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Air Quality and Carbon Monoxide Monitoring Using IOT-based System

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Abstract: The humans utilize around 95% of indoor air and air quality monitoring is essential for maintaining healthy environment. The Internet of Things (IoT) contributes to facilitate smart and safe lifestyle. The pollution monitoring is essential to avoid exposure to dust particles and harmful gases and minimize its impact on the surrounding environment. The paper presents an effective Air Quality Monitoring System (AQMS) to evaluate temperature, humidity and concentration of gasses like Carbon Dioxide (CO2), Carbon Monoxide (CO) respectively. It consists of Microcontroller (NodeMCU ESP32), Temperature and humidity sensor (DHT-11), Carbon Dioxide sensor (MQ-135), and Carbon Monoxide (MQ-7). Sensors fetch the environmental data and transmit to the Microcontroller (NodeMCU). The microcontroller generates alert for breach in normal concentration of environmental parameters. Moreover, the system is capable to open doors and windows through the servo motor. The model is capable to send information through a wireless link to blynk application. The Test-Driven Development Methodology for Internet of Things-based Systems (TDDMIoTS) and the technologies used to automate the creation of Internet of Things systems have simplified the monitoring mechanism. This system is easy to install in houses, industries and vehicles for protection of humans working as well as living in indoor and outdoor places.

Keywords: Internet of Things; CO; CO2; Air Quality; Pollution; Temperature; Humidity; TDDMIoTs.

1. Introduction

The Internet of Things (IoT) is defined as a network of physical items equipped with sensors, software, and technologies that enable connectivity and sharing through the internet. The sustainable development goals presented by the United Nations in 2015 focused on the achievement of health and well being [1]. A significant role has been played by the internet of things and cloud computing in making life easier and healthier for humans. There are diverse aspects related to the internet of things that prove useful to humans, such as monitoring patient care, smart cities, food supply chains, transportation, agriculture, and geriatric care, all attributed to the internet of things. The most prominent application of the internet of things is the monitoring and management of water and environmental contamination, as it has been utilized to reduce pollution levels [2]. Sustainable Development Goal 3 focuses on the reduction of air pollution, which kills about 7 million people every year, of whom 1.7 million are children. The figures illustrate the significant exposure of humans to the dangerous fine particles as a major threat to their survival [3].

The determination of air pollution has been carried out by the amount of dangerous gases in the atmosphere, such as ammonia (NH3), nitrogen dioxide (NO2), sulfur dioxide (SO2), benzene (C6H6), and airborne particulate matter (PM). In different settings, fossil fuels are used, such as in autos, refineries, thermoelectric power plants, industries, and even domestic appliances like water and electric heaters. The consumption of fossil fuels in these activities resulted in the production of the above stated gases. These gases in sufficiently high quantities resulted in harm to humans and even death [4].

Carbon monoxide is considered one of the most dangerous gases because it is odorless and colorless and does not even irritate the eyes. It is considered a silent killer and most of the individuals fell prey to death by it, especially in areas where the temperature is low and heaters are utilized by people, such as in Argentina and Ecuador [5]. The main source of carbon dioxide is the transport sector, which is powered by fossil fuels and will account for a major portion of sales in 2021. The increase in pollution by transport vehicles is continuously increasing as there is an increase in private service cars, which have an endless lifespan, like in Ecuador. On the other hand, compared to the public sector vehicle, the average lifetime is 15 years or more [6].

The challenges faced by pollutants have become more severe at higher altitudes where the oxygen level is low. Researchers forecast the level of pollution in relation to the number of deaths at the global level by using different sensors, visual perception, and algorithms. These forecasts have been carried out based on the indices revised by the World Health Organization for air quality, as it has been considered a fundamental human right.

