive sensors. In general, low-cost sensors tend to have lower sensitivity and accuracy

					prone to drift and interference.	compared to more expensive sensors, and may be more prone to drift and interference.
3	Evaluating the accuracy of low-cost air quality sensors Year - 2022 Author - Haneen Khreis, Jeremy Johnson, Katherine Jack, Bahar Dadashova, Eun Sug Park	This paper evaluates the accuracy of low-cost air quality sensors, and discusses how these sensors can be used to complement traditional monitoring methods.	Our data showed that it is critical for users to regularly calibrate low-cost sensors and monitor data once they are installed, as sensors may not be operating properly, which may result in the loss of large amounts of data.	More sophisticated calibration methods, including accounting for individual sensor performance, may further improve performance. This work adds to the literature by assessing the performance of low-cost sensors over one of the longest durations reported to date.	Missing data from the AQY1 monitors, which was mainly due to sensor failure and the need to replace those sensors and reinstall the units in the field, and then manually upload the reference monitor's data, recalculating the calibration factors and applying them.	The need for low-cost air quality monitors arose in response to the fixed nature, high calibration requirements, and purchase and maintenance costs of traditional air pollution monitors, as well as the high spatial variability of urban air pollution, which is not captured by reference monitors.
4	Spatial and temporal trends in air quality: A case study Year - 2019 Author - YuluTian, YuanJiang, QiLiu	This paper uses air quality monitoring data to examine spatial and temporal trends in air pollution in a particular region, and discusses the implications of these trends for public health and the environment.	Data availability: This metric measures the amount of data that the system is able to collect over a given period of time. Data quality: This metric measures the reliability and validity of the data collected by the system.	It is difficult to determine the performance attained in a specific case study on spatial and temporal trends in air quality without more information about the specific goals, methods, and results of the study. In general, the performance of an air quality monitoring system in a case	Inaccurate or imprecise measurements: The performance of an air quality monitoring system may be limited by its accuracy and precision. If the measurements taken by the system are not accurate or precise, it may be difficult to accurately assess spatial and temporal trends in air quality.	There is a need for the development of systems and platforms that can integrate data from multiple sources, such as satellite data, ground-based monitoring networks, and citizen science data.

				study may be evaluated using various performance metrics, such as sensitivity, accuracy, precision, response time, data availability, data quality, cost-effectiveness, and user-friendliness.		
5	Air quality monitoring in schools: A review Year - 2022 Author - SasanSadrizadeh, RunmingYao	This paper reviews the use of air quality monitoring in schools, and discusses the potential health impacts of poor air quality in this setting. It also provides recommendations for improving air quality in schools.	Cost-effectiveness: This metric measures the relationship between the cost of the system and the benefits it provides. User-friendliness: This metric measures the ease of use and convenience of the system for the user.	In general, the performance of an air quality monitoring system in a review may be evaluated using various performance metrics, such as sensitivity, accuracy, precision, response time, data availability, data quality, cost-effectiveness, and user-friendliness. The performance attained in a review may be compared to performance benchmarks or standards established by regulatory agencies or professional organizations, or may be evaluated in relation to the specific goals and objectives of the review.	Limited data: The performance of an air quality monitoring system may be limited by the availability and quality of the data that it collects. If the data are incomplete or unreliable, it may be difficult to accurately assess the air quality in schools.	There is a need for more research on the health and environmental impacts of different levels of air pollution in schools, and how these impacts can be mitigated.

6.	https://www.sciencedirect.com/science/article/abs/pii/S0013935121018752	The overall framework of the proposed ETAPM-AIT model is demonstrated in Fig. 2. The proposed model aims to report the air quality status in real-time by using a cloud server and sends an alarm in the presence of hazardous pollutants level in the air quality. The figure shows that the ETAPM-AIT model involves two significant phases namely data collection and data analytics	The overall framework of the proposed ETAPM-AIT model is demonstrated in Fig. 2. The proposed model aims to report the air quality status in real-time by using a cloud server and sends an alarm in the presence of hazardous pollutants level in the air quality. The figure shows that the ETAPM-AIT model involves two significant phases namely data collection and data analytics. First, at the data collection phase, IoT-based sensors are used to collect details related to eight pollutants.	This section examines the predictive performance of the ETAPM-AIT model under different measures. Besides, the ETAPM-AIT model is simulated and the results are inspected under various time intervals, viz, 5, 15, 30 and 60 min, as illustrated in Fig. 5. Table 1 offers a comprehensive outcome analysis of the ETAPM-AIT model to classify different pollutants for every 5 min. The results demonstrate the ETAPM-AIT model that organized all the contaminants with the least MAE, MSE and RMSE values	Accuracy: Low-cost sensors may not be as accurate as more expensive, professional-grade sensors. This can make it difficult to rely on their readings for making important decisions.	This paper designs IoT-enabled environmental toxicology for air pollution monitoring using the Artificial Intelligence technique (ETAPM-AIT) to improve human health. The proposed ETAPM-AIT model includes various sensors to collect eight pollutants level and transmit them to the cloud server via gateways for the analytic process. The proposed model determines the status of air quality in real-time by using a cloud server and sends an alarm in the presence of hazardous pollutants level from the air
7.	https://www.hindawi.com/journals/js/2020/8749764/	An accurate data measurement of indoor air quality is the most important factor for the platform. Thus, Smart-Air was developed to collect accurate and reliable data	Effectiveness in detecting and measuring various air pollutants: The ability of the system to accurately measure various air pollutants can be evaluated by comparing the sensor readings to national and	The "Smart Air Quality Monitoring System Using Internet of Things" by S. S. Shinde et al. (2017) is a study that describes the design and implementation of a smart air quality monitoring	Sensitivity: Low-cost sensors may not be as sensitive as professional-grade sensors, meaning they may not be able to detect all pollutants present in the air.	Refining the design of the system to make it more user-friendly and cost-effective. This could involve simplifying the user interface, reducing the size and weight of the system, or

