DEVELOPMENT OF IoT-BASED AIR QUALITY MONITORING SYSTEM FOR ENVIRONMENTAL SUSTAINABILITY

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Abstract

Internet of Things (IoT) solution type in the form of an air quality monitoring system, whose primary goal is to provide accurate, real-time measurements of air pollution levels, which are crucial for urban planning and public health protection. Air pollution is a serious environmental problem that jeopardises sustainable development and causes serious health hazards. Important sensors, such as the DHT22, which measures both temperature and humidity, the MQ-9, used to detect carbon monoxide, and the MQ-135, used to measure combustible gases. An I2C LCD is used to display the result. A system for monitoring and analysing major air pollutants in real time was created using the Internet of Things (IoT) in order to solve this problem. The system collects data using a microcontroller (ESP8266) that is interfaced with a collection of gas sensors, including those for CO_2, CO, and combustible gases. The gathered sensor data is sent to a cloud-based platform over Wireless Fidelity (Wi-Fi), allowing for ongoing online access and storage. Through the use of a web interface, users and environmental authorities can remotely monitor air quality levels in real time, via dashboards. PM2.5 concentrations ranged from 10–35 µg/m³ indoors and 18–90 µg/m³ outdoors, according to recorded measurements, while CO2 levels ranged from 420–950 ppm indoors and roughly 400–450 ppm outside. This method makes it easier to make data-driven decisions about public awareness and air quality management. By improving accessibility through cloud storage integration, stakeholders can react more quickly to potentially dangerous situations. The project's success demonstrates how the Internet of Things can promote smart city projects and encourage environmental sustainability.

Keywords
Cloud-based, Air Quality, WiFi, MQ-135, Health Protection

1. INTRODUCTION

These days, the air is highly contaminated. Automobile pollutants, industrial chemicals, smoke, and dust have all become ubiquitous in recent years. Our health is severely harmed by air pollution, particularly in areas where we breathe. Some illnesses, including asthma, coughing, and lung abnormalities, can be brought on by the lungs.

The next technology revolution Internet of Things (IoT), has made all objects intrinsically connected in the last ten years. IoT is nothing more than using networks and sensors to connect computers to the internet. These interconnected parts can be utilised in health monitoring systems. Cloud computing technology was utilised in this study to analyse and store data, while Internet of Things technology was utilised to measure and communicate air quality data. When it comes to minimising environmental issues, IoT technology is quite helpful and effective.

According to the World Health Organisation (WHO) estimates, urban air pollution causes over 2 million deaths annually, and many more have chronic respiratory illnesses. The growth of activities, especially in emerging economies, has caused emissions of pollutants to either stabilise or increase despite the emission control mechanisms put in place in developed countries to minimise air pollution. The air quality from these emission processes and their impact on global weather and climate need to be monitored. The Internet of Things (IoT) can be extremely useful for air quality monitoring. These days, air quality is a big concern that necessitates monitoring of a number of factors. Monitoring environmental conditions and changes requires a workable technical solution. An extremely efficient way to track air quality measurements is using the IoT

[1]. The air is extremely polluted by smoke, dust, industrial chemicals, and vehicle emissions. The public's health is negatively impacted by this pollution, which causes things like asthma and abnormalities of the lungs. Air quality monitoring is essential for public health protection and urban planning, particularly in light of growing industrialisation and urbanisation. The study is justified by the serious health dangers caused by urban air pollution, which is estimated by the WHO to cause over 2 million fatalities each year. Even with control measures in place, emissions are increasing as urban activities grow. In order to monitor pollution levels in real time and facilitate timely response, an Internet of Things (IoT)-based air quality monitoring system is required. This will help to create a more sustainable environment. A method for monitoring air quality based on the Internet of Things is the main topic of this study. It goes over setting up sensors to measure several air quality indices, integrating them with the ESP32 microcontroller, and using cloud services to analyze the results [2]. The scope of the system also includes its suitability for both residential and commercial settings, with the aim of offering a cost-effective and energy-efficient solution. Recent years have seen the development of several health monitoring systems to keep an eye on patients' health. We are examining some current research in this area. In this study, every system has been categorised according to the hardware components' priority, or which parts have been utilised more frequently than the others [3].

The goal of the system's creation was to automatically analyse the surroundings and use intelligent technologies to do so, since we are gradually becoming a more intelligent system. A web portal, a mobile application, and an Internet of Things-based infrastructure for air quality monitoring were made available [4] so that consumers could view the air quality. Numerous sensors that gather information on air quality, including CO_2, CO, smoke, dust, temperature, and humidity, are part of a device being developed dubbed "Smart-Air."

Human senses can't detect air pollution. Smoke, carbon monoxide, methane, LPG gas, and other harmful compounds can all be found in air pollution [5]. [6] created an Internet of Things mobile air pollution monitoring system (IoT-Mobair), which uses gas sensors to predict air pollution. However, the system analysis revealed that the system only looks for gaseous substances, not humidity. The air pollution contains extremely harmful substances. However, the results of the system analysis revealed that the system only checks for gaseous substances, ignoring humidity.

