An Efficient IoT Technology Cloud-Based Pollution Monitoring System

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Abstract: Air pollution is one of the major concerns in the world, especially some of the toxic gases when in excess may have dire impacts on human health and are like CO_2, NH_3, and Particulate Matter etc. The temperature, humidity, and wind speed are also the weather parameters having their effects and causes for other gases in the environment. This paper concerns with the development of hardware which provides the concentration level of significant gases i.e., CO_2, NH_3, O_2, PM2.5 using MQ-Series gas sensors and the environment parameters i.e., temperature, humidity, dew point, wind speed in real-time using the Raspberry Pi based on Internet of Things (IoT) platform. The data has been stored in the Firebase database for real-time monitoring. The cloud computing-based monitoring system with inbuilt Wi-Fi connectivity ensures the analysis of different air pollutants and weather parameters on a periodical basis to provide the general Air Quality Index (AQI) on a real-time basis. In the case of undesired conditions, the notification alert message will be sent to the user.

Keywords: Raspberry Pi, Firebase database, IoT, MQ-Series gas sensors, AQI, Cloud Computing

1.1. Introduction

The primary sources of air pollution are plume and vehicular exhaust, the increasing rate of industrialization, burning of fossil fuels, and emission of CFC’s from various households (air conditioner and refrigerator). This further enhances the degradation of air composure which is unsuitable for breathing and has detrimental effects on human health. These effects can be both short as well as long term; short term effects are temporary viz. dizziness, headache, irritation, nausea etc. while long term effects are due to the continuous exposure to polluted air which can have an adverse impacts on kidneys, liver, individual's nervous framework, mental and cardiac disorders, respiratory ailments and so on.

An IoT is a term, coined by Kevin Ashton that refers to the system connecting different devices such as mechanical, digital, and computing devices through the internet and accessing over it. The different devices then communicate with each other for transferring the data without the need of computer-to-human or human-to- human interaction. The existing pollution monitoring systems are bulkier, costlier, and provide AQI on a general basis by considering the weighted average calculation, which is common for all individuals. Hence, the need for a methodology is providing cost-effective, mobile and more individual-centric specific data analysis and alert notification services. An IoT based pollution monitoring platform is the solution for the above-stated problem. The key challenges in the design of this personalized pollution monitoring system. In the proposed model, we are using the processing unit i.e. Raspberry Pi 3B Model, analog to digital convertor i.e. ARPI600 module, MQ-series gas sensors and the monitor for analysis and visualization of different air pollutants.

1.2. Related Work

S. H. Kim et al. [1] proposed a model for pollution monitoring based on IoT for monitoring air pollutant levels such as ozone, particulate matter etc. and analyzing it using an LTE network. The observed data is then compared with the data provided by the National Ambient Air Quality Monitoring Information System (NAMIS). Swati Dhingra et al. [2] presented an air quality monitoring system consisting of the Arduino processing unit, Sensors array and Wi-Fi module and a server. It gathers air pollutant levels, transfers to the cloud using Wi-Fi and sent to a server, stored in a database and an Android application called IoT-Mobair is being developed for the real-time monitoring and analysis of data. J. Huang et al. [3] proposed an algorithm for the detection of air exchange state in vehicles, sampling the air quality parameter and analyzing it based on the cloud IoT platform. The real-time analysis is done particularly on fine-grained dust particles for the feature extraction and classification. A. Venkatanarayanan et al. [4] proposed a system of air pollution monitoring aided in bicycle for real-time monitoring provided mapping with an android application for visualization. The data is stored in an open IoT based Thingspeak platform and a fingerprint sensor deployed for alert in case of theft. S. Kumar et al. [5] proposed a system that uses a raspberry pi interfaced to an Arduino interfaced with the sensors for measurement of SO_2 and NO gases along with the humidity and temperature. The system uses IBM cloud bluemix to upload the data obtained on the pi to the cloud. It's a low cost, low power system for environment monitoring. M. F. M. Firdhous et al. [6] proposed an indoor environment monitoring method having IoT to monitor Ozone (O_3) concentration around the photocopy machine. The system takes the data at a span of every five minutes is stored in the cloud and the warning message is given in case exceeds the threshold limit. G. Parmar et al. [7] proposed a prototype model system of monitoring air quality using MQ7 and other with MQ135 (MQ7 is a CO sensor and MQ135 detects NH_3, CO_2 etc.). The Nucleo F401RE microcontroller is used as a processing unit along with a Wi-Fi module provided interface with a webpage using MEAN stack for visualization of JSON formatted data.

