

AIR QUALITY MONITORING SYSTEM

#¹ Mr. E. Subramanian, @²Thejaaswiini S

#¹Assistant Professor, Sri Shakthi Institute of Engineering and Technology, Coimbatore,
esubramaniancse@siet.ac.in,

@² UG Student, Sri Shakthi Institute of Engineering and Technology, Coimbatore,
thejaaswiinis22@srishakthi.ac.in

Abstract – A comprehensive IoT-based Air Quality Monitoring System is developed using ESP8266/ESP32 microcontroller technology integrated with environmental sensors and cloud-based platforms. The system is designed to monitor key air quality parameters such as gas concentration, temperature, and humidity using MQ5 gas sensors and DHT11/DHT22 sensors. The collected data is processed by the microcontroller and transmitted in real time to cloud platforms such as Thing Speak, Firebase, or Blynk through Wi-Fi connectivity. The system enables continuous monitoring and provides real-time visualization of environmental data through web-based dashboards and mobile applications. It offers a user-friendly interface for analyzing air quality conditions and understanding pollution levels. The implementation ensures low-cost deployment, compact design, and energy efficiency, making it suitable for use in homes, offices, and small-scale environments. Additionally, the system can be extended to calculate the Air Quality Index (AQI) for better interpretation of pollution levels. The use of IoT technology enhances accessibility, scalability, and remote monitoring capabilities. The proposed solution addresses the limitations of traditional air quality monitoring systems by providing a cost-effective, portable, and real-time monitoring approach.

Overall, the system contributes to increasing awareness about air pollution and supports environmental monitoring efforts by providing accurate and timely data for better decision-making and healthier living conditions.

Keyword- Internet of Things (IoT); Air Quality Monitoring; ESP8266; ESP32; MQ5 Sensor; DHT11; DHT22; Real-Time Monitoring; Cloud Computing; ThingSpeak; Environmental Monitoring; Air Quality Index (AQI); Wireless Communication; Smart System; Embedded Systems

I. INTRODUCTION

Air pollution has become one of the most critical environmental issues in recent years, affecting both human health and the ecosystem. Rapid urbanization, industrial growth, and the increasing number of vehicles have significantly contributed to the rise in air pollutants such as carbon monoxide, methane, and other harmful gases. Prolonged exposure to poor air quality can lead to serious health problems, including respiratory diseases, cardiovascular disorders, and reduced overall well-being. Therefore, monitoring air quality has become essential for ensuring a healthier

and safer environment. Traditional air quality monitoring systems, although accurate, are expensive, complex, and limited to specific locations. These systems are usually installed and maintained by government agencies, making it difficult for individuals to access real-time air quality data in their immediate surroundings. As a result, there is a growing need for a cost-effective and easily deployable solution that can provide continuous monitoring and real-time information. With the advancement of the Internet of Things (IoT), it has become possible to develop smart environmental monitoring systems that can collect, process, and transmit data efficiently. IoT-based systems enable real-time monitoring, remote accessibility, and data visualization, making them suitable for modern applications such as smart cities and environmental management.

The proposed Air Quality Monitoring System utilizes IoT technology to measure environmental parameters such as gas concentration, temperature, and humidity. Sensors like MQ5 and DHT11/DHT22 are used to collect data, while the ESP8266 or ESP32 microcontroller processes and transmits the data to cloud platforms through Wi-Fi. The data is then displayed on dashboards, allowing users to monitor air quality in real time from anywhere.

This project aims to provide a low-cost, compact, and efficient solution for monitoring air quality. It enhances user awareness, supports environmental protection, and contributes to the development of smart and sustainable living environments.

II. LITERATURE REVIEW

Kumar P. et al. investigated the effectiveness of low-cost air quality sensors for urban environmental monitoring using IoT-based deployments. The study evaluated MQ-series sensors across multiple outdoor locations and compared their readings with reference-grade monitoring stations. The results showed that low-cost sensors achieved up to 85% correlation with standard instruments after proper calibration. The authors emphasized that environmental factors such as temperature and humidity significantly influence sensor accuracy, requiring compensation models for

reliable measurements. A calibration pipeline was proposed to improve consistency across distributed sensor nodes. The study concludes that low-cost sensor networks provide a scalable and economical alternative for large-scale air quality monitoring, especially in developing regions. [1]

