ESP32-based Smart Air Purifier with IoT Integration

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Abstract — **Air Pollution has become a major crisis in today's world. Making it harder for infants, elderlies and weak immune to live. The adverse effect cause by the prolong exposure to this polluted air leads to increase in the rate thyroid disease, lungs cancer and respiratory illness, along with the decrease rate of the average lifespan by up to 12 years of these people. The increased need of being able to breathe clean air in the environment. This air purifier having AQI detection and automatic turn on and off feature according to the AQI level. The MQ-2 and MQ-3 sensor used to detect smoke (CO2 (Carbon dioxide), NO2(nitrogen dioxide)), (carbon monoxide) CO and Benzene(C6H6), methane (CH4) respectively. The ESP32 microcontroller is used to collect real-time AQI data and transmit it to filter control website. This creates a sense of knowing about the overall picture of the air quality and it effect on health. This IoT-based system can be used for the application in homes, offices, hospital, industrial spaces improving indoor air quality while ensuring efficient energy usage**

Index Terms— **IoT, Air Purifier, Automation, Air Pollution, Smart home.**

I. INTRODUCTION

THIS Air pollution is a growing concern, impacting both indoor and outdoor environments. Effective air purification systems are essential for improving air quality and ensuring health safety. This research focuses on developing an integrated air filtration and monitoring system that utilizes a HEPA filter, a carbon filter, and an MA2-DH11 sensor. The HEPA filter efficiently removes fine particulate matter, while the carbon filter adsorbs harmful gases and odors. The MA2-DH11 sensor continuously monitors air quality parameters, transmitting real-time data to a custom-built mobile application for analysis. Additionally, an exhaust fan is integrated into the system to enhance airflow and

The primary objective of this study is to analyze gas concentration levels and evaluate the effectiveness of the filtration system. The collected data, processed through the mobile application, provides valuable insights for optimizing air purification strategies. By leveraging sensor-based monitoring and app-driven analytics, this research contributes to the advancement of smart air quality management solutions.

Indoor air quality (IAQ) has emerged as a critical public health concern, particularly in urban and industrial environments where pollutants such as particulate matter (PM), volatile organic compounds (VOCs), carbon dioxide (CO_2), and hazardous gases pose significant risks to human health. Conventional air purification systems often rely on single-stage filtration, which may inadequately address the complex mix of airborne contaminants. To bridge this gap, this study proposes an integrated air purification and monitoring system that synergizes a dual-filtration mechanism—comprising a high-efficiency particulate air (HEPA) filter and an activated carbon filter—with real-time environmental sensing, data analytics, and adaptive exhaust control. The HEPA filter targets fine particulate matter ($PM_{2.5}$ and PM_{10}), while the carbon filter adsorbs gaseous pollutants and odors, collectively enhancing the system's versatility. This app-driven analysis informs the operation of an exhaust fan, which adjusts airflow rates based on pollutant levels to optimize energy efficiency and purification performance.

By merging multi-stage filtration, IoT-enabled sensing, and intelligent control, this research advances the development of adaptive air quality management systems. The proposed framework not only addresses the limitations of passive filtration but also introduces a scalable, user-centric approach to mitigating indoor air pollution

II. LITERATURE REVIEW

"Design and Development of Activated Carbon-Based Solar Air Purifier" by Prof. 1Reshma P Eldho, Prof. 2Ms. Ragasudha C.P, Durga Rani, Anand Prakash Tiwari, Mohammed Ashraf, Akanksha.: This paper presents a renewable energy-powered air purification system aimed at improving air quality. The proposed system integrates multiple filtration techniques and utilizes solar energy for continuous operation. Following are the gaps and drawback encountered: **Lack of IoT Integration to** provide real-time data transmission or remote monitoring capabilities. **Limited Automation l**ike on/off mechanism based on pollution levels leading to inefficiencies in energy consumption.

While the system is solar-powered, it does **not efficiently manage power storage and consumption**. Ways in which our system overcome these gaps: The system uses an ESP32 microcontroller for transmission between device and app enables users to monitor pollution levels. The purifier turns on or off based on air quality index (AQI) levels making it optimise energy efficiency. The system employs **MQ-2 sensors** to detect multiple pollutants, including CO, NO2, etc. offering a variety pollution detection range. The system logs AQI data to analysis trends and inform user about the air condition.