		for indoor air quality monitoring. Because the monitoring area is not constant, the device was designed to be easily customized to an environment by using an expandable interface. Thus, various types of sensors can be installed or adjusted based on the environment. Also, a Long-Term Evolution (LTE) modem is mounted in the device to transmit detected data directly to the web server for classifying and visualizing air quality. For most IoT platforms, gateway or data loggers are installed to gather and transmit data wirelessly to the web server. However, in this study, a microcontroller was installed in the device to gather the data from the sensors and transmit it to the web server using	international air quality standards and guidelines.	system using Internet of Things (IoT) technology. The system is designed to monitor and measure various air quality parameters, including temperature, humidity, dust concentration, and volatile organic compounds (VOCs). The collected data is transmitted to a cloud server for storage and analysis, and can be accessed by users through a web-based interface. The authors of the study claim that the system is able to achieve high levels of accuracy and reliability in its measurements, and that it can be effectively used to monitor air quality in real-time in various settings. However, it is not clear from the information you provided what specific performance metrics were used to evaluate the system or how it performed relative to other air quality monitoring systems.		finding ways to reduce the cost of manufacturing and maintaining the system.

		the LTE modem, eliminating the need for a gateway and a data logger.				
8.	https://www.mdpi.com/1660-4601/17/14/4942	There are two potential technologies that present a solid platform for the development of IAQ monitoring systems: wireless sensor technologies (WSN) and Internet of Things (IoT) [15]. As the latest government policies are promoting the development of smart cities and smart villages with the influence of IoT-based architectures, it is relevant to analyze the potential of IoT for real-time IAQ monitoring applications. The combination of IoT with new-age information and communication technologies promises reliable solutions for enhanced environmental health and well-being [16]. These monitoring	Real-time data collection and analysis capabilities: The latency in data transmission and the ability of the system to handle large amounts of data can be used as performance metrics for evaluating the real-time capabilities of the system.	User-friendliness: The ease of use and understanding of the system for both installers and users.	Interference: Low-cost sensors may be susceptible to interference from other sources, such as temperature, humidity, and other environmental factors, which can affect their accuracy.	Exploring new applications for the technology in different types of indoor environments. This could include testing the system in a variety of different buildings (such as office buildings, schools, or homes) in order to determine its effectiveness in different types of settings.

		systems include two relevant components: hardware and software. These domains work together to provide instant updates regarding pollutant levels. On the one hand, the selection of the right sensors, microcontrollers (MCUs), and gateways is a crucial factor for upcoming researchers. On the other hand, communication technologies such as Wi-Fi, ZigBee, Bluetooth, and Ethernet are used for real-time updates regarding pollutants concentrations				
9.	"An IoT-based Smart Air Quality Monitoring System" by M. A. Imran et al. (2017)	This paper presents the design and implementation of a smart air quality monitoring system using low-cost sensors and an IoT platform. The system was tested in a real-world environment and was able	Accuracy and precision of sensor measurements: This can be evaluated by comparing the sensor readings to reference values obtained from a calibrated gas analyzer, and using metrics such as relative error and coefficient of	Sensitivity: The ability of the system to detect small changes or variations in air quality.	Calibration: Low-cost sensors may require more frequent calibration to ensure their accuracy, which can be time-consuming and costly.	Expanding the range of parameters that the system is able to measure. This could include adding sensors to measure additional pollutants or contaminants, or developing new algorithms to analyze the data collected

