Air Quality Monitoring in Chittagong by a Low-Cost IoT Based Air Quality Monitoring System

Mohammad Mohiuddin¹, Md. Aminul Islam², Abyad Enan^{3✉}

¹Department of Electronics and Telecommunication Engineering, Chittagong University of Engineering and Technology (CUET), Chittagong, Bangladesh

²Department of Materials Science and Engineering, Rajshahi University of Engineering and Technology (RUET), Rajshahi 6204, Bangladesh

³Department of Electrical and Electronic Engineering, East Delta University, Chittagong, Bangladesh

Received: May 19, 2021

Revised: June 06, 2021

Accepted: November 28, 2021

Keywords

IoT

Air quality

ESP32

Gas sensor

Chittagong

Abstract: Air is an essential element of the environment we live in. Unfortunately, this air is polluted incessantly in many ways. With the advancement of technology, to make life easier, to live with full comfort, this essential part of the environment is being polluted without any interruption. This constant pollution poses a significant threat to the ecosystem as well as to all the living beings on this planet. To make this planet a suitable place for living, for the betterment of all the living beings of this nature, this pollution should be checked. To create awareness, at first, it is essential to show the current condition of the atmosphere, so that people will see the extent to which their activities affect the environment. In this work, we developed an Internet-of-Things (IoT) based low-cost air quality monitoring system to monitor the air quality of Chittagong, a district located in the south-eastern region of Bangladesh. Our proposed system is not only cost-efficient, it also monitors the air quality in real-time. The air quality measurement was taken based on Parts per Million (PPM) metrics and then analyzed. The proposed method provides accurate results.

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1. INTRODUCTION

The atmosphere, above the earth's surface, is full of air consisting of gases such as Nitrogen (N), Oxygen (O), Carbon Monoxide (CO) and other rare elements. We, the living beings of this planet, need air that is fresh and free from contaminants for our life and health. Any change in the air composition can cause significant harm to the life forms on earth. Air pollution is the presence of one or more atmospheric pollutants, such as chemicals, that can affect humans, animals and plants [1, 2]. The quantity of the contaminants in the air is measured in Parts per Million (ppm) or $\mu\text{g}/\text{m}^3$ [3]. There are different types of pollutants: primary and secondary. Primary pollutants are the pollutants released directly into the earth's atmosphere. This primary pollutant then undergoes some chemical reactions with the other elements of the atmosphere [4, 5]. This contaminated air is injurious to health, causing many difficulties: difficulty in breathing, coughing which result in asthma, emphysema [6] and many other diseases. Air pollution is responsible for the death of around 7 million people annually globally or one in eight

premature deaths annually [7]. Every year, nearly 570,000 children under the age of five die of respiratory infection associated with indoor or outdoor pollution and second-hand smoke [8]. Children exposed to air pollution are most likely to have a risk of suffering from asthma and other chronic respiratory problems. To monitor air quality, many researchers around the world have developed models focusing on the amount of different pollution gases such as Carbon Monoxide (CO), Carbon Dioxide (CO₂), Sulfur Dioxide (SO₂), Nitrogen Oxides (NO) etc. Our work focused on monitoring the level of pollutants in the atmosphere using a few gas sensors. We also showed the real time temperature and humidity of the environment. The primary aim of this work is to design an intelligent monitoring system for air pollution for Chittagong, that can track, analyze and log the air quality data to a remote server and keep the data up-to-date over the internet. Chittagong is the second largest and port city in Bangladesh. Moreover, there are very potential tourist spots that are present around the city. So monitoring air quality in Chittagong is very essential to make

✉ Corresponding author. E-mail address: abyad.e@eastdelta.edu.bd (Abyad Enan)

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Available online at <http://edu-journals.com/index.php/ejee>

<https://doi.org/10.46603/ejee.v2i1.25>

a healthy and green city. Many researchers have shown their significant contributions to the air quality monitoring system. Their works were based on IoT or Wireless Sensor Network (WSN) [9, 10]. For example, Ustad et al. [11] reported a wireless zigbee based air pollution monitoring system by using low cost, energy efficient sensors. Recently, Hojaiji et al. [12] proposed a portable device for air pollution monitoring. The device, however, was capable of measuring only one or two pollutants and the accuracy was not so good. Kaivonen and Ngai [13] proposed an IoT based device for measuring the air pollution level in Uppsala, a city in Sweden.

In Bangladesh, likewise, other countries also contains air quality monitoring systems at different cities such Dhaka, Rajshahi, Chittagong, Syllhet, Khulna, Barisal etc. However, these systems are mainly for broad area outdoor environment air quality monitoring. Nonetheless, the air quality of a particular place varies in real-time due to many factors, for instance, population density and distribution, wind speed, use of air pollutants emitting machinery, etc. So a portable air quality monitoring device is very beneficial to monitor both indoor and outdoor environments within particular zones, for example, industries, hospitals, education institutes, air and seaports, bus and railway stations, etc. The main objective of this work is to build an IoT-based, low-cost portable air quality monitoring device and monitor the air quality at different locations in Chittagong city.

