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An IoT-Based Air Quality Monitoring System Using Arduino for Healthy Environment

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ABSTRACT: *Air quality deterioration poses serious health and environmental challenges worldwide. To tackle this, an IoT-based air quality monitoring system using Arduino technology has been developed to deliver real-time data on air pollutants, promoting healthier environments. The system integrates various sensors, including those for CO2, CO, NO2, particulate matter, temperature, and humidity, all connected to an Arduino microcontroller. These sensors continuously collect air quality data, which is processed and transmitted to a centralized cloud server via Wi-Fi and LoRa modules. Key features include real-time monitoring, cloud-based analytics, scalability for adding sensors, and affordability due to cost-effective components. The system's development involves programming sensor modules, integrating them with the Arduino board, and ensuring reliable data transmission. Preliminary tests demonstrate the prototype's effectiveness in detecting and reporting air quality metrics. Future upgrades will focus on improving sensor accuracy, enhancing network capacity, and incorporating machine learning for predictive analytics. This system provides actionable insights, enabling individuals, communities, and policymakers to make informed decisions to combat air pollution and safeguard public health.*

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I. INTRODUCTION

Air pollution has emerged as an issue in times driven by rapid industrialization, urbanization and the growing number of vehicles, on the road. The rise in pollution levels poses a threat to health causing various respiratory illnesses, heart problems and overall impacting the quality of life. The existing air quality monitoring systems are outdated and expensive in developing areas where continuous monitoring's crucial [1-3]. Fortunately, advancements in Internet of Things (IoT) technology offer possibilities for accessible and scalable solutions. Through technology, networks of sensors enable time monitoring and data collection, paving the way for large-scale air quality assessment systems worldwide [4,5]. Leveraging platforms, like Arduino, opens up options to deploy monitoring systems effectively. It supports a wide range of sensors and modules, making it an ideal choice for integrating various environmental sensors [6]. This background study explores the necessity and feasibility of developing an IoT-based air quality monitoring system using Arduino, highlighting its potential to deliver timely and accurate air quality data [7-9]. This data can empower individuals, communities, and policymakers to take proactive measures in improving air quality and safeguarding public health. The air quality monitoring collects data regarding the current state of level air quality in a particular region and makes forecasts regarding the air quality conditions in a particular area to give warning.

Collecting data and providing notification alerts in an air quality monitoring project are essential components for effectively managing and mitigating air pollution. Continuous data collection allows for real-time monitoring of air quality, capturing variations in pollutant levels and identifying pollution sources. This data is critical for understanding trends, assessing the effectiveness of pollution control measures, and conducting health risk assessments [10]. Notification alerts play a vital role by providing immediate warnings when pollutant levels exceed safe thresholds, enabling timely interventions to protect public health. These alerts can inform individuals, especially vulnerable populations, to take precautionary measures, such as staying indoors or wearing masks. Additionally, alerts can prompt authorities to implement emergency response actions, such as traffic restrictions or industrial activity limitations. Integrating data collection and notification systems into an IoT-based air quality monitoring framework, particularly using Arduino technology, enhances the accessibility and responsiveness of air quality management [11]. This integrated approach ensures that accurate, up-to-date information is available to both the public and policymakers, fostering a proactive stance in maintaining healthy air quality and safeguarding environmental and public health [12].

II. METHDOLOGY

The IoT-based air quality monitoring system integrates multiple sensors, a microcontroller, and communication modules to collect, process, and transmit environmental data. The hardware includes an Arduino ESP32 microcontroller, MQ7 and MQ135 sensors for detecting carbon monoxide (CO), carbon dioxide (CO_2), ammonia, benzene, and smoke, and a DHT22 sensor for measuring temperature and humidity. A LoRa module ensures long-range, low-power communication, making the system ideal for remote monitoring. The software framework utilizes the Arduino IDE for programming, the Blynk App for real-time visualization and control, and the ThingSpeak platform for cloud-based analytics and long-term data storage. In the workflow, sensors continuously measure air quality parameters and send data to the ESP32 microcontroller, which processes and transmits the information to cloud servers or displays it locally on an LCD. Alerts are generated via the Blynk app and Telegram if pollutant levels exceed predefined thresholds. Historical data is stored on the ThingSpeak platform for further analysis and trend prediction. The experimental setup for the IoT-based air quality monitoring system was designed to efficiently collect and transmit data on air pollutants and environmental conditions. Fig. 1 illustrates the block diagram of the system, which outlines the integration of sensors (MQ135, MQ7, DHT22) with the ESP32 microcontroller and LoRa modules for data transmission. Figures 3 and 4 provide detailed images of the transmitter and receiver modules, showcasing the placement and connections of components like the sensors, breadboard, and communication modules. Table 1 is the list component that used in this system.