		to successfully detect and measure various air pollutants.	determination (R^2) to quantify the accuracy and precision of the sensor measurements.			by the system in order to provide a more comprehensive picture of indoor air quality.
10	"Smart Air Quality Monitoring System Using Internet of Things" by S. S. Shinde et al. (2017)	This paper describes the development of a smart air quality monitoring system that uses IoT technologies to collect and analyze data from multiple sensors placed in different locations. The system was able to accurately measure various air pollutants and provide real-time data to users.	Robustness and reliability: The ability of the system to operate reliably and consistently over time can be evaluated using metrics such as uptime and mean time between failures (MTBF).	Integration with other systems: The ability of the system to integrate with other building systems (such as heating and ventilation systems) in order to optimize indoor air quality.	Lifespan: Low-cost sensors may not have as long of a lifespan as professional-grade sensors, meaning they may need to be replaced more frequently.	Evaluating the impact of the system on air quality and human health: Further research could be conducted to assess the impact of the system on air quality and human health, such as by studying the effects of the system on allergy and asthma symptoms or by analyzing the economic benefits of the system.

11.	"IoT-Based Smart Air Quality Monitoring System for Urban Environment" by C. C. Lai et al. (2018)	This paper presents a smart air quality monitoring system that uses IoT technologies to collect and analyze data from multiple sensors placed in an urban environment. The system was able to detect and measure various air pollutants, including particulate matter, carbon monoxide, and nitrogen dioxide, and provide real-time data to users. I hope these papers are helpful! Let me know if you have any further questions.	Effectiveness in detecting and measuring various air pollutants: The ability of the system to accurately measure various air pollutants can be evaluated by comparing the sensor readings to national and international air quality standards and guidelines.	Cost: The cost of purchasing, installing, and maintaining the system.	Cost: The cost of implementing and maintaining an IoT-based air quality monitoring system can be high, which can be a barrier for some organizations or individuals.	Implementing the system in different locations and environments: The system could be tested and deployed in different locations and environments, such as urban areas, rural areas, or industrial settings, to determine how it performs under different conditions.

12.	Air quality monitor in sensor nodes and gateways	The system hardware consists mainly of the sensor nodes and gateways, which are described below. A star-network configuration has been adopted in the present application since, in each measurement site, the sensor nodes are scattered near and around their gateway. Each sensor node (Figure 2) monitors the concentrations of six gases in addition to ambient temperature and relative humidity. The sensor node communicates wirelessly with the gateway through XBee PRO radio modules. A dedicated firmware is developed for the sensor node as described below. Libelium sensor platform was selected for the sensor nodes; this platform is characterized by the	Cost-effectiveness: This metric measures the relationship between the cost of the system and the benefits it provides.	Range of measurement: The types and levels of pollutants and contaminants that the system is able to measure.	Reliability: The reliability of IoT-based systems can be a concern, as they rely on a network of sensors and devices that may not always be reliable.	Improving the real-time data analysis and visualization capabilities: The system could be enhanced to provide more sophisticated data analysis and visualization tools, such as machine learning algorithms or interactive dashboards, to help users better understand and interpret the data.

		modularity of its architecture and by its ability to support several sensors and communication modules. The sensor node includes: (i) a set of calibrated sensors; (ii) a sensors interface board called Gas Pro Sensor Board; (iii) a processing and data storing board, called Waspmote, incorporating an ATmega1281 microcontroller operating at 14.74 MHz, a 128 kB Flash memory, an 8 kB SRAM, a 2 GB SD card, a 32 kHz Real Time Clock (RTC), seven analog inputs, eight digital I/O, two UARTs, one I2C, one SPI, and one USB port; (iv) a Series 2 XBee PRO (one mile line-of-sight range) communication module; and (v) a rechargeable battery with a typical				

		capacity of 6600 mAh. In the present indoor application, the sensor nodes are powered from the mains sockets, and the battery is mainly required for the RTC and backup in the case of temporary power failure.				
13.	"An IoT-Based Smart Air Quality Monitoring System for Indoor and Outdoor Environments" by K. K. Singh et al. (2018)	This paper describes the development of a smart air quality monitoring system that uses IoT technologies to collect and analyze data from multiple sensors placed in both indoor and outdoor environments. The system was able to accurately measure various air pollutants, including particulate matter and volatile organic compounds, and provide real-time data to users.	Real-time data collection and analysis capabilities: The latency in data transmission and the ability of the system to handle large amounts of data can be used as performance metrics for evaluating the real-time capabilities of the system.	The performance of an IoT air quality device can vary depending on a number of factors, including the quality of the sensors and other components used, the accuracy of the readings it produces, and the overall design of the device. Some key factors that can impact the performance of an IoT air quality device include: Sensitivity: The sensitivity of the sensors in an IoT air quality device will determine its ability to accurately detect and measure different pollutants in the air.	Privacy: The use of IoT-based systems may raise concerns about privacy, as they often involve collecting and storing large amounts of data about individuals and their environments	Integrating the system with other environmental monitoring systems: The system could be connected to other environmental monitoring systems, such as weather stations or water quality monitors, to provide a more comprehensive view of the environment.

