Implementation and Measurement of IOT Based Indoor Air Quality Monitoring System

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***Abstract*: The problem of environmental pollution has posed a major challenge to society's growth and human life. Indoor air quality parameters are critical for maintaining a productive and stable atmosphere, but most indoor air quality parameters are well above the healthy threshold. The proposed system consists of a low-cost air quality sensor and an ESP32 controller with a new generation embedded system architecture. Furthermore, the proposed system uses the Blynk IoT platform to provide real-time monitoring of indoor air quality parameters through a mobile user interface. The results from the framework showed that the proposed measurement system, with its low cost, open source technology, ease of implementation, and mobility, can make a major contribution to Ambient Aided Living.**

***Index Terms*: Internet of Things, Indoor Air Quality, ESP-32, Blynk**

I. INTRODUCTION

Air pollution has become a significant environmental issue and a global concern in recent years, exceeding recommended national limits. Air pollution has harmful consequences for human health and habitats, as well as a global warming impact. Depending on where the activities take place, air pollution may be categorized as internal or external [1, 2]. Outdoor air pollution takes place in an open space and affects the whole atmosphere. The key contributors to agricultural and mining outdoor air emissions are fossil fuels used to meet the energy needs of mills, industries, and automobiles. Nitrogen oxides (NOx), nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), hydrocarbons, and particulate matter (PM) in varying particle sizes make up the majority of external air contaminants. Indoor air pollution, which can be detected in offices, hospitals, colleges, libraries, entertainment centers, gymnasiums, public transportation vehicles, and other locations. NOx, SO_2, O_3, CO, carbon dioxide (CO_2), volatile and semi-volatile organic compounds (VOCs), PM, radon, and microorganisms are all major indoor air pollutants. An internationally accepted parameter for measuring air quality is included in the air quality index. Environmental considerations have influenced the market for smart monitoring systems as infrastructure and industrial plants have expanded rapidly.

Internet of Things (IoT) is becoming increasingly common due to its low cost, high performance, and flexibility. The Internet of Things (IoT) enables computers and humans to communicate. It serves as a conduit for human-to-machine communication. Data collectors used to have to travel long distances to different places to collect data, which was then analyzed. This was a long and time-consuming process. However, internet-connected sensors and microcontrollers can now make environmental parameter monitoring more versatile, precise, and time-consuming. A smart environment is created when the environment combines with sensors and devices to self-protect and self-monitor. In the proposed system, Gas sensors, temperature sensor, humidity sensor, Arduino UNO microcontroller and a Wi-Fi module were used to build an IoT package (ESP8266). This device can be mounted in a number of locations to control air pollution in the city. The sensors collect data from the air and send it to the Arduino UNO. The ESP8266 module on the Arduino UNO sends the data to the cloud. Air Pollution Monitoring is an Android-based application that is being developed. Users would be able to access data on air quality through the cloud. If a user is heading to a specific spot, the pollution level of the entire route is predicted using a sensor, and the user is alerted if the pollution level is too high [3-6].

II. PROPOSED SYSTEM

The proposed embedded system would track CO levels in the atmosphere in order to make the environment smarter or more interactive with objects through wireless communication. Figure 1 depicts the proposed model, which is more adaptable and distributive in nature when monitoring environmental parameters. Anyone can use this system to get real-time information about pollution in their region. It is made with an Arduino and a sensor. Specific gas sensors for air and emissions, such as carbon monoxide, carbon dioxide, particulate matter, humidity, and smoke, measure the concentration of each gas separately. Two sensors, namely temperature and smoke sensors, are located for fire detection. When the sensor parameters exceed a threshold value, the Arduino is programmed to trigger the buzzer and LCD which assists the user in monitoring the status [7, 8].

Here, the sensor provides data on the parameters in the area that will be controlled for air quality. Sensor devices with acceptable characteristics and features are managed and controlled based on their sensitivity and sensing range. Between sensing and regulating, behavior will be taken based on the circumstances, such as setting the threshold value, sensing periodicity, messages like alarm, buzzer, or LED, and so on. The parameter threshold values for critical circumstances or normal working conditions are calculated using data analysis conducted in between sensing and regulating behavior, as well as previous experiences. Data collection from sensor devices is also included in decision-making. The sensed data will be processed, stored in the cloud and a trend of the sensed parameters will be displayed in relation to the specified values. Cell phones, PCs, and other devices can be used to access the data.

