An IoT-Based Alarm Air Quality Monitoring System

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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, NodeMCU, 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.

1. Introduction

Every South-East Asia country will experience and face a seasoning haze issue that is caused by forest fire. The seasoning haze which is also known as Southeast Asian haze occurs every year. An open fire-related large-scale air pollution problem occurs regularly between July and October, for example Southeast Asian haze [1-2]. During this period, it was the worst case for the air pollution until the air quality falls to an unhealthy and danger level for human health. The main factor that caused this haze is illegal agricultural fires due to industrial-scale slash-and-burn practices in Indonesia, especially from Kalimantan on Indonesian Borneo and the provinces of South Sumatra and Riau in Indonesia's Sumatra
Island. This open burning on the agricultural land will raise the price of the burned land and burned land will be sold at higher price illegally. This open burning process is cheapest and fastest process for agricultural production if compared to cutting or clearing the plantation using excavators. Nevertheless, it is causing a major air pollution [3-5].

In order to monitor the air pollution, the Air Quality Monitoring System (AQMS) is developed to measure concentration of air pollutants such as NO2, CO, SO2, THC and O3), particulate matters, wind speed, direction and other weather parameters continuously all year round. Mobile AQMS can also be customized to monitor multiple sites via one system for example phone or Android app. All the data that measured by the system can be exported in various formats to the local central authorities and monitored remotely. Besides, the sensors can publish the data to the website, web application or any Internet of Things (IoT) platform with the use of the internet or Wi-Fi module for easy public access in order to alarm and raise the awareness on the air pollution or air quality levels. Consequently, the public will be able to prevent any outdoor activity when the air quality on outdoor is bad. Besides, the health impacts due to air pollution such as cardiovascular and lung disease can be avoided [6].

The indoor and outdoor air pollution cause harmful effects on human health and illness. Sick Building Syndrome (SBS) which caused by indoor air pollution while cardiovascular and lung disease caused by outdoor air pollution [7-8]. Common air quality sensor was more focusing on monitoring outdoor air quality rather than indoor air quality monitoring. Indoor air quality monitoring is often considered as not important role for productive and healthy lifestyle. Nevertheless, indoor air quality does give a major impact to human body as people spend more time indoors than outdoors. Most people spend their time in indoor such as office and this environment can affects the health condition that caused by pollutant gases, dust particles and decomposed food particles by microbes [9-10].

Typically, air quality monitoring system monitored different type of gas, temperature and humidity. However, it is deficient in real-time sensing unit that enables remote monitoring of environmental. Previous system lack of alert notification and development of mobile apps, where it is important to give alert to a user an in-situ information. Furthermore, IoT integration with cognitive computing and real-time data exchanges are essential for real-time realizations of air quality in smart environments.

In order to connect the devices to the cloud computing and let the user to monitor the air quality, the IoT platform is used. Internet of Things (IoT) is a paradigm where objects are connected to the internet and support sense capabilities. Internet of Things (IoT) acts as a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human- to-computer interaction. The Internet of Things (IoT) system consists of all the sensors connected to the internet via wired and wireless network structure and the things in the real world. The connected sensors and devices require a protocol in order to communicate with Internet of Things (IoT) platform such as MQTT [11-12].

From researched paper the MQTT protocol stands for Message Queuing Telemetry Transport (MQTT) and it is one of the popular protocols which plays an important role in communicating Internet of Things (IoT) platform. MQTT is a simple messaging protocol for the communication of the connected devices and it based on the 2 principles which are publishing and subscribing messages to topics. In a nutshell, the MQTT sends a command to control an output by reading and publishing the data from the sensors. In this research work, MQTT has been chosen it this alarm system [13-15].

The alarm system will send an alert notification to the public on current air quality condition. For example, the system able to send a notification in message form to the user or public when the sensors detect a critical condition that may bring the threat to public health. Figure 1 shows the overall concept of the Internet of Things (IoT) air quality monitoring system.
2. **IoT Alarm Air Quality Monitoring System Development and Configuration**

This section provides the information and the process of the research work development for IoT alarm air quality monitoring system. The main ideas on how to develop and implement is part of this section.

2.1 **Block Diagram**

Figure 2 shows the block diagram of the hardware for IoT alarm air quality monitoring system. The DHT22 is a digital output sensor which is connected to a NodeMCU’s digital pin to measure temperature and humidity. The DSM501A is used to measure dust concentration by connecting it to 2 digital pins of the NodeMCU, whilst the buzzer and LED are used as an indicator and alert system in the hardware. The MQ135 and MQ7 are an analog output sensor. It is used to measure parts per million (ppm) for the carbon dioxide (CO2) and carbon monoxide (CO). The MQ7 is connected to an analog pin in the NodeMCU while MQ135 is connected to an analog pin in the ADS1115 due to insufficient analog pin in the NodeMCU.