1.3. The Layer Architecture Model

The proposed system design constitutes four layers, i.e. sensing layer, the Network layer, the Processing layer and the Application layer, as depicted in Fig. 1. The Sensing layer comprises sensors array interfaced with processing unit sense the air pollutants in real-time and collects the data [9]. The Network layer is a communication medium between the Sensing layer and the processing layer. The Processing layer uses a cloud server database to receive, store and process the data based on big data analysis and used for forecasting and prediction of data. The Application layer makes use of Android and Web application used to retrieve data from the cloud database for end-users to monitor the real-time data.

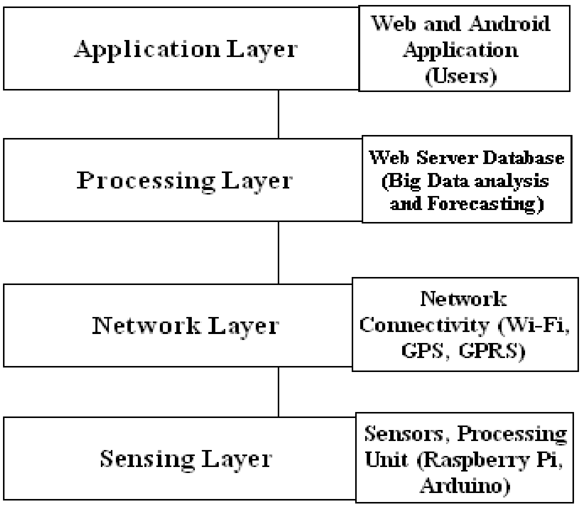

Fig. 1. The Layer architecture of system model

1.4. Hardware and Software Unit

1.4.1. Gas Sensors

MQ-Series Sensors: The MQ-Series gas sensors [7], i.e. MQ-137 for NH_3 and MQ-135 for CO_2 as shown in Fig. 3 and Fig. 2 resp., are used for the monitoring of air pollutants, and finally, the air quality index determined itself by MQ-135. The operating voltage and current of the sensors are 5V and 40mA resp.

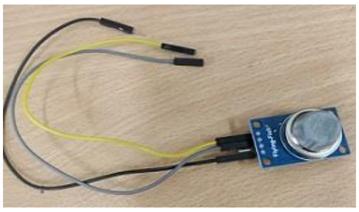

Fig. 2. CO_2 Sensor (MQ-135)

Fig. 3. NH_3 Sensor (MQ-137)

Oxygen and Dust Sensor: KE-25 is the oxygen sensor as shown in Fig. 4, which is an electrochemical gas sensor used to monitor the oxygen level in the environment. Its characteristics are no external power required; long span time, no influence of other air pollutants and no warm-up time is required provided with stable output. GP2Y1010AU0F is the dust sensor as shown in Fig. 5 based on optical sensing technology. It can distinguish smoke from the dust.

Fig. 4. O_2 Sensor (KE-25)

Fig. 5. PM Sensor (GP2Y1010AU0F)

Temperature and Humidity Sensor and Wind Speed Sensor: DHT11 as in Fig. 6 is a sensor used to monitor the real-time temperature and humidity levels. Then, to monitor the dew point, we calculate it by using the formula discussed below in eqn. (iii). An Anemometer as in Fig. 7 is a device to measure the wind speed in m/sec. It measures the analog voltage, which ranges from 0.4V to 2.0V i.e. wind speed ranges from 0m/sec to 32m/sec.

