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Design and Development of Air Quality Monitoring and Alert Systtem using IoT

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Abstract: In the air, there are many dust particles and pollutant gases such as carbon dioxide and carbon monoxide that created an air pollution. The indoor and outdoor air pollution has brought the illness and harmful effect to human health. This creates a need for an IoT Alarm Air Quality Monitoring System to detect the dust particle, pollutant gases, temperature and humidity in the surrounding. The objective of this research work is to develop an indoor and outdoor air quality monitoring system for different air quality parameters (carbon dioxide and carbon monoxide), temperature, humidity, and dust concentration (air particle). Besides, the Node-RED dashboard and Android app are developed for real-time remotely applications in this system. The system performance is evaluated by testing the sensor used in the research work. In this research work, ESP-32, MQ7, MQ135, DHT22, and DSM501A are mainly used to develop the hardware. The MQTT is implemented as publish-subscribe network protocol to transfer the data as a message with the specific topic name. In the MQTT, the Node-RED dashboard, Android app and hardware are the MQTT client which are able to publish and subscribe the message. The Node RED dashboard acts as a live dashboard for monitoring and alarming purpose whilst the Android Studio is used to develop an Android app for the monitoring and alarm system in the smartphone. The Node-RED dashboard and Android app are able to display the data and notification message for different parameters on healthy or unhealthy level. The user can activate and deactivate the alarm system in the Node-RED dashboard or Android app as well

Keywords: Air Quality Monitoring, IoT, ESP32, MQ-7, MQ-135, MQTT, Node-RED, Real-Time Monitoring, Smart Alert System.

I. INTRODUCTION

Air pollution has emerged as a major environmental and public health challenge worldwide due to the increasing concentration of harmful gases and particulate matter in both indoor and outdoor environments. Pollutant gases such as carbon monoxide (CO), carbon dioxide (CO_2), ammonia (NH_3), nitrogen oxides (NO_x), and airborne particulate matter are commonly present in residential, industrial, and urban atmospheres. Prolonged exposure to these pollutants can lead to severe health issues including respiratory disorders, cardiovascular diseases, eye irritation, and reduced overall air quality comfort. In addition, environmental factors such as temperature and humidity influence pollutant dispersion and human thermal comfort. Therefore, continuous monitoring of air quality parameters is essential to ensure safe living and working conditions.

Conventional air quality monitoring systems are typically expensive, bulky, and deployed only at centralized monitoring stations, which limits their ability to provide localized, real-time air quality information. Moreover, such systems are not easily accessible for residential, institutional, or small-scale industrial environments where air quality conditions may vary significantly. As a result, there is a growing need for a low-cost, portable, and intelligent air quality monitoring system capable of continuous sensing, real-time analysis, and remote user notification.

Recent advancements in the Internet of Things (IoT), low-power microcontrollers, and semiconductor gas sensors have enabled the development of smart environmental monitoring solutions. IoT-based systems integrate sensing, processing, and wireless communication to provide real-time environmental awareness and early warning capabilities. Gas sensors from the MQ series, combined with environmental sensors and wireless microcontrollers such as the ESP32, offer an effective platform for distributed air quality monitoring. Furthermore, lightweight communication protocols such as MQTT enable efficient real-time data transmission to cloud dashboards and mobile applications for remote monitoring.
This paper presents the design and development of an IoT-based air quality monitoring and alert system capable of measuring pollutant gas concentration, airborne particulate matter, temperature, and humidity in indoor and outdoor environments. The proposed system utilizes MQ-7 and MQ-135 gas sensors, a DSM501A dust sensor, and a DHT22 temperature-humidity sensor interfaced with an ESP32 microcontroller for data acquisition and processing. The sensed data are transmitted using the MQTT publish–subscribe protocol to a Node-RED dashboard and an Android application for real-time visualization and monitoring. The system generates alerts when measured air quality parameters exceed predefined safety thresholds, enabling timely user awareness and preventive action.

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Unlike traditional stationary monitoring stations, the proposed system provides a low-cost, compact, and scalable solution for localized air quality assessment with remote accessibility. The integration of IoT communication, cloud-based visualization, and mobile notification makes the system suitable for smart homes, industrial workplaces, healthcare facilities, educational institutions, and urban environmental monitoring applications. The developed platform demonstrates the feasibility of deploying distributed IoT-based air quality monitoring systems for improving environmental safety and public health awareness.