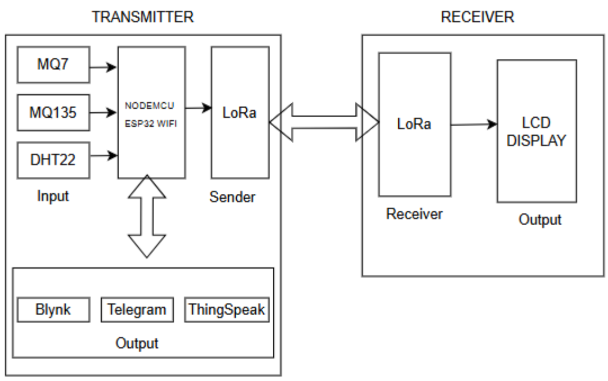

Fig. 1 Block diagram of the IoT-Air Quality Monitoring system

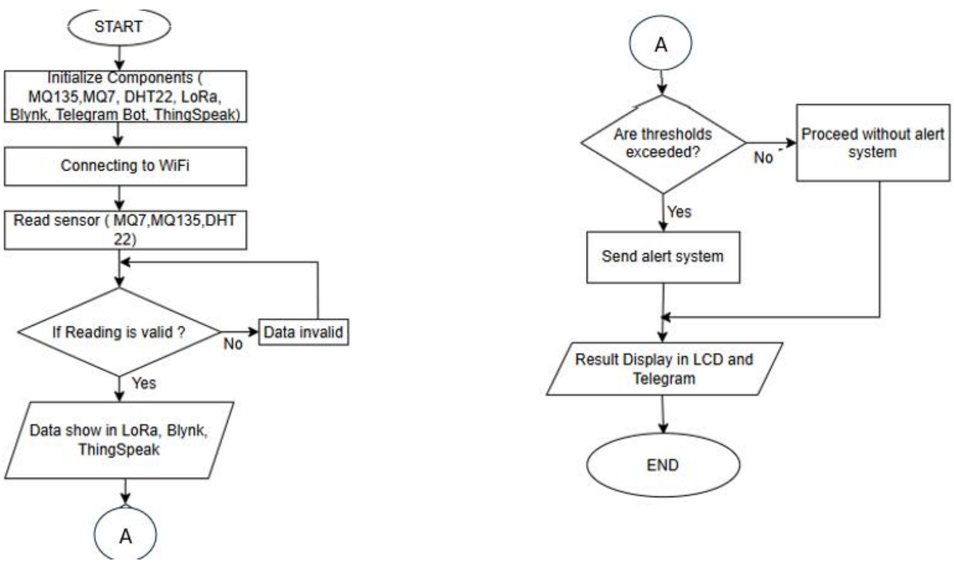

Fig. 2 Flow chart system IoT Air Quality Monitoring system

Table 1: List of the components in this system

No	Components Required	Quantity
1	Breadboard	1
2	MQ 7	1
3	MQ 135	1
4	DHT22	1
5	LoRa	2
6	NodeMCU ESP32 WiFI	1
7	Wire	As per requirement