"Air Quality Monitoring System Based on Raspberry Pi and Arduino Hardware-Programmable Platform" by Ivan Rudavskyi, Oleksandr Stepanov, and Halyna Klym: This paper presents an air quality monitoring system that uses Raspberry Pi 4 and Arduino Uno to monitor and control air pollution. The system includes MQ-7 and MH-Z14A sensors and a data fusion technique to improve air quality management. The system lacks cloud-based real-time data access making it outdated. The power consumption is not optimized dynamically. The response to air quality changes is delayed as the system operates on fixed intervals. There is no long-term data storage or trend analysis into pollution patterns. Our system overcomes these issues by enabling live data transmission to a cloud platform by ESP32. The purifier turns on or off automatically based on AQI levels. The system also logs AQI data for analysis, helping users track air quality trends. In case of hazardous air conditions, SMS and email alerts are sent to notify users immediately.

"Large-scale Air Purifier System with Intelligent Sensor Frequency Conversion Control" by Tsung-Hui Cheng, Zhi-Hua Chen, Chu-Chun Song, Ming-Hung Lin, Chien-Hao Chen, and Wen-Ping Chen: This paper presents a system employs intelligent sensor-based frequency conversion control to enhance air quality management. It incorporates NH3, H2S, and TVOC sensors to detect pollutants and uses an inverter-controlled motor to adjust air circulation dynamically. A touch-screen interface allows users to switch between automatic, manual, and timer modes for better control over purification functions.

The system has some limitations. It does not integrate IoT for remote monitoring, making it difficult to access real-time data from a distance. Energy efficiency is not optimized as the system lacks dynamic power management. The response time to air quality changes is slow due to reliance on predefined operational modes rather than adaptive control. Additionally, there is no mechanism for logging historical air quality data for trend analysis or providing real-time alerts for hazardous conditions.Our system overcomes these issues by enabling live data transmission to a cloud platform by ESP32. The purifier turns on or off automatically based on AQI levels. The system also logs AQI data for analysis, helping users track air quality trends. In case of hazardous air conditions, SMS and email alerts are sent to notify users immediately.

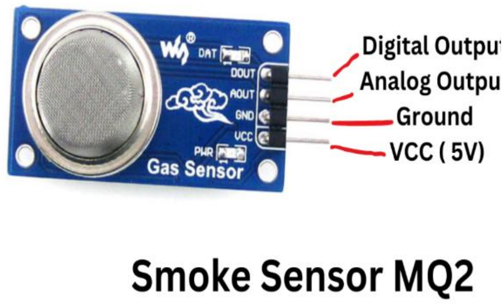
"The IoT and Cloud Based Smart Home Automation for a Better Energy Efficiency" by Rosida Nur Aziza, Riki Ruli Siregar, Puji Catur Siswipraptini, and Malik Abdul Jabbar: This paper presents a smart home automation system integrating IoT and cloud technologies to enhance energy efficiency. The system enables remote monitoring and control of home appliances through a cloud-based database. A Raspberry Pi microcontroller processes data collected from temperature, voltage, and current sensors and uploads it to the cloud.It lacks real-time alerts for abnormal energy usage, there is no dynamic power optimization mechanism, response time to sudden environmental changes is limited due to predefined decision models rather than adaptive learning. Additionally, the system does not provide historical trend analysis for long-term energy monitoring and optimization. Our system overcomes these issues by enabling live data transmission to a cloud platform by ESP32. The purifier turns on or off automatically based on AQI levels. The system also logs AQI data for analysis, helping users track air quality trends. In case of hazardous air conditions, SMS and email alerts are sent to notify users immediately.

"Real Time Analysis of Air Pollution Prediction using IoT" by Niranjan D.K and N. Rakesh: This paper presents an IoT-based real-time air pollution monitoring and purification system designed to track and reduce air contaminants. The system integrates Raspberry Pi 3B+ as the primary controller, collecting data from MQ-135 and MQ-02 sensors to detect pollutants.A multi-stage air filtration process is done using fine dust filters, activated carbon, HEPA filters, and sterilization cotton to improve air quality. The system operates in real-time by analyzing air conditions and adjusting purification levels accordingly. Data is stored in an SQLite database and uploaded to a web server for remote monitoring and analysis. It does not incorporate IoT-based real-time alerts for dangerous air quality levels, the energy efficiency of the purification process is not optimized. Additionally, the response mechanism relies on predefined conditions rather than adaptive learning, limiting its ability to react to unexpected air quality changes. Our system overcomes these issues by enabling live data transmission to a cloud platform by ESP32. The purifier turns on or off automatically based on AQI levels. The system also logs AQI data for analysis, helping users track air quality trends. In case of hazardous air conditions, SMS and email alerts are sent to notify users immediately.