In the current research, poisoning from carbon monoxide and carbon dioxide prevention using the internet of things based systems have been presented. The monitoring system for the detection and mitigation of pollution from the environment and fields is the Air Quality Monitoring System (AQMS) [7,8]. The basic purpose of this system is to offer a reasonable solution for pollution, as discussed above. The system can also serve as a verification tool because of the innovative method of IoTS development implementation [9]. The main objectives of this paper are;

- To detect and alert users to potential environmental hazards, emphasizing air quality fluctuations and elevated carbon monoxide concentrations.
- To enable remote monitoring and reporting capabilities to facilitate immediate response, data analysis, and decision-making for authorities and individuals.
- To implement predictive analytics to forecast air quality trends and identify patterns, enabling proactive measures to mitigate pollution risks.2. Materials and Methods

"World's Air Pollution: Real-time Air Quality Index" illustrates the pollution index in major cities of the world to increase awareness among people regarding the impact of air pollution [10]. New suggestions by the World Health Organization have also been presented for the reduction of air pollution such as reducing the particulate matter of 2.5 micrometers or larger, as it is the reason behind several respiratory diseases in humans [11] [23].

The toxicity of combustion gas has also been reduced by the physico-chemical process through which oxygen has been produced in vulnerable locations, particularly indoor locations like households and businesses [12]. Real-time monitoring of air quality has been provided by a mobile device known as an E-nose. Different air factors are measured by the device, such as CO2, NO2, PM10, temperature, and humidity [13,14]. Low-cost sensors have been used, which provide alerts on the mobile application through the LCD. The Raspberry Pi has been connected to the internet through a wireless connection, which provides data for web applications. It is considered more expensive but it can increase the capability of the system [15] [25].

Another open multi-sensor platform, AirSensEUR, has been developed for monitoring pollution by the plug-and-play interoperable sensor node. It costs around $1000 but a variety of indicators are monitored by it, such as CO2 and PM2.5 [16,17]. The level of air pollution inside the building has been measured by iAir, which allows a manager to query about the unhealthiness level and also provides alerts through the smartphone app. However, there is no method available to educate building occupants about the pollution level in the environment [18,19].

There is no technique for improving the air quality, as all of the above systems only examine the air quality. Furthermore, there is no other way of communicating except through mobile apps so the end user is not warned by systems. In a crisis situation, email notification is found to be ineffective. The costs of the above stated method are high as well [20] [22].

2. Proposed System

Real time quality report for both indoor and outdoor air has been provided by continuous gas concentration detection through AQMS. Reporting incorporated the historical data queries as the current gas measurement to provide a more effective evaluation. The concentration of CO is presented on LCD screen through this system. There are different ways in which end users are warned about pollution levels, as illustrated in Table 1, which shows three levels of pollution in the air:

Table 1. Air Quality Level

Level	Quality	Concentration (ppm)	Notifications (Light)	Actions
1	Good	≤500	Green	No action Required
2	Moderate	(500, 750)	Blue	Low sound Produced
3	Low	(750 >)	Red	Notification on App

Detection of gasses by AQMS is an IoTS that utilizes less energy and detects gasses that are produced from indoor, water heaters, and other gas-emitting devices.

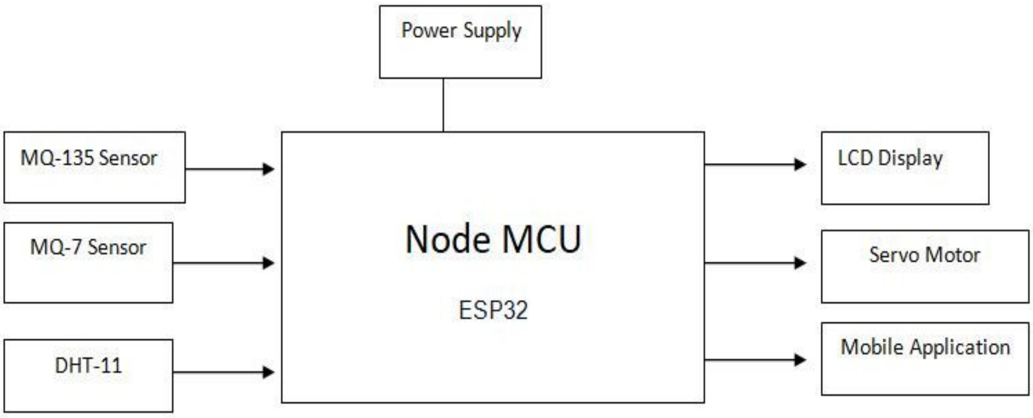

Figure 1. Air Quality Monitoring System Workflow

The current project has been simplified and made easier by categorizing it in different sections. Hardware, databases, mobile applications, graphical user interfaces, and internet of things are deployed to balance themes [24] [27]. Verification has been carried out by the real time user for the functional and nonfunctional requirements for the creation of AQMS.