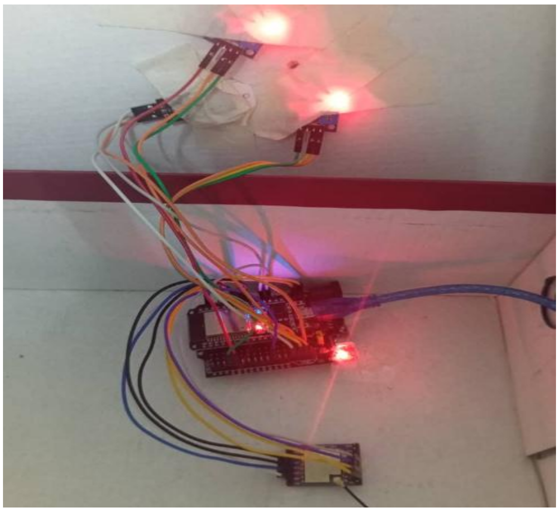

Fig. 3 Transmitter

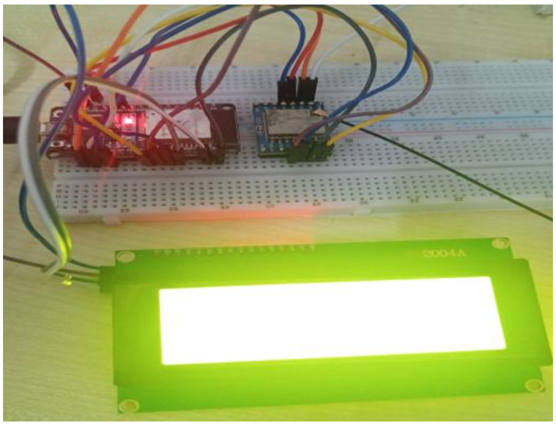

Fig. 4 Receiver

The integration of software tools such as Arduino, ThingSpeak, Blynk, LoRa, and Telegram plays a crucial role in ensuring seamless communication, real-time data visualization, and user notifications in the IoT-based air quality monitoring system. Each software component interacts harmoniously to deliver an efficient and user-friendly monitoring experience.

The Arduino IDE is the primary development platform used to program the ESP32 microcontroller. It enables the configuration and control of sensors (MQ135, MQ7, and DHT22) and communication modules (LoRa). The microcontroller collects data from the sensors, processes it, and prepares it for transmission via LoRa and Wi-Fi. Custom libraries for LoRa, ThingSpeak, and Telegram are integrated into the code to establish communication and functionality.

LoRa facilitates the transmission of environmental data collected by sensors over long distances to a central gateway. The gateway receives these packets and processes the data for onward transmission to cloud platforms. LoRa's low-power consumption ensures reliable and efficient data transfer, even in remote areas.

ThingSpeak serves as a cloud-based platform for data storage, analysis, and visualization. The ESP32 sends processed data to ThingSpeak via HTTP requests over Wi-Fi. ThingSpeak's built-in tools enable users to visualize air quality metrics such as CO levels, temperature, and humidity through real-time graphs and historical data charts.

Blynk provides a mobile-friendly interface for real-time data visualization and remote monitoring. Data sent to ThingSpeak is mirrored on Blynk, offering users instant access to key air quality parameters. The Blynk app also provides real-time alerts and notifications when pollutant levels exceed predefined thresholds. Users can customize dashboards within the app to display parameters such as CO concentration, temperature, and humidity.

Telegram is used to deliver critical notifications to users in real-time. Using the Telegram Bot API, the ESP32 is programmed to send alert messages when sensor readings surpass safe thresholds. For instance, a sudden spike in CO levels triggers an alert via Telegram, ensuring users can take immediate action to mitigate risks.

III. RESULTS AND DISCUSSION

The IoT-based air quality monitoring system effectively tracked and analyzed environmental parameters such as temperature, humidity, CO levels, and air quality. The system demonstrated its ability to provide real-time alerts via Telegram when thresholds were exceeded, as seen in the notifications where temperature ranged between 28.6°C to 29.0°C, humidity levels varied from 75.5% to 76.5%, and air quality fluctuated between 52 PPM and 62 PPM.

The ThingSpeak data visualizations further illustrated trends over time, with humidity steadily increasing to around 29.2% and temperature rising from 72°C to 78°C. CO levels, initially stable at 0 PPM, showed a sharp spike to 40 PPM, suggesting a sudden localized event affecting air quality. Similarly, the air quality index displayed dynamic changes, dropping to 10 PPM before climbing to 40 PPM. These observations confirm the system's ability to detect and notify users of changing environmental conditions promptly, allowing for timely interventions. The results highlight the reliability and precision of the sensors, with consistent performance for temperature and humidity readings, though occasional network delays during peak transmission periods were noted. Fig.5 shows the visualization result from ThinkSpeak.