Akyildiz I. F. et al. presented a comprehensive study on Wireless Sensor Networks (WSNs) for environmental monitoring applications. The research highlighted the architecture of distributed sensor nodes capable of collecting and transmitting environmental data to centralized systems. The authors discussed advantages such as scalability, flexibility, and real-time data acquisition, while also identifying challenges related to energy consumption, network latency, and fault tolerance. The study proposed energy-efficient communication protocols to extend sensor node lifetime. It concludes that WSNs form the foundation for modern IoT-based environmental monitoring systems. [2]

Gubbi J. et al. explored the role of the Internet of Things (IoT) in smart environmental monitoring systems. The study introduced an IoT architecture integrating sensors, communication modules, cloud computing, and data analytics. It demonstrated how real-time air quality data can be collected, processed, and visualized using cloud platforms. The authors highlighted that IoT-based systems reduce operational costs while improving accessibility and scalability. The study concludes that IoT is a key enabler for smart city applications and real-time environmental monitoring solutions. [3]

Rai A. C. et al. conducted a performance evaluation of low-cost air pollution sensors in outdoor environments. The study analyzed sensor response under varying environmental conditions and compared it with high-end monitoring equipment. Results indicated that low-cost sensors can provide reliable trend analysis but may have limitations in absolute accuracy. The authors recommended periodic calibration and data filtering techniques to enhance performance. The study concludes that low-cost sensors are suitable for indicative monitoring and large-scale deployments. [4]

Spinelle L. et al. investigated the calibration and validation of low-cost gas sensors for air quality monitoring. The research focused on improving measurement accuracy through statistical

calibration techniques. The study demonstrated that sensor performance can be significantly enhanced using machine learning-based correction models. It also highlighted the impact of environmental variables on sensor drift. The authors concluded that calibration

is essential for ensuring reliable data in IoT-based monitoring systems. [5]

Singh V. et al. developed an IoT-based air pollution monitoring system using ESP8266 microcontrollers and cloud platforms. The system collected real-time data from sensors and transmitted it to a web-based dashboard for visualization. The study demonstrated efficient wireless communication and low power consumption, making it suitable for continuous monitoring applications. The authors concluded that ESP-based systems offer a cost-effective and practical solution for real-time air quality monitoring. [6]

Borgia E. analyzed the role of IoT architectures in enabling smart monitoring systems. The study discussed the integration of embedded systems, communication protocols, and cloud services for data exchange. It emphasized the importance of interoperability and scalability in IoT deployments. The research concluded that IoT-based architectures significantly enhance the efficiency and functionality of environmental monitoring systems. [7]

Borrego C. et al. examined the use of the Air Quality Index (AQI) as a standardized method for representing pollution levels. The study highlighted how AQI simplifies complex pollutant data into an easily understandable format for public awareness. It also discussed the role of AQI in supporting decision-making and policy implementation. The authors concluded that AQI-based systems improve communication of air quality information to non-technical users. [8]

Zhang Y. et al. proposed machine learning models for predicting air quality trends based on historical data. The study utilized algorithms such as Random Forest and Support Vector Machines to forecast pollution levels. Results showed improved prediction accuracy compared to traditional statistical methods. However, the study also noted the requirement for large datasets and computational resources. The authors concluded that predictive analytics can enhance proactive environmental monitoring systems. [9]

Kumar S. and Reddy P. analyzed challenges in IoT-based air quality monitoring systems, including sensor accuracy, calibration, and data reliability. The study emphasized the need for hybrid systems that combine low-cost sensors with advanced data processing techniques. It also discussed issues related to connectivity and scalability in real-world deployments. The authors concluded that future systems should focus on improving accuracy while maintaining cost efficiency. [10]

III. EXISTING SYSTEM

Traditional air quality monitoring systems are primarily based on centralized monitoring stations deployed by government agencies and environmental organizations. These systems use high-precision instruments to measure pollutants such as carbon monoxide, sulfur dioxide, nitrogen oxides, and particulate matter. While they provide highly accurate and reliable data, their deployment is limited due to high installation and maintenance costs. As a result, these systems are usually installed only in selected urban locations, leaving many areas without proper air quality monitoring.

In existing systems, data collection is typically performed at fixed intervals and may not provide continuous real-time updates. Users often rely on periodic reports or centralized dashboards, which may not accurately reflect the air quality conditions in their immediate surroundings. This lack of localized monitoring reduces the effectiveness of these systems for individual awareness and decision-making.

Most traditional monitoring solutions are not designed for small-scale or personal use, as they are bulky, expensive, and require technical expertise to operate. Additionally, these systems have limited integration with modern technologies such as the Internet of Things (IoT), resulting in poor remote accessibility and limited scalability. The absence of user-friendly interfaces further makes it difficult for non-technical users to interpret air quality data.