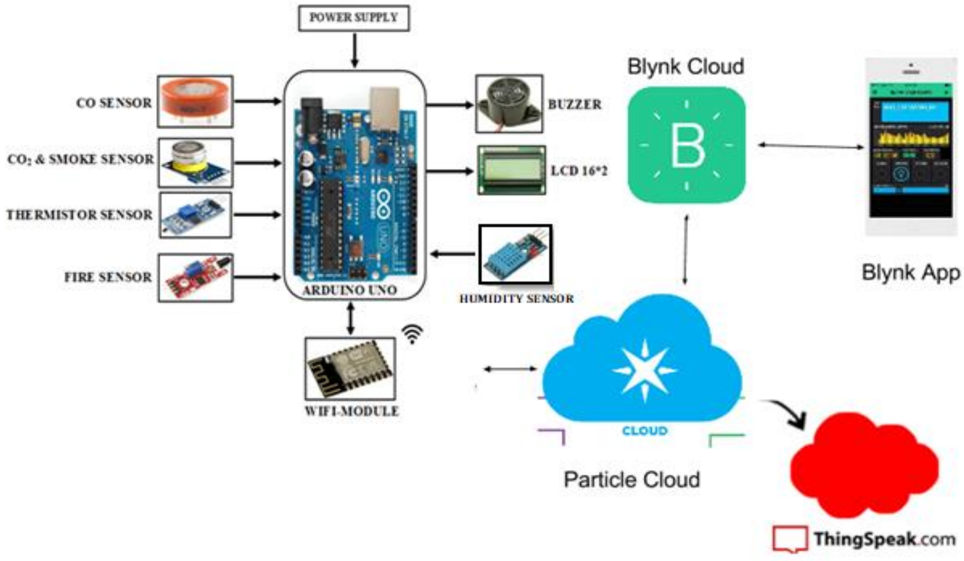

Figure 1. Block Diagram of the proposed IoT based Air Pollution Monitoring System

The framework implementation of the proposed IOT based model is shown in Figure 2 that consists of various sensor devices and other modules. An Arduino UNO board with a Wi-Fi module as an embedded platform for sensing and storing data in the cloud is included in this model. The analog input pins (A_0-A_5), digital output pins (D_0-D_{13}), inbuilt ADC, and Wi-Fi module on the Arduino UNO board link the embedded system to the internet. Sensors are attached to the Arduino UNO board for monitoring; the ADC will convert the sensor reading to a digital value, and the corresponding environmental parameter will be determined from that value. The Wi-Fi link must be developed in order to send sensor data to the end user as well as to cloud storage for later use.

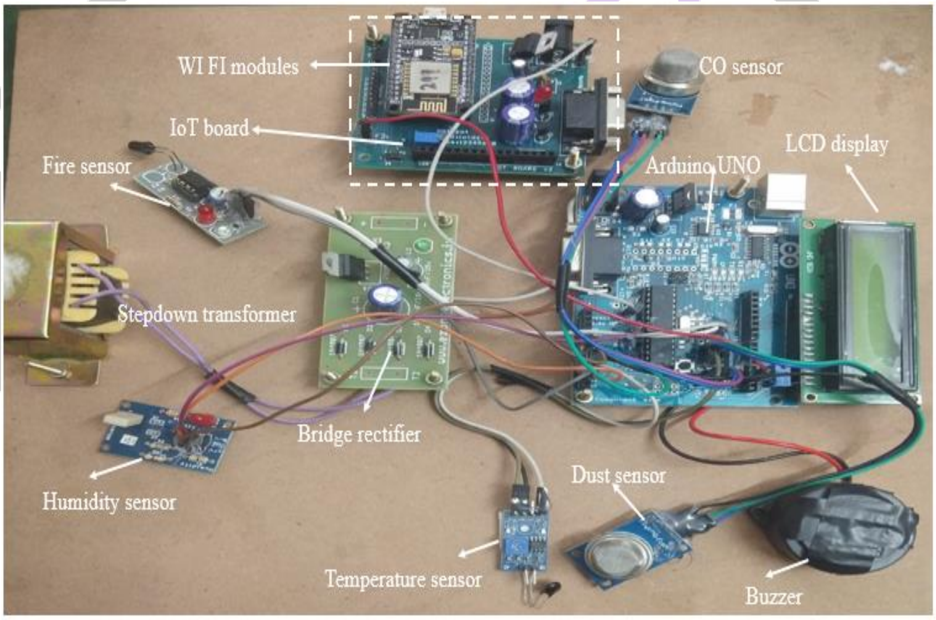

Figure 2. Framework Implementation of the proposed IoT based Air Pollution Monitoring System