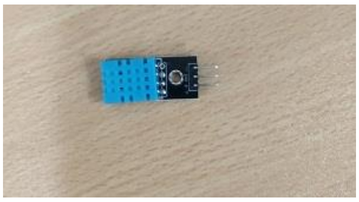

Fig. 6. DHT11 Sensor

Fig. 7. Wind speed Sensor (Anemometer)

1.4.2. Hardware Unit

Raspberry Pi, ARPI600 and GPRS Module: An ARM-based Raspberry Pi 3B Model [5] as in Fig. 8 is used as a processing unit. Its feature is no external hardware required for network connectivity. It is used to analyze the converted digital data and send it to the cloud database used for monitoring purposes. ARPI600 module as in Fig. 9 is an analog to digital converter used for the gas sensors that provide analog values are to be converted to digital form for processing in the Pi. GPRS module as in Fig. 10 provides communication link between the PC and GSM systems. It requires a SIM for activating a connection to the module. The alert notification is sent to a mobile using the same module.

Fig. 8. Raspberry Pi 3B

Fig. 9. ARPI600 Module

Fig. 10. GPRS Module

1.5. The Complete System Model – Methodology

The system model [2] comprises a hardware unit, gateway, cloud database, and user interface as shown in Fig. 11. The hardware unit consists of MQ-Series gas sensors, Anemometer etc. along with processing unit as Raspberry Pi A/D converter (ARPI600) and power supply unit. The gateway provides the communication link between the hardware unit and a cloud server. The cloud database stores the data in real-time which is used for analysis and forecasting [8].

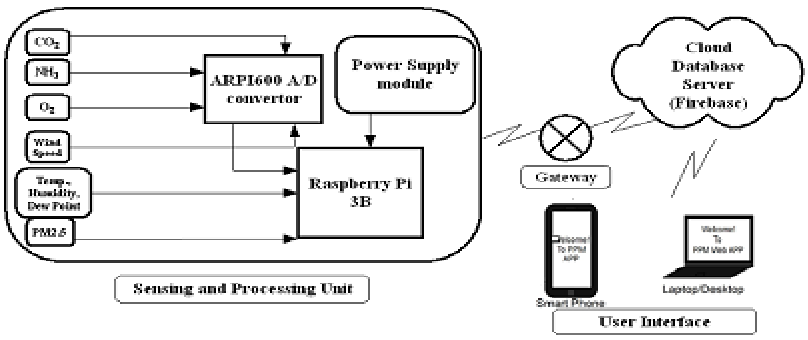

Fig. 11. The System Model Diagram

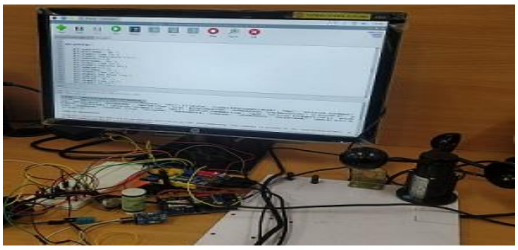

Fig. 12. Experimental Setup

1.5.1. Air Quality Index

The AQI is the value given by the Central Pollution Control Board (CPCB), which is obtained by calculation of average pollutant concentration. Higher the value of AQI, a number of health hazards add up. The Sub-index (I_i) for a given concentration (C_P) of each pollutant can be represented as [10],

$$I_i = \left[\left\{ \frac{(I_{HI} - I_{LO})}{(B_{HI} - B_{LO})} \right\} \times (C_P - B_{LO}) \right] + I_{LO} \quad \text{(i)}$$

where, B_{HI} is the Concentration breakpoint, i.e.,$\geq C_P$, B_{LO} is the Concentration breakpoint i.e., $\leq C_P$, I_{HI} and I_{LO} are the AQI values corresponding to B_{HI} and B_{LO} resp. The Overall AQI is calculated as,

$$AQI = \sum_{i=1}^{n} W_i I_i \quad \text{(ii)}$$

where, W_i is the weight of each pollutant such that $\sum W_i = 1$ and n is the number of air pollutants.