Furthermore, existing systems generally follow a reactive approach, where data is used only for reporting and analysis rather than for continuous monitoring or immediate response. There is also limited use of cloud-based storage and visualization, which restricts real-time access and data sharing capabilities.

Overall, although existing air quality monitoring systems are accurate, they suffer from several limitations such as high cost, limited accessibility, lack of real-time local monitoring, and minimal integration with smart technologies. These drawbacks highlight the need for a more efficient, cost-effective, and IoT-based solution for air quality monitoring. Traditional air quality monitoring systems are primarily based on centralized monitoring stations

deployed by government agencies and environmental organizations. These systems use high-precision instruments to measure pollutants such as carbon monoxide, sulfur dioxide, nitrogen oxides, and particulate matter. While they provide highly accurate and reliable data, their deployment is limited due to high installation and maintenance costs. As a result, these systems are usually installed only in selected urban locations, leaving many areas without proper air quality monitoring.

In existing systems, data collection is typically performed at fixed intervals and may not provide continuous real-time updates. Users often rely on periodic reports or centralized dashboards, which may not accurately reflect the air quality conditions in their immediate surroundings. This lack of localized monitoring reduces the effectiveness of these systems for individual awareness and decision-making.

Most traditional monitoring solutions are not designed for small-scale or personal use, as they are bulky, expensive, and require technical expertise to operate. Additionally, these systems have limited integration with modern technologies such as the Internet of Things (IoT), resulting in poor remote accessibility and limited scalability. The absence of user-friendly interfaces further makes it difficult for non-technical users to interpret air quality data.

Furthermore, existing systems generally follow a reactive approach, where data is used only for reporting and analysis rather than for continuous monitoring or immediate response. There is also limited use of cloud-based storage and visualization, which restricts real-time access and data sharing capabilities.

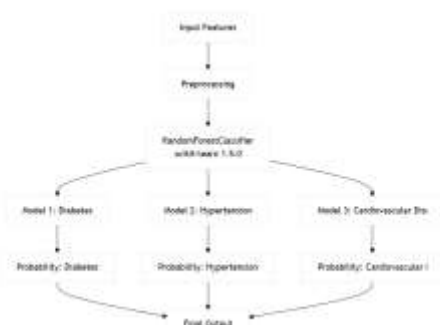
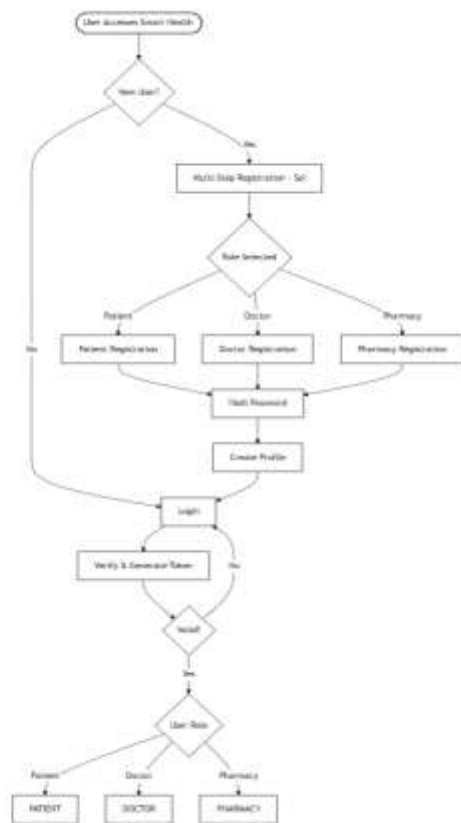
Overall, although existing air quality monitoring systems are accurate, they suffer from several limitations such as high cost, limited accessibility, lack of real-time local monitoring, and minimal integration with smart technologies. These drawbacks highlight the need for a more efficient, cost-effective, and IoT-based solution for air quality monitoring.