II. LITERATURE SURVEY

[1] Dutta et al. (2009) developed one of the early low-cost urban air quality sensing systems using distributed sensor nodes capable of monitoring gases such as CO and NO_2. Their work demonstrated the feasibility of wireless sensor networks for environmental monitoring in urban areas. However, the system relied on relatively bulky sensor nodes and lacked real-time user alert mechanisms.

[2] Kumar and Jasuja (2017) proposed an air quality monitoring system based on the Internet of Things using MQ-series gas sensors interfaced with an Arduino platform. The sensed data were transmitted to a cloud server for remote visualization. Their system showed that low-cost gas sensors could effectively monitor environmental pollutants. However, the system focused mainly on gas concentration and did not include particulate matter sensing.

[3] Marques and Pitarma (2018) developed an indoor air quality monitoring system using the ESP8266 microcontroller and MQ-135 sensor integrated with temperature and humidity sensing. The system transmitted environmental data to an IoT cloud platform for real-time monitoring. Their results demonstrated reliable indoor pollutant detection. Nevertheless, the work did not incorporate dust particle measurement or mobile alert capability.

[4] Liu et al. (2019) proposed an IoT-based environmental monitoring system integrating gas sensors, dust sensors, and environmental sensors with MQTT communication. The system enabled real-time data transmission and visualization through a web dashboard. Their architecture demonstrated scalability and efficient IoT communication. However, the hardware platform used was relatively complex and costly for large-scale deployment.

[5] Hossain et al. (2020) designed a smart air quality monitoring system using ESP32 and multiple environmental sensors to measure temperature, humidity, and gas concentration. The collected data were transmitted via Wi-Fi to a cloud interface for remote monitoring. The ESP32 platform improved wireless reliability and reduced system cost. However, particulate matter sensing was not included in their implementation.

[6] Kim et al. (2021) presented a real-time air quality monitoring system integrating particulate matter sensors and gas sensors for comprehensive pollution assessment. The system generated threshold-based alerts when pollutant levels exceeded safety limits. Their work emphasized the importance of combining gas and dust sensing for accurate air quality evaluation. However, the use of high-precision industrial sensors increased overall system cost.

[7] Patel et al. (2022) implemented an IoT-based environmental monitoring system using MQTT protocol and Node-RED dashboard for real-time visualization. The system demonstrated efficient publish–subscribe communication and scalable monitoring architecture. However, the sensing parameters were limited primarily to temperature and humidity, without detailed gas pollutant analysis

[8] Singh et al. (2023) developed a mobile-integrated air quality monitoring device using ESP32 and MQ-series sensors with Android application connectivity. The system provided real-time monitoring and user alerts via smartphone notifications. The proposed solution improved accessibility and portability. However, particulate matter sensing and multi-parameter fusion were not extensively explored.

III. PROPOSED SYSTEM DESIGN

The Sensing Unit comprises MQ-7 and MQ-135 gas sensors, a DSM501A dust sensor, and a DHT22 temperature–humidity sensor for measuring environmental parameters and air pollutant levels. The MQ-7 sensor detects carbon monoxide concentration, while the MQ-135 sensor measures overall air quality by sensing gases such as ammonia, nitrogen oxides, and smoke. The DSM501A sensor measures airborne particulate matter concentration, and the DHT22 sensor provides ambient temperature and humidity values. These sensors generate electrical signals proportional to the measured environmental conditions and transmit them to the controller.The Processing and Communication Unit is centered around the ESP32 microcontroller. The ESP32 acquires analog and digital sensor signals through its input interfaces, processes the environmental data, and compares the measured values with predefined safety thresholds. The controller then formats the sensor data and transmits them over Wi-Fi using the MQTT publish–subscribe protocol for real-time monitoring and alert generation.The Power Supply Unit provides regulated electrical power to the ESP32 and sensing modules. A DC power source and voltage regulation circuitry ensure stable operation of all sensors and communication components required for continuous environmental monitoring.