A mobile sensor network and WSN were used by [7] to develop an IoT environmental monitoring application. The system that was created can grow. Thus, new capabilities might be added to the network during runtime. This adaptability can work well in other extremely dynamic IoT settings, such as mobile health, and has previously been demonstrated in AmI applications [8]. This system's computational complexity is a difficulty because of the large amount of data that is recorded. [9] created an environmental monitoring system utilizing IoT protocols and standards. Heterogeneous sensors are a problem for it. Using the Internet of Things [10] created a monitoring system to keep an eye on environmental humidity and dust levels.

The public's health is negatively impacted by this pollution, which causes things like asthma and abnormalities of the lungs. Air quality monitoring is crucial for protecting public health and informing urban planning, particularly in the context of increasing industrialisation and urbanisation. The concept was discovered to be portable, affordable, and effective. However, a crucial aspect of this system is its failure to monitor the presence of gaseous contaminants in the air.

2. MATERIALS AND METHOD

The air quality monitoring system involves an inter-relationship between the ESP32 microcontroller, which serves as the Wireless Fidelity Wi-Fi module or web server. The DHT22 is the sensor responsible for measuring and monitoring the ambient temperature and humidity. The MQ-9 Gas sensor is used to monitor the concentration levels of flammable gases and carbon monoxide. The MQ-135, used to measure combustible gases, is used together with an LCD, which is controlled via I2C. The Powerpack serves as a dependable portable power source to power the system. A heterogeneous sensor infrastructure provides an effective and scalable foundation for this air quality monitoring system, allowing users to track their daily exposure to air pollutants. Sensor readings are sent to a back-end server, which saves the collected data and makes sure it is available, secure, and intact. The server also offers data for several services. The architecture of the IoT-based air quality monitoring system is presented in Figure 1.

In Figure 2, the circuit diagram explains that the ESP32 microcontroller (U2) is the focal point of the Internet of Things-based air quality monitoring system, acting as the setup's central processing unit. The RP2405S voltage regulator module (U7) powers the system by supplying steady +5V and +3.3V outputs needed for the microcontroller, sensors, and display modules. This design makes use of the MQ-5 and MQ-9 gas sensors. The MQ-9 sensor is usually used to detect flammable gases like carbon monoxide and methane, although the MQ-5 sensor can also detect gases, including hydrogen, natural gas, and LPG. Analogue signals representing the concentration of gases in the surrounding air are provided by both sensors.

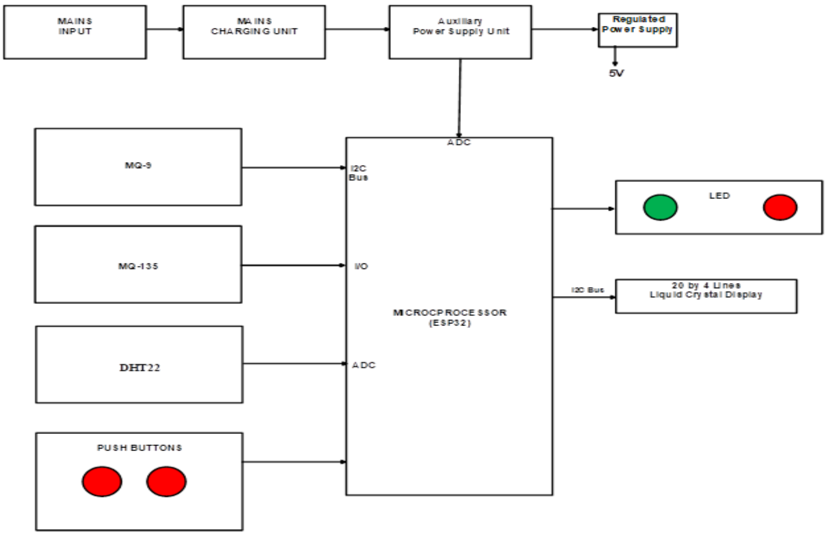

Figure 1: Block Diagram of IoT-Based Air Quality Monitoring System Architecture

The ESP32 receives these signals and processes them to calculate the gas levels in parts per million (PPM) using its ADC pins. The system includes a DHT22 sensor (U6) that detects the ambient temperature and humidity in addition to gas detection. This sensor provides precise environmental readings that supplement the gas concentration measurements by digitally communicating with the ESP32. An I2C interface (U5: PCF8574) connects a 20x4 LCD (LCD1) to the system. By enabling the display to be controlled with just two communication lines (SCL and SDA), this module simplifies wiring. Temperature, humidity, gas levels, and the general state of air quality are all displayed in real time on the LCD.

Two LEDs are also used as visual indications. When the air quality falls within acceptable bounds, the green LED (D2) turns on, and when dangerous gas concentrations are found, the red LED (D1) turns on. To ensure dependable functioning and stop excessive current flow. Lastly, the processed data is sent to a cloud-based server by the ESP32 using its Wi-Fi capability. This allows customers to use any internet-enabled device to remotely monitor air quality in real time. Data accessibility, security, and suitability for additional analysis and decision-making are guaranteed by the incorporation of cloud storage.