2. METHODOLOGY

2.1 Architecture Diagram

Figure 1 shows the basic block diagram of our proposed system. Here, when the ESP32 is loaded, it sends a message to the LCD and the server. MQ series sensors were used to collect the air quality data. The sensor was calibrated such that it gives the analog output voltage, which is proportional to the concentration of polluting gases in Parts per Million (ppm). The data, at first, is displayed on the LCD screen and then sent to the Wi-Fi module, which transfers the measured data value to the server via the internet, an application on a remote server on the cloud. The online application offers global access to the measured data via any device that has an internet connection. The data collected from the sensor is translated into a string which is updated continuously and sent to the remote server. Here, the ESP32 development board has a built-in Wi-Fi card port where the card is inserted to prepare the webserver. This system can be accessed by any internet connected device from anywhere in the world through server IP. Wi-Fi technology, in our proposed system, creates the network infrastructure which connects the server and the sensors. The system security can be improved by using a secure Wi-Fi connection. The main advantage of using Wi-Fi technology is to increase system mobility and scalability.

2.2 Web Server

In this work, we exploited the advantages of IoT, where the air quality data is sent to a web server, directly, via the internet so that anyone from anywhere in the world can access the data from any device if there is an internet connection available using the server IP. In this project, Ubidots has been used as a web server. It provides IoT-based data analytic and visualization services.

2.3 Cloud Storage

In cloud computing, there is no need to use any computer to manage, store and process data. The web server via the internet stores this data so that any user with the help of any internet connected device, using the appropriate IP, can see the data from anywhere in the world. In this work, we used Gmail for storing our data like [14].

Figure 1. Architecture diagram of the proposed system.

3. HARDWARE IMPLEMENTATION

The hardware setup and physical view of the proposed system are shown in Figure 2 and Figure 4 respectively. The different components such as buck converter, pH level module, relay module, moisture sensor module and ESP8266, etc., are marked in the picture.

Figure 2. Interior design of the proposed air pollution monitoring system.

3.1 Gas Sensors

Several gas sensors have been used in this work to measure the concentration of the pollutant gas in the atmosphere. The system generates a corresponding electrical potential on the basis of the gas concentration by the dynamic resistance of the fabric within, which can be measured as the output voltage. Based on this electric signal, the type and concentration of the gas are calculated. The kind of gas that the sensor might detect depends on the sensing material inside the detector. These sensors are usually available as modules with comparators. A specific threshold value of the concentration of gas is set for these comparators. The digital pin goes up when the concentration of the gas reaches this threshold. The analog pin can also be used to measure the gas concentration. In our work, to monitor the air quality, we used MQ135, MQ7,

MQ4 gas sensors, respectively, to measure Carbon dioxide, Carbon monoxide, and methane gases.

3.2 Temperature and Humidity Sensor

The temperature and humidity sensor is capable of taking data from the environment. The data it takes is in the analog form that is converted to digital form in order to be able to send this data to the server. There are several numbers of data taken by this sensor and they are processed in a continuous process on the server after a 12-second interval. A standard mean value is determined to get the most average output from those to get the best reliable result. In this work, we used a DHT11 sensor to detect the temperature and humidity of the atmosphere.

3.3 Control Circuit

Circuit connections of the proposed air pollution monitoring system is shown in Figure 3. ESP32 is used to control the entire system which is connected to the sensors, LCD display, and server through the internet. ESP32 is a low-power System on Chip (SoC) microcontroller having a built-in Wi-Fi module and dual-mode

Bluetooth. It has an operating temperature between -40°C to 125°C , which is feasible for our purpose. It sends data to a web server through this Wi-Fi module without requiring any additional device to connect our system to the internet. Comparative interpretation of this project has been presented in Table 1.

Figure 3. Circuit connections of the proposed air pollution monitoring system.

Figure 4. (a) Physical View of the project (Side View), (b) Physical View of the Project (Top View).

Table 1. Comparative outlook of this project with others available in the literature

References	Application	System components
Lambebo and Haghani [15]	Real-time temperature and greenhouse gas monitoring	Arduino Uno with microcontroller and radio module XBee IEEE 802.15.4. Server communicates with the local network through Wi-Fi module.
Fioccolari et al. [16]	Air quality monitoring	Arduino board and cloud-based platform
Firdhous et al. [17]	Air quality monitoring is limited to O ₃ (Ozon) concentration near photocopy machine.	IoT base Arduino BT board, Raspberry Pi 3 Gateway Node
Benammar et al [2]	Air quality monitoring: CO ₂ , CO, SO ₂ , NO ₂ , O ₃ , Cl ₂ , ambient temperature, relative humidity	Open-source IoT web server platform Emoncms, ATmega 1281 MCU, Raspberry Pi 2
This project	Air quality monitoring: CO ₂ , CO, CH ₄ , ambient temperature, relative humidity	Arduino board, ESP 32 MCU, Ubidots web server