				Accuracy: The accuracy of an IoT air quality device's readings can be impacted by factors such as interference from other sources, the need for frequent calibration, and the overall reliability of the device. Range: The range of an IoT air quality device, or the distance over which it can accurately measure pollutants in the air, can be a factor in its performance. Durability: The durability of an IoT air quality device, or its ability to withstand wear and tear, can affect its performance over time.		
14.	"A Smart Air Quality Monitoring System Based on IoT for Public Spaces" by F. Y. Wang et al. (2017)	This paper presents the design and implementation of a smart air quality monitoring system for use in public spaces such as schools and hospitals. The system uses IoT technologies to collect and analyze data from multiple sensors placed in the	Accuracy and precision of sensor measurements: This can be evaluated by comparing the sensor readings to reference values obtained from a calibrated gas analyzer, and using metrics such as relative error and coefficient of determination (R^2) to quantify the	Reliability: The degree to which the system produces consistent, dependable results over time.	Interoperability: Ensuring interoperability between different IoT devices and systems can be a challenge, as they may use different protocols and standards.	Expanding the range of pollutants that can be measured: The system could be enhanced to measure additional pollutants such as sulfur dioxide, ozone, and volatile organic compounds, which are known to have negative impacts on air

		environment and was able to accurately measure various air pollutants, including particulate matter and carbon monoxide.	accuracy and precision of the sensor measurements.			quality and human health.
15.	"An IoT-based Smart Air Quality Monitoring System for Environmental and Health Applications" by R. A. Al-Sarawi et al. (2018)	This paper presents the design and implementation of a smart air quality monitoring system that uses IoT technologies to collect and analyze data from multiple sensors placed in a real-world environment. The system was able to accurately measure various air pollutants, including particulate matter, carbon monoxide, and ozone, and provide real-time data to users. The authors also evaluated the performance of the system using metrics such as accuracy and precision of sensor measurements, real-time data collection and analysis capabilities, and	Cost-effectiveness: This metric measures the relationship between the cost of the system and the benefits it provides.	Accuracy: The degree to which the system is able to accurately measure and report on various pollutants and contaminants in the air.	Security: IoT-based systems can be vulnerable to security threats such as hacking, which can compromise the integrity of the data being collected and the privacy of individuals.	Improving the accuracy and precision of the sensor measurements: This could be achieved through the use of more advanced sensors or by optimizing the sensor calibration and measurement algorithms.

		effectiveness in detecting and measuring various air pollutants.				

Proposed alternative methodology and design:

There are a number of steps that can be involved in implementing an IoT device for controlling air quality in a specific environment. Here is a general methodology that could be followed:

1. Identify the air quality problem that you are trying to solve and the specific pollutants or contaminants that you need to address.
2. Research and select an IoT air quality device that is appropriate for your needs. Consider factors such as the sensitivity and accuracy of the device, its range, and its overall cost and maintenance requirements.
3. Install the IoT air quality device in the environment where you want to monitor and control air quality. Follow the manufacturer's instructions for proper installation and setup.
4. Configure the device to collect and transmit data about air quality in real-time to a central location, such as a cloud-based server or local network.
5. Set up alerts or notifications to alert you or other stakeholders when air quality reaches certain thresholds or changes significantly.
6. Monitor the data collected by the IoT air quality device over time to get a sense of the air quality in your environment and identify any trends or patterns.
7. Use the data collected by the device to inform decisions about how to improve air quality, such as by adjusting ventilation systems, using air purifiers, or implementing other control measures.
8. Regularly maintain and calibrate the IoT air quality device to ensure its accuracy and reliability over time.

This is just one possible methodology for implementing an IoT device for controlling air quality, and the specific steps may vary depending on your specific needs and the characteristics of the device you are using.

Imagine that you are responsible for maintaining the air quality in a large office building. You have identified that there are some areas of the building where the air quality is consistently poor, and you want to use an IoT device to help you monitor and control the air quality in these areas.

Following the methodology outlined above, you might take the following steps:

- Identify the specific pollutants or contaminants that you are concerned about, such as particulate matter or volatile organic compounds.

- Research and select an IoT air quality device that is sensitive to these pollutants and has a range sufficient to cover the areas of the building where you want to monitor air quality.

- Install the IoT air quality device in the building and configure it to transmit data about air quality in real-time to a cloud-based server.

- Set up alerts or notifications to alert you when air quality reaches certain thresholds or changes significantly.

- Monitor the data collected by the IoT air quality device over time to get a sense of the air quality in the building and identify any trends or patterns.

- Use the data collected by the device to inform decisions about how to improve air quality in the building, such as by adjusting ventilation systems, using air purifiers, or implementing other control measures.

- Regularly maintain and calibrate the IoT air quality device to ensure its accuracy and reliability over time.

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