The circuit offers a complete solution for environmental sustainability by skillfully integrating gas sensing, environmental monitoring, local display, warning mechanisms, and Internet of Things-based data transmission.

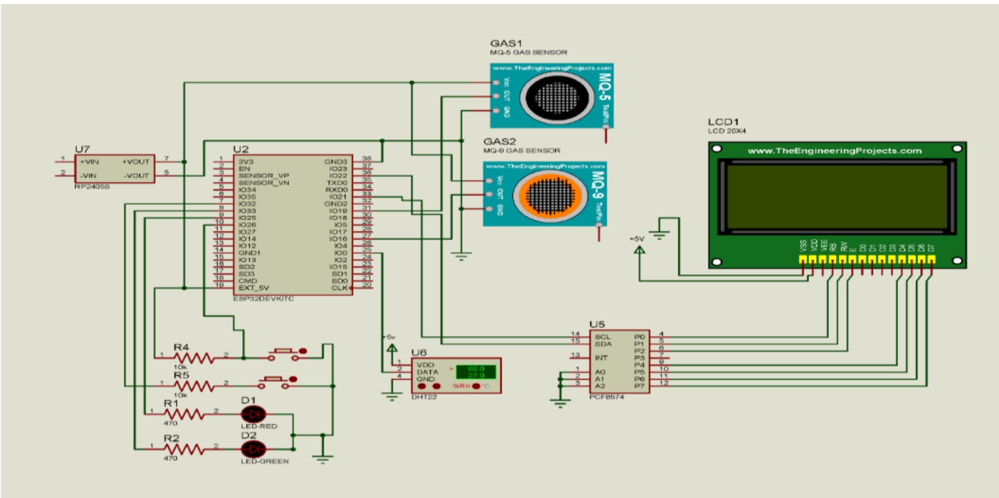

Figure 2: Circuit Diagram of IoT-Based Air Quality Monitoring System

3. RESULTS AND DISCUSSION

Figure 3a shows the complete device used in testing the quality of air in the environment, while not being powered, and Figure 3b shows a relatively powered air quality system. When the green indicator is 'ON', it

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depicts that the air quality in the environment is good but once the red light indicator is 'ON', it depicts poor air quality.

Figure 3a: Complete System (Not Testing)

Figure 3b: Complete System (Testing)

Figure 4 shows the air quality monitoring system results obtained from the cloud server (IP: 192.168.4.1), which shows that gas levels for NH_4, Acetone, Toluene, and CO were all 0.00 PPM, indicating no presence of harmful gases, while the overall air quality status was marked "Good." The atmosphere is well-ventilated because the CO_2 concentration was 400.0 PPM during testing, which is lower than the safety standard of 600.0 PPM. There were no other gases found in the measured area, including NH_4 (0.0 PPM), alcohol (0.0 PPM), acetone (0.0 PPM), or toluene (0.0 PPM). The associated CO status was deemed safe (0.1%) based on the MQ7 Carbon Monoxide sensor's reading of 0.0 PPM.

30.1°C, 66.4% humidity, and 100% light intensity were recorded in the environmental data; these are typical values for tropical indoor and outdoor environments. The system's dependability was confirmed by the battery voltage, which remained steady at 7.60 V. The system threshold for CO_2 was set at 600.0 PPM, allowing the device to trigger alerts once this level is exceeded.

The absence of toluene, acetone, alcohol, and NH_4 suggests that there were no volatile organic compounds (VOCs) present in the monitored environment during the test period. Similarly, the absence of carbon monoxide indicates that no contaminants linked to combustion were present. The system's dependability in evaluating important pollutants that provide significant health hazards is further demonstrated by the CO status of Safe.

The cloud-based result of the air quality that the system detected. The image displays the user interface of the Uni-Osun Air Quality Monitor, showing various sensor readings and system statuses.

The system's capacity to provide precise and consistent data attests to its applicability for real-time air quality monitoring in Nigerian settings. This demonstrates how well the ESP32-based architecture integrates several sensors for applications related to health and safety.

Figure 4: Cloud-based result, Complete System (Result: Good Air Quality)

4. CONCLUSION

The solution of the Internet of Things (IoT) type in the form of an air quality monitoring system, whose major goal will be to provide close real-time measurements of the levels of pollution in the air, which is important for urban planning and protection of public health. This IoT device shows that the air in our environment can be monitored, and it will assist in ensuring the quality of the air is made available. It helps in ensuring a safe environment and maintaining good health in our environment. In conclusion, the urgent demand for real-time pollution monitoring is successfully met by the Internet of Things-based air quality monitoring system. The potential for IoT solutions to improve environmental sustainability is demonstrated by the effective integration of sensors and cloud computing. Future work should focus on expanding the system's capabilities, such as incorporating additional environmental parameters and enhancing data analytics for more comprehensive air quality assessments.

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