3. RESULTS AND DISCUSSIONS

Figure 5 shows the view of our web page where Figures 5.a, 5.b and 5.c show the amount of Methane, Carbon Monoxide and,

Carbon Dioxide in PPM, respectively. Figure 5.d shows the temperature and humidity in real-time. The web page also shows the graphical values of Methane, Carbon Monoxide, Carbon Dioxide, temperature, and humidity as shown in Figures 6, 7, 8, 9

and 10 respectively. This work is extended further to show the air quality of different locations of Chittagong city as shown in Table 2 from which we can find the highly polluted sites of this city. We have studied 7 locations, shown in Table 2, where the highest amount of Methane in Oxygen area, Carbon Monoxide in Bayezid area and Carbon Dioxide in Oxygen area, is observed.

Since we had only one air quality monitoring device, we took these data from different locations, from different time periods of the day. With the help of air quality monitoring set up, located at different locations, we could be able to see the air quality of different locations at the same time, which will be shown in future works.

Figure 5. Online Visualization of web page.

Figure 6. Graphical view of Methane gas monitoring.

Figure 7. Graphical view of carbon monoxide monitoring.

Figure 8. Graphical view of Carbon Dioxide monitoring.

Figure 9. Graphical view of temperature monitoring.

Figure 10. Graphical view of humidity monitoring

Table 2. Data table of difference places in Chittagong.

Location	CH ₄ (PPB)	CO(PPM)	CO ₂ (PPM)	Temperature	Humidity	Date	Time
Oxygen	1406	26	650	35° C	64.6%	02/09/2020	12:12 pm
Bayezid	1266	27	529	36° C	59.2%	02/09/2020	12:35 pm
East Delta University	1195	14	529	35° C	62.6%	02/09/2020	12:50 pm
Foy's Lake	1214	14	529	31° C	73.3%	02/09/2020	02:04 pm
Agrabad	1223	23	530	32° C	71.5%	02/09/2020	02:28 pm
GEC More	1209	20	529	32° C	77.4%	02/09/2020	02:48 pm
2 No Gate	1190	21	529	32° C	76.6%	02/09/2020	03:02 pm

5. RESULTS VERIFICATION AND COST ANALYSIS

Results, drawn by this low-cost air quality monitoring system, are verified by comparing the data with the data of Continuous Air Monitoring Stations (CAMS), Chittagong. CAMS is an institute run by the Government People's Republic of Bangladesh to monitor air quality. The comparative results are shown in Table 3, where it can be seen that our proposed air quality monitoring

system shows almost the same results at a given time. The outputs of the sensors of this project are also compared with the literature, as shown in Table 4. The performances of the sensors were very similar to the reported literature. The cost breakdown of this project has been depicted in Table 5. The total cost of this project was 2380 BDT.

Table 3. Compare the Measured values of the device with CAMS, Chittagong.

Name	Measured Value	CAMS Value	Date	Time
CH ₄	1214 ppb	1222 ppb	02/09/2020	2:04 pm
CO	15 ppm	13 ppm	02/09/2020	2:04 pm
CO ₂	529 ppm	530 ppm	02/09/2020	2:04 pm
Temperature	31° C	31°C	02/09/2020	2:04 pm
Humidity	73.3%	72.5%	02/09/2020	2:04 pm

Table 4. Compare the sensors' performances with the literature reported for Chittagong.

References and Location	CH ₄	CO ₂	CO	Temperature	Relative Humidity
Chowdhury and et al. [18] Chittagong	1.8 ppm	700 ppm (max)	0.29 ppm	28	Max 75%
This project Chittagong (Oxygen)	1.406 ppm	650 ppm	26 ppm	35	64.6%

Table 5. Cost breakdown of the project.

Component	Price (BDT)
MQ4 Sensor	130
MQ7 Sensor	130
MQ135 Sensor	210
DHT11 Sensor	590
ESP32 MCU	750
Buck converter	80
LCD display	230
Adapter	150
PVC sheet	40
Super glue (2 pieces)	40
Connecting Wire	30
Total	2380

5. CONCLUSIONS

Wireless sensor monitoring of air quality has numerous advantages over the conventional environment. This system has its benefits such as cost-effectiveness, ease of installation and real-time data transmission. The proposed monitoring station is used for studying and processing real-time pollutant data from road traffic emissions. It is a difficult task to track the level of pollution from various areas of view, which needs a broad infrastructure setup and careful management, however, if the system can segment the level of pollution according to the region so that it can be better tracked and better solutions can be provided. In the future, a web-based monitoring system incorporated with Google Maps can be implemented to see the live map view of air pollution. Individuals suffering from different respiratory diseases will be benefitted by checking the level of pollution in Google maps to choose an alternative safe route to their destination. CO, N₂, CH₄, DHT11 sensors have been used in our work. The proposed system can be updated with additional

sensors to sense the existence of other gases such as Oxygen, Hydrogen, and pH etc. These readings will provide the real-time condition of the atmosphere and further preventive measures can be taken accordingly.

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