2.1. Criteria of AQMS

The following criteria for AQMS were decided upon:

- Detection of dangerous gases, like carbon monoxide, and carbon dioxide, and also temperature and humidity.
- The use of mobile app and buzzers for warning.
- Opening of Windows by service motor in emergency case
- Resulting in the identified gases being released into the surrounding environment or vented to the outside of the building or vehicle.

2.2. Design of the Technological Layer

Mobile applications is utilized for user interaction as they are at the top of the stack. Different components, such as sensors and microcontrollers, are included in the physical and preprocessing layers shown in figure 2. Monitoring the surrounding environment and regulating it have been carried out by this layer. The real time data has been displayed in mobile application.

AQMS gadget is shown in Figure 3. It displays the device's physical layer design to detect air quality, inform user and monitor the air quality. Components of AQMS;

- Arduino UNO board is installed to get MQ135, MQ7, and DHT-11 sensor data.
- A buzzer is used for sound alerts.
- LEDs for indication.
- The Servo motor is used to open the windows in case of emergency.
- DHT11 sensor to measure the temperature and humidity level.

- MQ135 sensor is used to detect CO2 and MQ7 is used to Detect CO.

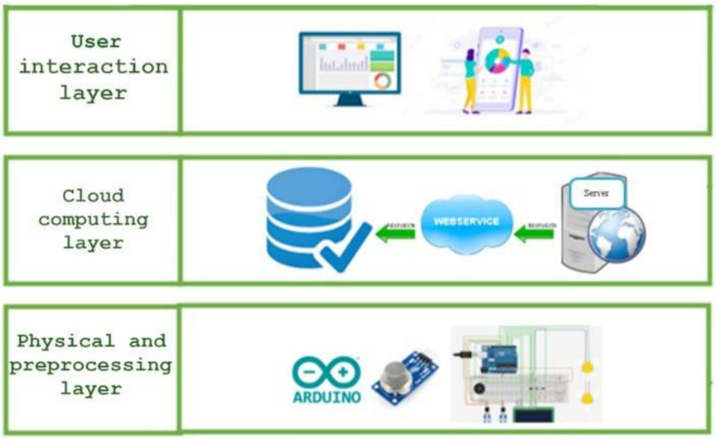

Figure 2. Air Quality Monitoring System Architecture

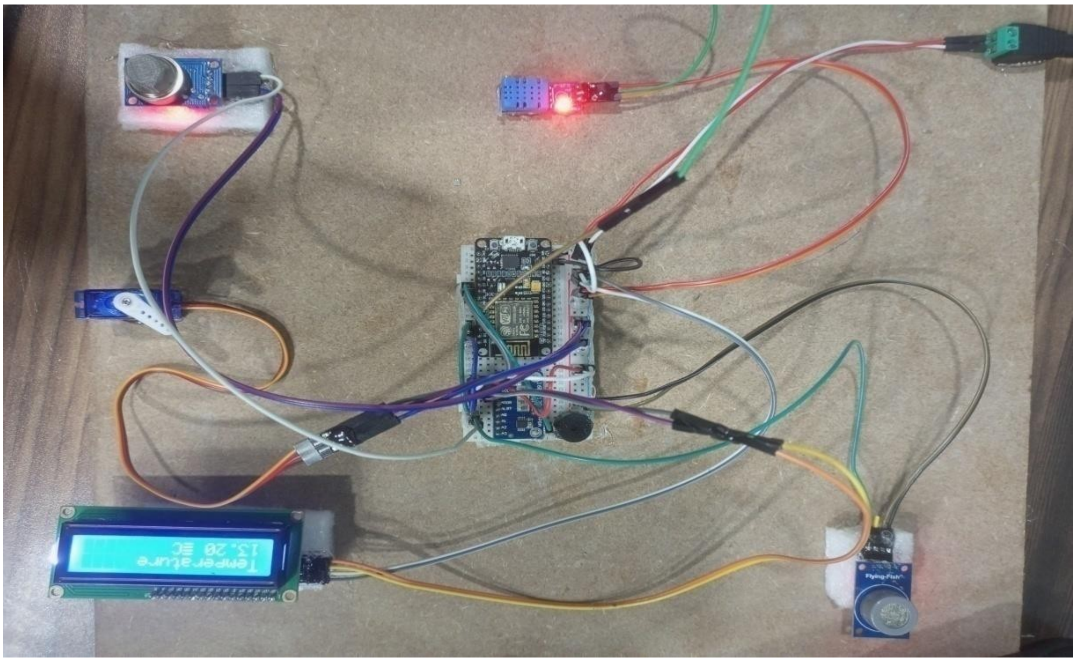

Figure 3. Environment Air Quality Monitoring System

In the first iteration of the AQMS development process, basic analysis and the design of the technology layer were completed. This method began with predetermined criteria already in place. Users participated actively in this step to ensure that the design of the system met their needs and expectations [21] [26].

MQ135, MQ7, sensors detect gases, and DTH-11 sensor measures the temperature and humidity, sending them to the mobile app using ESP8266. If the internet is unavailable, the system issues notifications and makes choices locally to maintain air quality. The Components used in this project are given below in Table 2.