1.5.2. Dew Point Calculation

The dew point ($D.P.$) is calculated by using temperature (T) and relative humidity (RH) as per August-Roche-Magnus Approximation,

$$D.P. = 243.04 \times \frac{\left(\frac{ln(RH)}{100}\right) + \left(\frac{17.625 \times T}{243.04 + T}\right)}{17.625 - ln\left(\frac{RH}{100}\right) - \left(\frac{17.625 \times T}{243.04 + T}\right)} \quad \text{(iii)}$$

1.5.3. Wind Speed Calculation

As discussed above, by using two-point equation formulations, the wind speed (V_w) can be calculated as,

$$V_w = 20.25 \times V - 8.1 \quad \text{(iv)}$$

Where, V is the sensor output voltage

1.6. Proposed Flowchart Model

The proposed model, as shown in Fig. 13, depicts the overall process of the working system model. The hardware setup is done first, then the processing and each air pollutant level is obtained and monitored. Then, the AQI is calculated, and if each air pollutant level crosses a certain threshold limit, the alert notification message is sent to the user's mobile [4]. Otherwise, the concentration of each pollutant is continuously stored in the firebase cloud database.

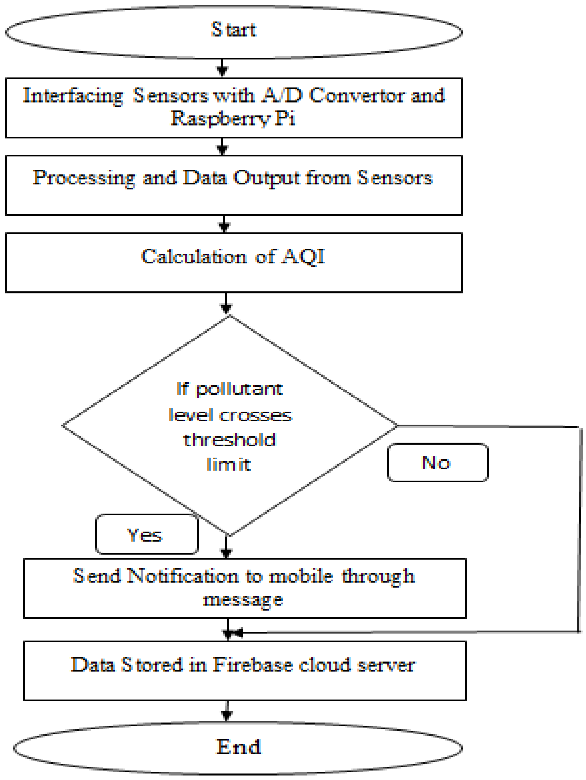

Fig. 13. The Flowchart Diagram

1.7. Results and Discussions

As shown in Fig. 12, the complete experimental setup is being done based on which the real-time sensor parameters are obtained, as shown in Fig. 14. The values are obtained as per in our campus environment.