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A. System Architecture

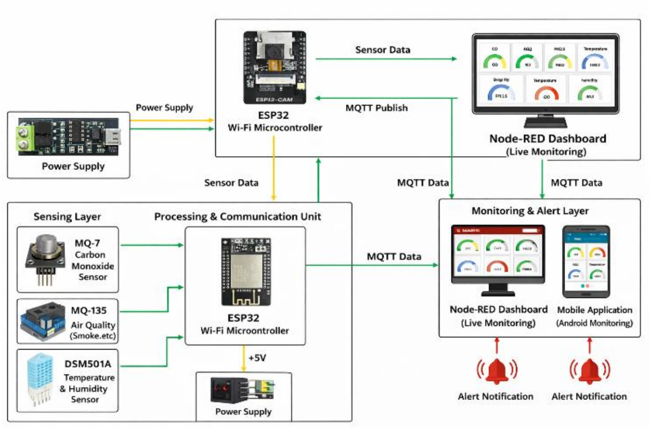

Fig. 1. Block Diagram of IoT-Based Air Quality Monitoring System

The proposed system consists of five main units: the Sensing Unit, Processing and Communication Unit, Power Supply Unit, Cloud Monitoring Unit, and User Alert Unit, as shown in Fig. 1.

The Cloud Monitoring Unit consists of an MQTT broker and a Node-RED dashboard that subscribe to the transmitted sensor data. The Node-RED interface displays real-time values of gas concentration, dust level, temperature, and humidity through graphical gauges and indicators for continuous environmental assessment.

The User Alert Unit includes a mobile application and dashboard notification system. When pollutant gas concentration or particulate levels exceed predefined safe limits, the system generates warning alerts that are delivered to the user through the Node-RED dashboard and smartphone interface, enabling timely awareness of hazardous air quality conditions.

IV. METHODOLOGY

A. Flowchart

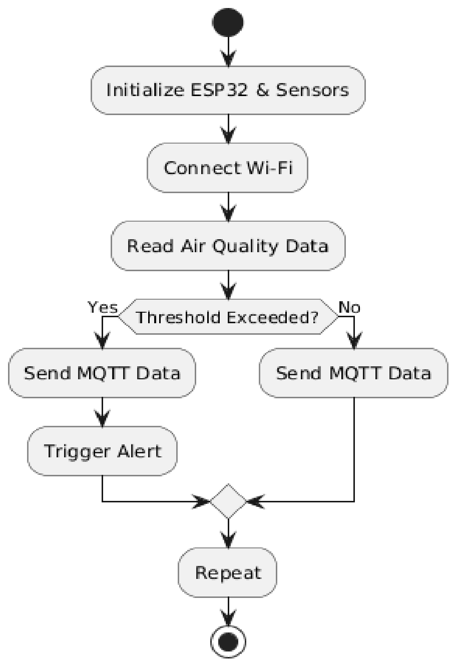

Fig. 2. Workflow of Air Quality Monitoring System

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Fig. 2. Illustrates the operational workflow of the proposed IoT-based air quality monitoring and alert system. The system begins with powering the hardware using a regulated DC supply to ensure stable and continuous operation. Once powered, the ESP32 microcontroller and the sensing modules (MQ-7, MQ-135, DSM501A, and DHT22) are initialized. After initialization, the system establishes a Wi-Fi connection to enable Internet communication. Following successful network connectivity, the ESP32 periodically acquires environmental data from the gas, dust, temperature, and humidity sensors. The measured parameters, including carbon monoxide concentration, overall air quality level, particulate matter concentration, temperature, and humidity, are processed and compared with predefined safety threshold values stored in the controller. If all measured parameters remain within safe limits, the ESP32 publishes the environmental data via the MQTT protocol to the cloud monitoring platform, where the Node-RED dashboard and mobile application display real-time air quality conditions. If any pollutant gas concentration or particulate level exceeds the predefined threshold, the system identifies the condition as unhealthy air quality. In this case, the ESP32 transmits warning messages along with sensor readings through MQTT, triggering alert notifications on the Node-RED dashboard and the user's smartphone interface. After data transmission and alert handling, the system continues periodic sensing and monitoring in a loop to provide continuous real-time air quality assessment.

V. IMPLEMENTATION

A. *Hardware Requirements*

Fig. 3. ESP32 Module

Fig. 3. Shows the ESP32 microcontroller module used in the proposed air quality monitoring system. It is a compact and low-cost microcontroller with integrated Wi-Fi and Bluetooth connectivity, enabling wireless data communication for IoT applications. The ESP32 provides multiple analog and digital input interfaces for acquiring signals from environmental sensors such as MQ-7, MQ-135, DSM501A, and DHT22. The module has sufficient processing capability to perform real-time sensor data acquisition, threshold evaluation, and MQTT-based data transmission. Processing.