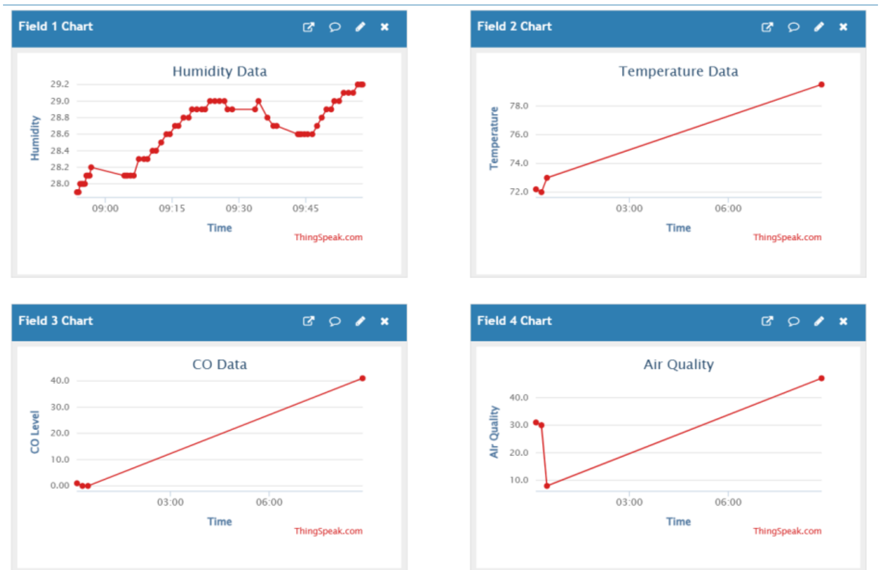

Fig. 5 Data visualizations from ThinkSpeak

Fig. 6 Telegram notification for user alert

Fig. 7 User interface dashboard in Blynk apps

Fig. 8 Transmitter data to receiver

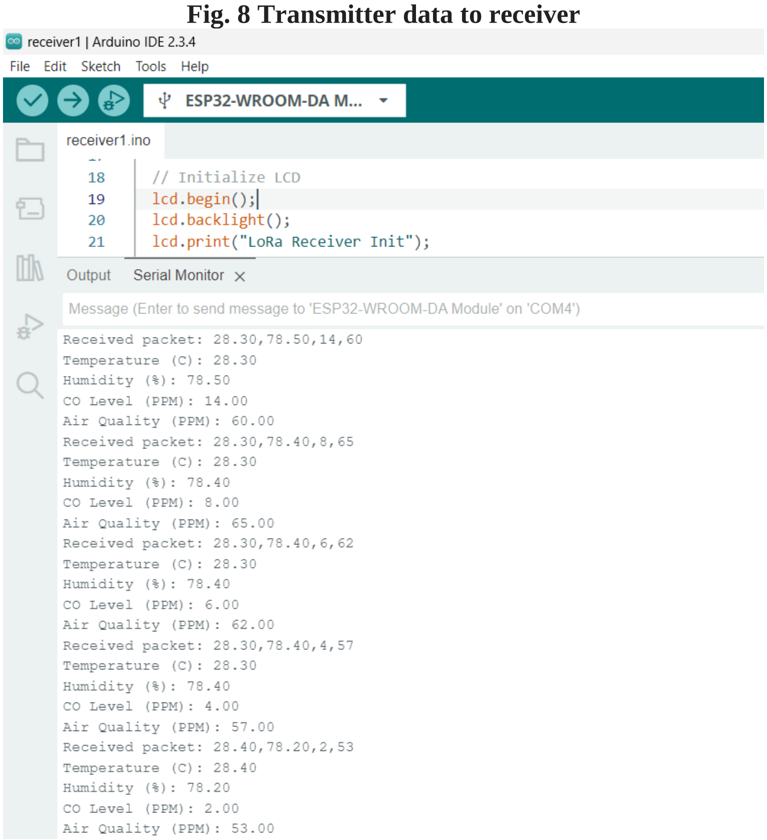

Fig. 9 Receiver data from transmitter

IV. CONCLUSION

The IoT-based air quality monitoring system using Arduino demonstrated its capability to provide real-time monitoring of key environmental parameters such as CO, CO2, and temperature. By integrating sensors like MQ135, MQ7, and DHT22 with an ESP32 microcontroller and leveraging IoT platforms, the system effectively tracked air pollutant levels and provided timely alerts. This project highlights the potential of IoT technology in creating cost-effective, scalable solutions for air quality management. It empowers individuals and communities to take proactive measures, ultimately improving public health and environmental sustainability. To enhance the system's effectiveness, several improvements are recommended. First, periodic calibration and integration of more advanced sensors can improve accuracy in detecting pollutants at low concentrations. Second, incorporating predictive analytics through machine learning can help forecast air quality trends and provide actionable insights. Additionally, energy optimization strategies can extend the operational lifespan in remote deployments. Expanding the system to detect other critical pollutants, such as NOx, SO2, and ozone, would increase its comprehensiveness.

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