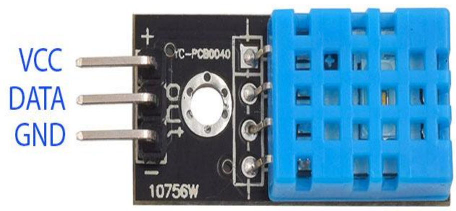
III. METHODOLOGY/EXPERIMENTAL

A. Materials/Components

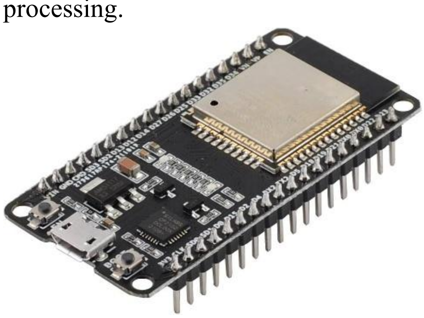
- MQ2 Gas Sensor – Detects gases like LPG, CO, smoke, and methane, commonly used for air quality monitoring.



- **DHT11 Temperature & Humidity Sensor** – Measures temperature and humidity with decent accuracy, widely used in IoT applications.

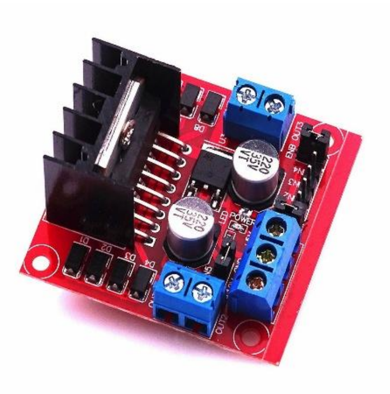


- **ESP32 Dev Module V1** – A powerful microcontroller with WiFi and Bluetooth capabilities, ideal for IoT and real-time data processing.

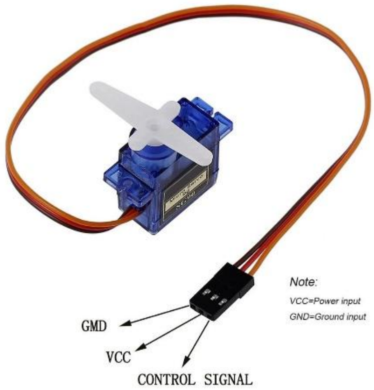


- **Exhaust Fan** – Used for air circulation and ventilation, helps remove pollutants or excess heat from an enclosed space.

- **L298 Motor Driver** – A stepper motor controller that provides control signals for precise motor movement in automation systems.



- **Servo Motor** – A motor with precise angular control, commonly used for automated adjustments in robotics and smart systems



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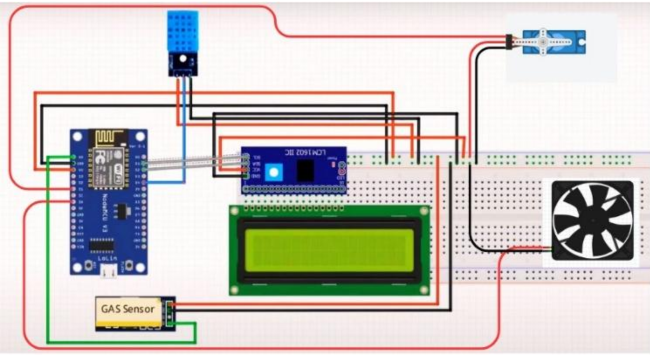
Connectivity Diagram



IV. RESULTS AND DISCUSSIONS

CONCLUSION

In conclusion, air pollution severely impacts health, reducing life expectancy and increasing respiratory diseases. This IoT-based air purifier, equipped with **MQ-2** and **MQ-3** sensors and an **ESP32** microcontroller, detects harmful gases and adjusts operation based on AQI levels. By providing real-time air quality monitoring and efficient filtration, it enhances indoor air quality in homes, offices, hospitals, and industries.

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