Fig. 4. MQ-135 Sensor

Shows the MQ-135 air quality sensor used in the proposed air quality monitoring system. The MQ-135 sensor is employed for detecting harmful gases and overall air pollution levels in the surrounding environment. The sensor operates based on the variation in electrical resistance of a heated tin dioxide (SnO_2) sensing element when exposed to gases such as ammonia (NH_3), nitrogen oxides (NO_x), benzene, smoke, and carbon dioxide. The resulting analog voltage output proportional to gas concentration is acquired by the ESP32 microcontroller through its analog-to-digital converter. The MQ-135 sensor provides reliable detection of air pollutants over a wide concentration range with good sensitivity. The integration of the MQ-135 sensor enables the system to assess general air quality conditions and generate alerts when pollution levels exceed safe thresholds, thereby enhancing environmental monitoring capability.

Fig. 5. MQ-7 Sensor

Fig. 7. Shows the MQ-7 gas sensor module used in the proposed air quality monitoring system. The MQ-7 sensor is a semiconductor-based gas sensing device specifically designed for the detection of carbon monoxide (CO) in ambient air.

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The sensing element consists of a tin dioxide (SnO_2) layer deposited on an alumina substrate with an integrated heater coil. When exposed to carbon monoxide, the conductivity of the sensing layer changes due to surface chemical reactions between the gas molecules and the heated semiconductor material. This change in resistance produces a corresponding analog voltage output proportional to the CO concentration, which is acquired by the ESP32 microcontroller through its analog-to-digital conversion interface.

The MQ-7 sensor operates with a cyclic heating mechanism that enhances its selectivity to carbon monoxide and improves detection accuracy across a wide concentration range. The module provides adjustable sensitivity through an onboard potentiometer and conditioning circuitry, enabling calibration for different environmental conditions. Due to its high sensitivity to CO, low cost, and stable performance, the MQ-7 sensor is widely used in environmental monitoring and safety detection systems. In the proposed system, the MQ-7 sensor continuously monitors carbon monoxide levels in the surrounding environment, allowing the controller to identify hazardous air conditions and generate timely alerts when the measured concentration exceeds predefined safety thresholds, thereby improving air quality awareness and user safety.

Fig. 6. DSM501A Dust Sensor:

The Fig. 6 Shows the DSM501A dust sensor used in the proposed air quality monitoring system. The DSM501A sensor is applied for measuring airborne particulate matter concentration in the surrounding environment. The sensor operates based on the optical scattering principle, where an internal infrared light source detects suspended dust particles passing through the sensing chamber. The presence of particles produces a digital pulse output whose duty cycle is proportional to particle concentration. This signal is measured and processed by the ESP32 microcontroller to estimate dust levels in the air. The DSM501A sensor is suitable for environmental monitoring applications due to its ability to detect fine particulate matter over a practical concentration range. In this project, the DSM501A sensor enables continuous monitoring of airborne particles and supports the detection of unhealthy air quality conditions caused by dust pollution.

B. *Software Requirements*

Arduino Integrated Development Environment (IDE):
It is employed for the development and deployment of embedded C/C++ firmware for the ESP32 microcontroller. The Arduino IDE provides a user-friendly platform for integrating sensor drivers, Wi-Fi communication libraries, and MQTT client protocols required for the air quality monitoring system. It supports the necessary libraries for interfacing MQ-series gas sensors, the DSM501A dust sensor, and the DHT22 temperature–humidity sensor. Moreover, the IDE's serial monitor facilitates real-time debugging, sensor calibration, and performance analysis of the environmental monitoring system.

MQTT Protocol and Broker: MQTT is a lightweight publish–subscribe messaging protocol used for real-time data communication between the ESP32 device and remote monitoring interfaces. In the proposed system, the ESP32 acts as an MQTT client that publishes environmental sensor data such as gas concentration, dust level, temperature, and humidity to predefined topics. The MQTT broker manages message distribution to subscribed clients including the Node-RED dashboard and mobile application. The protocol ensures efficient bandwidth usage, low latency communication, and reliable data transmission suitable for IoT-based environmental monitoring.

Node-RED Dashboard: Node-RED is a flow-based IoT development tool used for data visualization and monitoring. It subscribes to MQTT topics published by the ESP32 and displays real-time air quality parameters through graphical elements such as gauges, charts, and indicators. The dashboard also implements threshold-based logic to generate warning notifications when pollutant levels exceed safe limits. Its web-based interface enables remote monitoring from any connected device, making it suitable for continuous environmental assessment applications.