The CO sensor, MQ-9 records air quality in that area; if the threshold limit is exceeded, the required regulating action is taken like issuing message alarm or buzzer or LED blink. The Wi-Fi module links all of the sensor devices to the internet. The cloud-based embedded framework with its components for reading and storing emission parameters. The data will be processed and stored in a database after the sensing has been completed successfully. The threshold values will be set for controlling purposes after the data analysis is completed.

CO levels in the air are measured at regular intervals. All of the above data will be stored in the cloud. After collecting data from numerous sensor devices, a proper connection is formed with the server computer, the sensed data will be automatically transmitted to the web server. The data collected would be processed in the cloud. The data stored in the cloud can be used for parameter analysis and continuous monitoring.

III. MEASUREMENT AND MONITORING USING IOT

In light of a household's daily obligations, real-time parameter tracking is extremely advantageous for maintaining an organized and well-informed standard of living. Here, parameters such as gases, dust, room temperatures, and humidity levels that are needed for a comfortable living environment. After sensing, the parameters are sent to the microcontroller. The MQ-2 sensor is a gas sensor that can detect flammable gases like i-butane, LPG, hydrogen, and methane [9]. CO_2, ammonia, nitrogen, oxygen, alcohols, aromatic compounds, sulphide, and smoke are all detected by the MQ-135 gas sensor. This gas sensor's operating voltage ranges from 2.5V to 5.0V. Polluting gases can be found in the atmosphere, but the conductivity of a gas sensor increases as the concentration of polluting gas rises. The MQ-135 gas sensor can be used to detect dangerous gases such as smoke, benzene, steam, and others. It has the ability to detect a variety of dangerous gases.

The ESP8266 module is a Wi-Fi module that serves as the framework's backbone. It is used to bind the microcontroller to an access point in this case (Wi-Fi). This module includes a series of Attention Commands that must be used to configure it. The ESP8266 module is first flashed with software, then set in Wi-Fi mode with Attention Commands, and finally linked to a mobile hotspot or a Wi-Fi. This information stored on the cloud server can be emailed to the customer. The average of 12 measurements taken at 5-second intervals is used to determine the values of climate parameters and gas concentrations. The effect of a fake measurement by the sensors is reduced in this way. The device notifies users when the threshold values for gas concentrations and environment parameters are exceeded.

(a) (b) (c) (d)

Figure 3. Client Interface; a) Numerical display b) Graphical display, c) Setting display, d) Notification screen display

Blynk is a hardware-independent IoT platform that includes custom mobile applications, a private cloud, system management, analytics, and machine learning. The data is stored on the Blynk cloud server without being deleted for up to a year and can be accessed at any time. Figure 3(a, b, and c) shows the front panel views of the mobile user interface created through Blynk. Figure 3(d) depicts the warning message of CO_2 gas concentration exceeding the limit value.

IV. RESULTS AND DISCUSSIONS

Air quality measurements are sent to the cloud server in one minute intervals in the IoT-based proposed system. In the house where the measurements are made, there is no air purification facility. Natural ventilation of the indoor atmosphere is accomplished by manually opening doors and windows. Figures 4, 5, and 6 display the graphs of weekly shifts in climate parameters and gas concentrations.

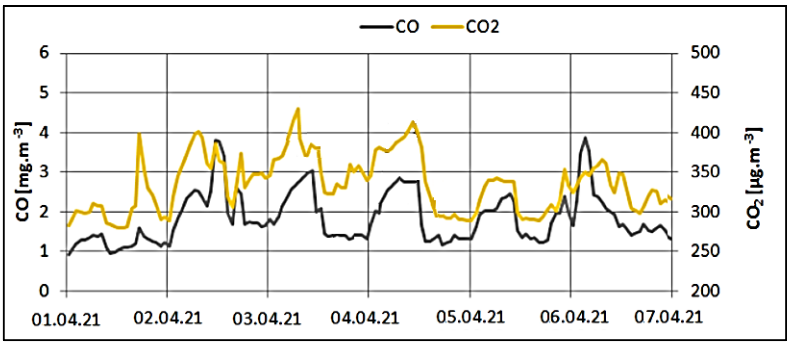

Figure 4. Weekly CO - CO_2 shift graph

Figure 4 depicts the CO-CO_2 weekly shift graph. By looking at the CO graph, it can be seen that the concentration value ranges from 0.9-3.9 mg.m^{-3}. By looking at the CO_2 graph, it can be seen that the concentration of this hazardous gas varies weekly between 275 and 425 µg.m^{-3}. It was witnessed that the concentrations of both gases peaked during the night hours and then steadily decreased during the day due to ventilation.