![Figure 2. The block diagram of the hardware system.](image)
2.2 Circuit Diagram

Figure 3 shows the circuit diagram which relates to all the components such as sensors, microcontroller, 16-bit ADC converter, indicators and breadboard. Table 1 shows the pin connection between the components in the hardware.

Table 1. The pin connection of the component

| Component | Pin   | Connection to NodeMCU Pin |
|-----------|-------|---------------------------|
| DHT22     | VCC   | 3.3V                      |
|           | Output| D0                        |
|           | GND   | GND                       |
| MQ7       | A0    | A0                        |
|           | D0    | -                         |
|           | GND   | GND                       |
|           | VCC   | VV (5V)                   |
| DSM501A   | Control 1 | -                        |
|           | Vout 2 (PM1.0) | D3              |
|           | VCC   | VV (5V)                   |
|           | Vout 1 (PM2.5) | D4              |
|           | GND   | GND                       |
| Red LED   | +     | D5                        |
|           | -     | GND                       |
| Buzzer    | +     | D6                        |
|           | -     | GND                       |
| ADS1115   | VDD   | 3.3V                      |
|           | GND   | GND                       |
|           | SCL   | D1                        |
|           | SDA   | D2                        |
|           | A0    | A0 (MQ135)                |
|           | A1    | -                         |
|           | A2    | -                         |
|           | A3    | -                         |
| MQ135     | A0    | A0 (ADS1115)              |
|           | D0    | -                         |
|           | GND   | GND                       |
2.3 Architecture

In the IoT alarm air quality monitoring system, the CloudMQTT has 3 MQTT clients which are hardware, Node-RED dashboard and Android app as shown in figure 4 and 5 respectively. The CloudMQTT acts as a broker to collect all the published and subscribed data with its own specific topic. The hardware which consists of NodeMCU, MQ7, MQ135, ADS1115, red LED, Buzzer, DHT22 and DSM501A, is to publish the sensor value to the CloudMQTT for further data display in the Node-RED dashboard and Android app while subscribe the data from the CloudMQTT to turn on or off the indicator in the hardware for alarm system. The Node-RED dashboard and Android app display or subscribe the published data from the hardware for the monitoring system. Besides, the Node-RED dashboard and Android app can also publish the data with its specific name topic to turn on or off the alarm system or indicator in the hardware for drawing the attention of the user. Figure 6 shows the architecture of the IoT alarm air quality monitoring system.
Figure 4. (a) The concept on the connection between the MQTT client and broker, (b) The example of the MQTT, (c) The Cute Cat package for the CloudMQTT.

Figure 5. Node-RED dashboard.
2.4 Hardware Development

Figure 7 shows the hardware for IoT alarm air quality monitoring system. The hardware system is one of the MQTT clients. The hardware system acts as a publisher when it publishes the data as message with the specific topic to the MQTT. However, the hardware also acts as a subscriber for the alarm system.

In the Node-RED dashboard and Android app, there is a section for the alarm system. In that section, the user is able to activate or deactivate the hardware’s indicator for the alarm system. The user or monitor person can press the on button on the Node-RED dashboard or the Android app when they receive the notification for the unhealthy condition or status. Nevertheless, the user or monitor person can switch off the alarm system when the healthy condition or level is met. In the Figure 8, it shows the activation of the alarm system when the on button is pressed on the Node-RED dashboard or Android app.
3. Result and Discussion
Table 2 describes the condition for the parameters such as temperature, humidity, dust concentration (PM2.5), carbon dioxide (CO2) and carbon monoxide (CO) based on their current reading. The threshold of the sensor code is set based on the current reading column in order to identify the current condition for the surrounding.

The DHT22 is used to detect the environment temperature and humidity in this research work. The candle is used to produce the heat and test the DHT22 as shown in Figure 9. The changes of the reading caused by the heat is shown in Figure 10 and 11. In Figure 10 and 11, the temperature is increased from 32 °C to 34 °C and the humidity is decreased from 68 % to 65 %. Hence, the status of the temperature is changed from normal level to high level due the heat produced by the candle. In Figure 11, the attention subsection for the temperature shows “Temperature is high” message in the Android app.