Android Mobile Application: An Android-based monitoring interface is used to provide portable and user-friendly access to air quality data. The mobile application subscribes to MQTT data streams or dashboard services to display real-time environmental parameters and alert notifications. When pollutant gas concentration or particulate levels exceed predefined thresholds, the application provides instant user alerts, enabling timely awareness of hazardous air conditions.

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The mobile interface enhances accessibility and supports remote environmental monitoring in smart home and urban sensing scenarios.

VI. RESULTS AND DISCUSSION

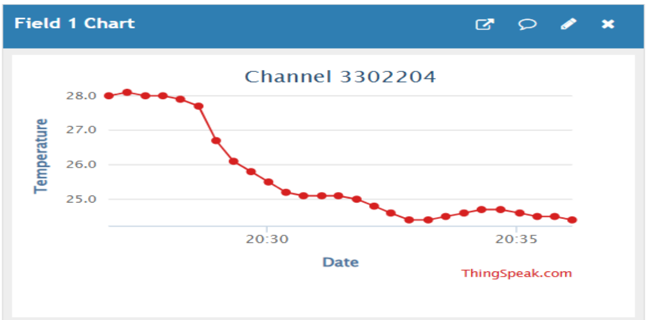

Fig 7. Temperature Readings

The temperature initially recorded was high (~28°C), then gradually decreased and stabilized around 24–25°C. This indicates environmental cooling over time and shows that the sensor is successfully capturing real-time environmental changes. The stabilization phase indicates consistent environmental conditions and proper sensor functioning.

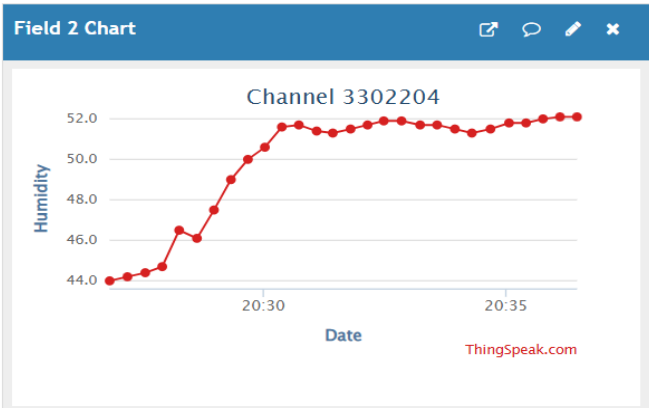

Fig 8. Humidity Readings

The humidity initially recorded was around 44% and gradually increased to about 52%, after which it stabilized. The increase in humidity corresponds with the decrease in temperature observed earlier, showing an inverse relationship between temperature and relative humidity. This demonstrates that the system is effectively monitoring environmental parameters in real time.

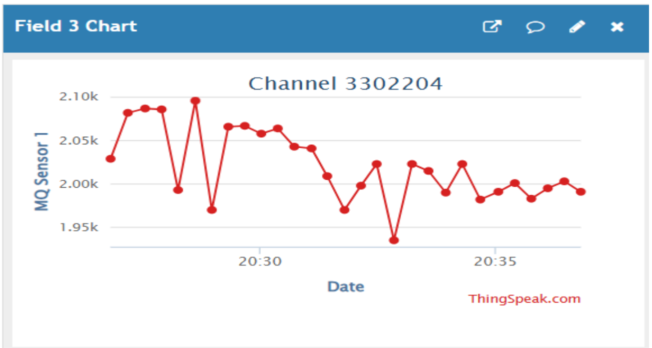

Fig 9: Gas Variation readings

The MQ sensor readings show fluctuations between 1950 and 2100, indicating variations in gas concentration in the environment. Gas sensor readings typically fluctuate due to changes in air composition, airflow, and nearby pollutant sources. The graph demonstrates that the system is capable of detecting changes in air quality in real time.