Table 2. Hardware components used in this project

Requirements	**Components**	**Function**
Data Acquisition	NodeMCU ESP32	Wi-Fi data connection and development board for sensor control.
Open the Window	Servo Motor	Use to open and close the window
Text Display	LCD16x2 iC2	Used to display the real-time results on screen.
CO detection	MQ7	Detect the CO in PPM

CO_2 detection	MQ135	Detect the CO_2
Sound Notification	Buzzer	Produce the alert
Converter	ADS	Increase the Analog Pins

2.3. Hardware and Software Deployment

The AQMS gadget is used in a room mock-up throughout the system's prototyping process. The servo motors were not powerful enough to open and close the window. In addition, the mobile app makes it possible to register the AQMS device (or devices) fx`x`xor real-time data monitoring and to receive notifications when gas levels are at unsafe levels for human health. It also makes it possible to carry out routine tasks such as registering as a user, logging in, reporting data captured, and viewing information about the system.

3. Results

AQMS records the concentrations of gases like CO_2 968PPM, CO 594PPM, temperature 10.8 degrees cen- tigrade, and humidity level of 77.40%. The data is displayed on the LCD and Bylnk App. Figure 4 displays the concentration level of CO and CO.

Figure 4. CO_2 and CO Concentration Level

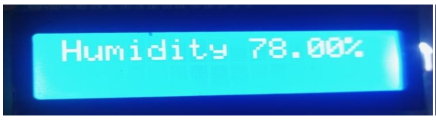

Figure 5. Humidity Level **Figure 6.** Temperature

Figure 5 shows the humidity level in percentage and Figure 6 shows the temperature in degrees centi grade. Blynk App is used to show the result on mobile. In Figure 7 (a) to log-in to the AQMS unique ID is re- quired and the user also creates its new ID (b) device connection setting menu allows the user to connect with the micro controller via wifi(c) real-time Data monitoring Bar shows actual results. It refreshes the results after the fixed interval.