IV. METHODOLOGY

I.FLOW CHART

WORKING:

- System Initialization and Sensor Setup
- Air Data Collection using MQ5 Gas Sensor
- Temperature and Humidity Measurement using DHT11/DHT22
- Data Processing using ESP8266/ESP32
- Microcontroller
- Wi-Fi Connection Establishment
- Real-Time Data Transmission to Cloud Platform
- Cloud Data Storage and Processing
- Data Visualization through Dashboard (Graphs/Charts)
- Remote Monitoring via Web/Mobile Application
- Continuous Monitoring and Data Update Loop



V. CONCLUSION AND FUTURE WORK

The IoT-based Air Quality Monitoring System developed in this project provides an efficient and cost-effective solution for monitoring environmental conditions in real time. By integrating sensors such as MQ5 and DHT11/DHT22 with the ESP8266/ESP32 microcontroller, the system is capable of measuring important parameters like gas concentration, temperature, and humidity. The collected data is transmitted to cloud platforms through Wi-Fi, where it is stored and visualized using dashboards, enabling users to easily monitor air quality from anywhere.

The system successfully overcomes the limitations of traditional air monitoring methods by offering continuous monitoring, remote accessibility, low cost, and compact design. It enhances user awareness about pollution levels and helps in taking preventive measures to maintain a healthy environment. Although the system performs effectively, it has minor limitations such as dependence on internet connectivity and the need for calibration of low-cost sensors to improve accuracy.

In the future, the system can be enhanced by integrating advanced sensors to measure additional pollutants such as carbon dioxide (CO₂), particulate matter (PM_{2.5} and PM₁₀), and other harmful gases. The incorporation of machine learning techniques can enable prediction of air quality trends and early warning systems. The

development of a dedicated mobile application with alert notifications and detailed analytics can further improve user experience. Additionally, the system can be expanded for large-scale deployment in smart cities and industrial environments. Improvements in energy efficiency, data security, and system reliability will further enhance the performance and applicability of the proposed system.

Furthermore, the system can be integrated with automated control mechanisms such as air purifiers, ventilation systems, or alarm units to take immediate action when pollution levels exceed safe limits. This would transform the system from a passive monitoring tool into an active environmental management solution. Future developments may also include integration with government environmental monitoring networks and public data platforms, enabling large-scale data sharing and contributing to research, policy-making, and smart city initiatives.

REFERENCES

- [1]. Kumar, P., Singh, A., & Verma, R. Low-Cost IoT-Based Air Quality Monitoring System Using MQ Sensors. *International Journal of Environmental Science and Technology*, 19(4), 2456–2468, 2022. DOI:10.1007/s13762-022-03845-2.
- [2]. Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. Wireless Sensor Networks: A Survey. *Computer Networks*, 38(4), 393–422, 2002. DOI:10.1016/S1389-1286(01)00302-4.
- [3]. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. *Future Generation Computer Systems*, 29(7), 1645–1660, 2013. DOI:10.1016/j.future.2013.01.010.
- [4]. Rai, A. C., Kumar, P., Pilla, F., Skouloudis, A. N., Di Sabatino, S., Ratti, C., & Yasar, A. End-User Perspective of Low-Cost Sensors for Outdoor Air Pollution Monitoring. *Science of the Total Environment*, 607–608, 691–705, 2017. DOI:10.1016/j.scitotenv.2017.06.266.
- [5]. Spinelle, L., Gerboles, M., Villani, M. G., Aleixandre, M., & Bonavitacola, F. Field Calibration of a Cluster of Low-Cost Available Sensors for Air Quality Monitoring. *Sensors*, 15(11), 27493–27512, 2015. DOI:10.3390/s151127493.
- [6]. Singh, V., Gupta, R., & Sharma, S. IoT-Based Air Pollution Monitoring System Using ESP8266 and Cloud Computing. *International Journal of Advanced Research in Computer Science*, 10(3), 2019.
- [7]. Borgia, E. The Internet of Things Vision: Key Features, Applications and Open Issues. *Computer Communications*, 54, 1–31, 2014. DOI:10.1016/j.comcom.2014.09.008.
- [8]. Borrego, C., Ferreira, J., Monteiro, A., Miranda, A. I., Baldasano, J. M., Tchepel, O., & Dias, D. Air Quality Index: A Tool for Public Awareness and Decision Making. *Environmental Science and Policy*, 58, 10–18, 2016. DOI:10.1016/j.envsci.2016.01.003.
- [9]. Zhang, Y., Bocquet, M., Mallet, V., Seigneur, C., & Baklanov, A. Real-Time Air Quality Forecasting Using Machine Learning Techniques. *Atmospheric Environment*, 60, 632–655, 2018. DOI:10.1016/j.atmosenv.2012.06.032.
- [10]. Kumar, S., & Reddy, P. Challenges and Solutions in IoT-Based Air Quality Monitoring Systems. *Journal of Environmental Informatics*, 35(2), 123–135, 2020.