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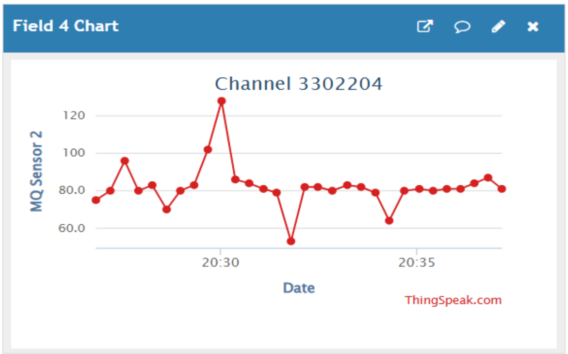

Fig 10: Gas particles reading

The MQ sensor 2 readings mostly remain in the range of 75–85, indicating normal air quality conditions. A sudden spike to around 125 indicates a temporary increase in gas particles or pollutants in the air, while a sudden drop indicates cleaner air or airflow changes. Sudden peaks in MQ sensor readings indicate the presence of pollutants such as smoke or harmful gases, while stable readings indicate normal air conditions.

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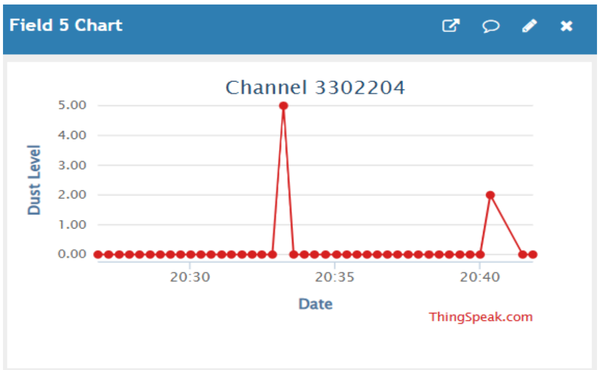

Fig 11: Dust level Readings

The dust sensor readings show that the dust level remained at 0 for most of the time, indicating clean air conditions. However, sudden spikes were observed, indicating the presence of dust or particulate matter in the air. Sudden spikes in dust sensor readings indicate particulate matter events, which are important for air quality monitoring because particulate matter can affect human health.

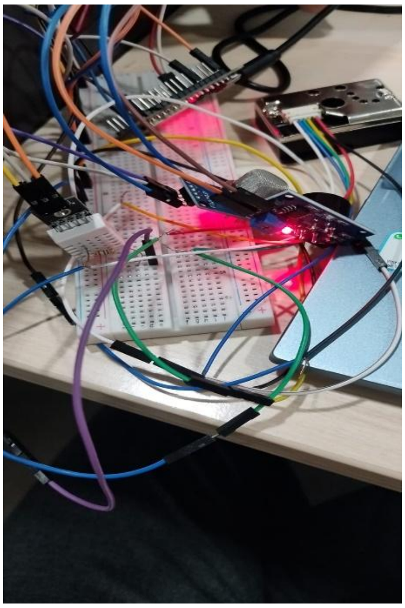

Fig 12: Hardware Implementation

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The ESP32 microcontroller collects data from the DHT22 temperature and humidity sensor, MQ gas sensors, and dust sensor. The sensor data is processed by the ESP32 and transmitted to the ThingSpeak cloud platform via WiFi. The data is then visualized in the form of graphs for real-time air quality monitoring. The hardware components are connected using a breadboard and jumper wires for prototyping purposes.

VII. CONCLUSION AND FUTURE SCOPE

This paper presented an IoT-based air quality monitoring and alert system using an ESP32 microcontroller and multiple environmental sensors for real-time monitoring of air pollution parameters. The proposed system integrates MQ-7 and MQ-135 gas sensors, a DSM501A dust sensor, and a DHT22 temperature–humidity sensor to measure carbon monoxide concentration, overall air quality, particulate matter levels, temperature, and humidity. The sensed data are processed locally by the ESP32 and transmitted via the MQTT protocol to a Node-RED dashboard and mobile interface for remote visualization and user notification. The system generates alerts when pollutant levels exceed predefined safety thresholds, enabling timely awareness of hazardous environmental conditions. The developed prototype demonstrates an efficient, low-cost, and scalable solution for continuous indoor and outdoor air quality monitoring.

The proposed system can be further enhanced by incorporating calibrated air quality index (AQI) computation models to improve the accuracy and interpretability of pollution assessment under varying environmental conditions. Future work may include the integration of additional environmental sensors for monitoring gases such as CO_2 and volatile organic compounds (VOCs), enabling more comprehensive air quality analysis. The inclusion of cloud-based data storage and analytics can support long-term environmental trend analysis and predictive air quality assessment. Furthermore, the development of a dedicated mobile application with advanced visualization and alert customization features can improve user interaction and accessibility. Energy-efficient hardware design and battery-powered operation can also be explored to enable portable and large-scale deployment in smart city and environmental monitoring applications.

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