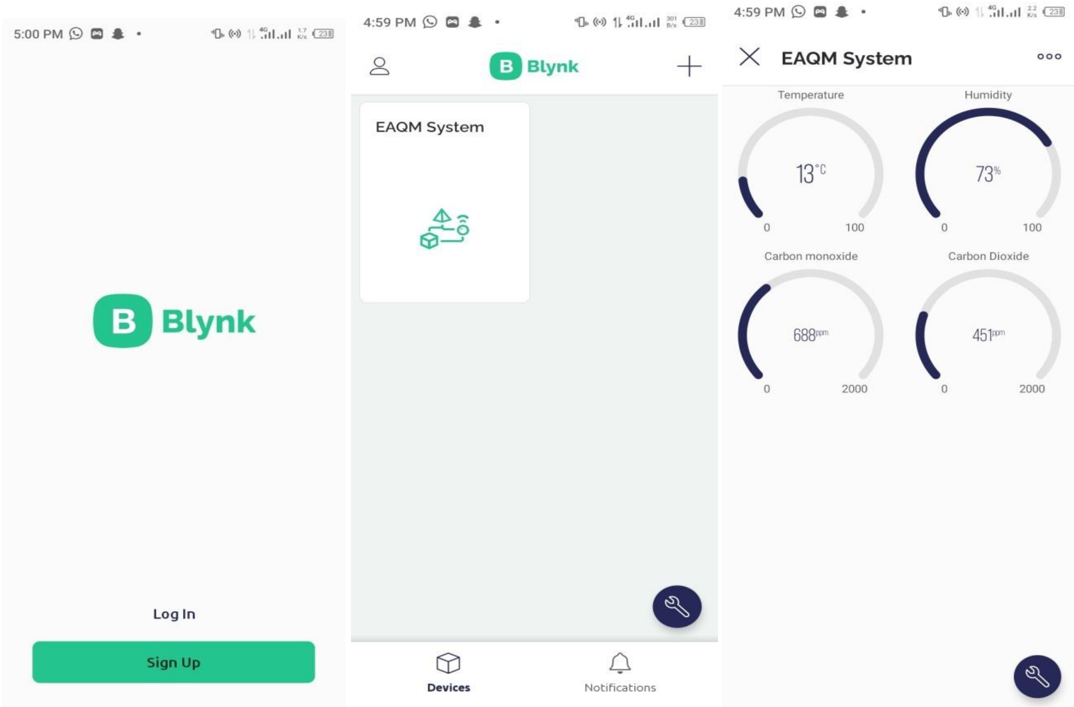

Figure 7. Mobile Application on Display (signup; device connection; Real time data)

4. Discussion

AQMS has unique attributes that distinguish it from conventional air quality management systems. It is cost-effective, and capability to detect temperature, humidity, and concentration of CO, CO2, and energy efficiency. The assessment of the AQMS indicates that it may be liked by those who are likely to use it. Users perceived auditory and visual alerts in the room about the levels of toxic substances in the air to be more practical and efficient compared to receiving notifications on their mobile devices. Various modalities, including auditory, visual, and textual cues, are used to notify diverse users about alerts, since some individuals may possess special requirements. The form of the device should be altered to enable its manufacturing on a large-scale assembly line. There is a possibility that this kind of redesign might further reduce the final cost.

There are very few Internet of Things development strategies that span all stages, and TDDM4IoTS is one such way. On the other hand, TDDM4IoTS defines environment analysis, whereas other systems leave it up to the developers. Being based on Test Driven Development (TDD) makes it possible for the final product to satisfy the requirements of the end-user and to undergo systematic code testing.

Finally, TDDM4IoTS should be applied to more case studies by other developers to get more feedback and see if the methodology can be improved to better cover specific development scenarios.

5. Conclusion

The AQMS system is a low-cost and energy-efficient method of evaluating the quality of the air within a building, house, or vehicle. It generates alert for potentially hazardous environmental parameters. The indoor and outdoor monitoring is carried out by the proposed system as it has been tested several times for calculating the results of temperature, humidity and concentration of carbon monoxide and carbon di-oxide and successful throw out. It consists of an IoTs-based system capable of measuring the air quality and displays the notification on LCD and Mobile Applications. The real-time data monitoring is done through the mobile app. The proposed solution is around ten percent overall cost of the existing air quality monitoring systems that have equivalent features; however, these systems do not include all of the capabilities that IoT possesses.

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