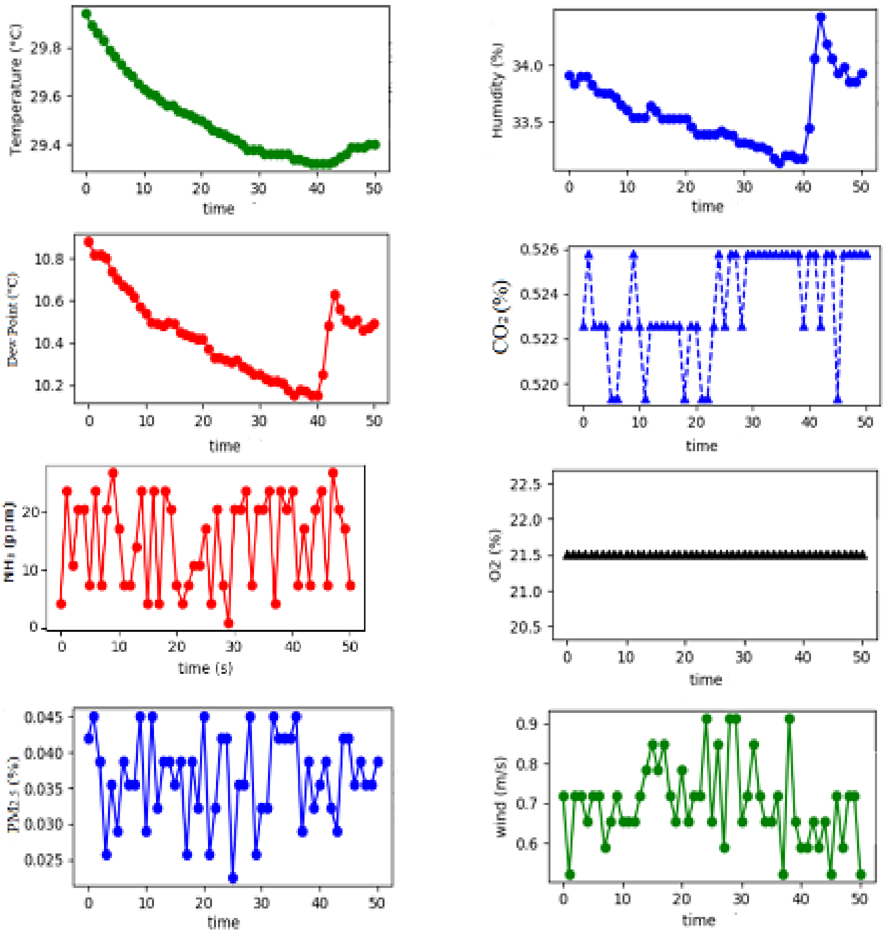

Fig. 14. Real time Sensors Readings Output

In Fig. 15, the data output stored in the firebase database, in the packet form is shown and as the pollutant level, NH_3 level as it crosses some threshold limit, i.e., here, 21 ppm, it sends a notification message to the mobile as an alert message and if it comes back to normal, then also it notifies for it as shown in Fig. 16. Thus, the different pollutant parameters are monitored and stored in the database server for further analysis.

Fig. 15. Firebase Data Output

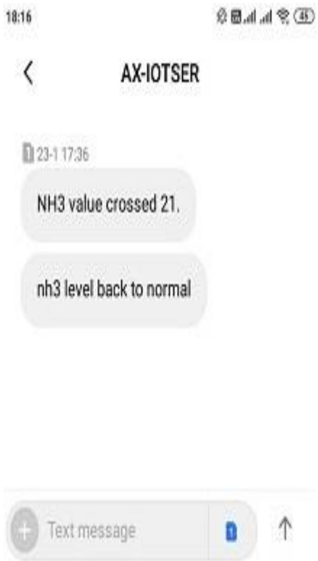

Fig. 16. Notification Message in mobile

1.8. Conclusion and Future Work

In this paper, we have discussed the development of air quality monitoring systems using the Raspberry Pi based on IoT platform that monitors different air pollutants providing low cost and efficient methods of developing the whole system. There is a tradeoff between cost and accuracy of the sensing system. The different gas parameters CO_2, NH_3, O_2, particulate matter PM2.5, and weather parameters temperature, humidity, dew point, wind speed are monitored and are stored in the Firebase cloud database. The notification message is sent to the user's mobile in an alert case when value exceeds the threshold limit. Furthermore, the machine learning and deep learning can be implemented on the stored data to predict and forecast it such that estimation of upcoming environmental conditions can be done. The User-specific android application is to be developed for monitoring the air quality and providing navigation through Google maps by using routing algorithms to provide healthier paths for a specific individual.

Acknowledgment

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