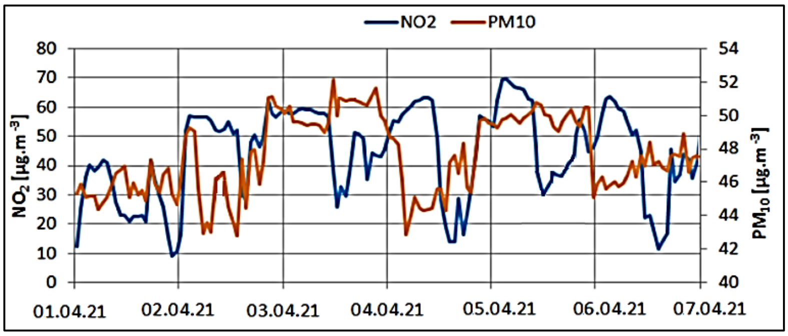

Figure 5. Weekly NO_2-PM_{10} shift graph

The graph of NO_2 and PM_{10} weekly changes is shown in Figure 5. When looking at the one-week change, it can be shown that NO_2 levels fluctuate between 70 µg.m^{-3} and 12 µg.m^{-3} during this period. Particulate matter varied between 30 and 52 µg.m^{-3} over a seven-day period, according to the PM_{10} shift graph.

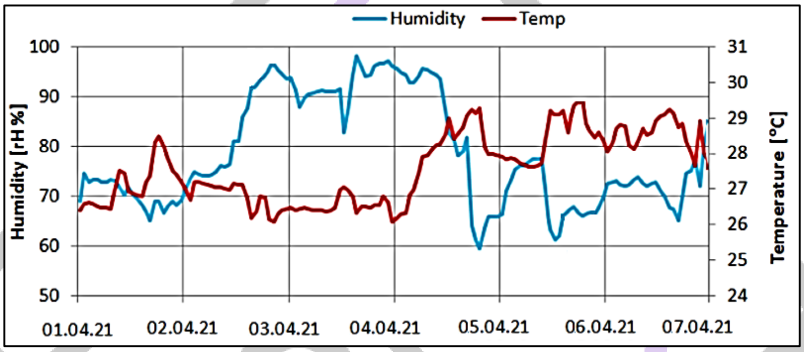

Figure 6. Weekly Temperature-Humidity shift graph.

The weekly shift graph of indoor climate parameters is shown in Figure 6. The temperature varies between 27-30.5°C, and the humidity varies between 68-98%, according to a one-week temperature and humidity shift graph. When examined all the graphs, it is clear that natural ventilation by opening windows and doors in the morning decreases indoor CO, CO_2, and NO_2 concentrations rapidly. When the findings are analyzed, it is clear that indoor air quality varies depending on household activities. The natural ventilation mechanism, as a result of the alerts sent to users through the proposed system, has resulted in substantial improvements in indoor air quality.

V. CONCLUSION

An Ambient Aided Living framework was proposed in this paper as a way to build a safe living atmosphere in smart houses that are part of smart cities. The proposed system is a wireless solution that includes a mobile application, data collection hardware, data consulting, and alerts, and is designed to protect children and the elderly persons from indoor contaminants. The proposed low-cost IoT-based system, which tracks environment parameters such as CO, NO_2, and CO_2 gas concentrations, particulate matter PM_{10}, and temperature-humidity in real time. This system includes five sensors for precise parameter monitoring. The proposed framework uses a smartphone application to warn users about the pollution levels. The programme sends them alerts if the emission level thresholds are exceeded. Indoor air quality is known to fluctuate depending on everyday household activities. Also easy steps like just opening doors and windows to minimize the concentration of toxic gases in the atmosphere will increase indoor air quality significantly.

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