Table 2. The condition of the parameter

| Parameter               | Threshold (Current Reading) | Condition |
|-------------------------|-----------------------------|-----------|
| Temperature             | > 32 °C                     | High      |
|                         | < 24 °C                     | Low       |
|                         | Otherwise                   | Normal    |
| Humidity                | > 70%                       | High      |
|                         | < 30%                       | Low       |
|                         | Otherwise                   | Normal    |
| Dust Concentration (PM2.5) | > 20000 pcs/0.01cf          | Danger    |
|                         | Otherwise                   | Normal    |
| Carbon Dioxide (CO2)    | > 400 ppm                   | Danger    |
|                         | Otherwise                   | Normal    |
| Carbon Monoxide (CO)    | > 50 ppm                    | Danger    |
|                         | Otherwise                   | Normal    |
Figure 9. Test the DHT22 with and without the candle.

(a) Test without candle, (b) Test with candle.

Figure 10. The output shown in the Node-RED dashboard. (a) Test without candle, (b) Test with candle.

Figure 11. The output shown in the Android app (test with and without candle).
The ice is used to create a low temperature and high humidity condition in order to test the DHT22 as shown in Figure 3.33. The temperature is dropped from 31 °C to 24°C while the humidity is raised from 67 % to 78 % as shown in Figure 13 and 14. This is because the humidity is increasing with respect to the ice or frozen water. The status of the humidity is changed to high level as shown in Figure 13 and 14. In Figure 14, the attention subsection for the humidity shows “Humidity is high” message in the Android app. In a nutshell, the DHT22 is able to function and detect the temperature and humidity well.

Figure 12. Test the DHT22 with the ice.

Figure 13. The output shown in the Node-RED dashboard. (a) test without ice, (b) test with ice.
Figure 14. The output shown in the Android app. (a) Test without ice, (b) Test with ice.

The talc-based powder is used to produce the fine particle to test the DSM501A as shown in Figure 15. In this research work, the DSM501A is used to detect the dust concentration in the environment. The container of the talc-based powder is pressed slightly so that the DSM501A is able to detect the powder. After the DSM501A detected the powder (particle), the dust concentration is increased from 471 pcs/0.01cf to 8684 pcs/0.01cf as shown in Figure 16 and 17. Briefly, the DSM501A is able to detect the particle and measure the dust concentration well.

In this research work, the MQ7 is used to detect the carbon monoxide (CO) in the environment. Thus, the joss stick is burnt to produce the carbon monoxide (CO) in the surrounding as shown in Figure 18. The carbon monoxide level is increased from 10 ppm to 76 ppm and the status of the carbon monoxide is changed from normal level to danger level as shown in Figure 19 and 20. In the Android app, the attention subsection for the carbon monoxide shows “Carbon monoxide level is high” message as shown in Figure 20. In a word, the MQ7 is able to detect the changes in carbon monoxide level in the surrounding.

Figure 15. Test the DSM501A with the talc-based powder.
Figure 16. The output shown in the Node-RED dashboard. (a) Test without talc-based powder, (b) Test with talc-based powder.

Figure 17. The output shown in the Android app. (a) Test without talc-based powder, (b) Test with talc-based powder.
Figure 18. Test the MQ7 with the joss stick.

Figure 19. The output shown in the Node-RED dashboard. (a) Test without joss stick. (b) Test with joss stick.
Figure 20. The output shown in the Android app. (a) Test without joss stick. (b) Test with joss stick.

The MQ135 is used to detect the existence of the carbon dioxide (CO2), so it is tested with a candle in the same container as shown in Figure 21. The candle’s fire goes off when there is no more oxygen in the container, hence the carbon dioxide (CO2) is produced in the container. When the candle’s fire goes off, the carbon dioxide level in the container is raised from 280 ppm to 291 ppm as shown in Figure 22 and 23. In a nutshell, the MQ135 is able to sense the changes in the carbon dioxide level in the environment.

Figure 21. Test the MQ135 with the candle in the container.
4. Conclusion

NodeMCU microcontroller board is used to connect all the sensing units which is sensors with an open source IoT platform and MQTT protocol via built-in WiFi module. The MQ135 and MQ7 are used to sense the presence of carbon dioxide and carbon monoxide. The 16-bit analog-to-digital is used to convert the analog signal or output from MQ135 and MQ7 to digital signal. DHT22 is used to detect the surrounding temperature and humidity while the DSM501A is used to measure the air-borne particle or
dust particle for air quality. As for software development, Arduino (IDE) is used to program the code for the hardware which is sensors and microcontroller board. Node-RED is used to create a dashboard for the monitoring system in web application or IoT platform. There is a protocol used to integrate the hardware and the IoT platform which is MQTT.

In other words, MQTT is also used to transfer or receive the messages between the devices and IoT platform by using “publish” and “subscribe” command. For Android development, the Android Studio is used to create a mobile app for the monitoring system. For prototype testing, the sensors such as DHT22, DSM501A, MQ135 and MQ7 can function very well and detect the changes in the parameters. Hence, the third objective which is to evaluate the system performance by testing the sensors in the prototype is achieved.

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