IoT based Air Pollution Monitoring System using Raspberry Pi

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Abstract— Air pollution has been tremendously increasing these days. The quality of air has been affected by various factors like industrial emissions, heavy usage of automobiles etc. The evolution of various technologies like Internet of Things, Raspberry Pi makes easier for us to deploy sensors and allows us to detect the quality of air in real time. Air Pollution monitoring system using raspberry pi provides an effective solution than others that are previously used. The working performance of the proposed model is evaluated using prototype implementation, consisting of raspberry pi, gas sensors like MQ135 and MQ2 for measuring NO2 and CO ppm levels in atmosphere, A/D converter, python software package and Thing Speak cloud services. The results obtained from these gas sensors are evaluated using Thing Speak cloud services.

Key words: Raspberry Pi 3B Model, MQ135, MQ2 Gas Sensors, A/D Converter-MCP3008

I. INTRODUCTION

India is the third largest country in the world in terms of pollution. With such heavy pollution, there is a need for proper monitoring system in India. So, an efficient environmental monitoring system is required to monitor and assess the conditions in case of exceeding the prescribed level of parameters (e.g., CO and No2 levels). When the environment is equipped with the objects like sensor devices, microcontroller and various software applications, it becomes a self-protecting and self-monitoring environment. Human needs demands different types of monitoring systems. These depend on the type of data gathered by the sensor devices. Event Detection based and Spatial Process Estimation are the two categories to which applications are classified. Initially the sensor devices are deployed in environment to detect the parameters (e.g., NO2 and CO ppm levels etc.) while the data acquisition, computation and controlling action (e.g., the variations in the NO2 and CO ppm levels with respect to the specified levels). Sensor devices are placed at different locations to collect the data to predict the behaviour of a particular area of interest.

The main aim of this paper is to design and implement an efficient IoT based air pollution monitoring system through which the required parameters are monitored remotely using internet and the data gathered from the sensors are stored in the cloud and to project the estimated trend on the web browser. One of the main reasons for global warming is carbon monoxide (CO) and nitrogen dioxide (NO2) emissions into the atmosphere. There are several traditional methods espoused for monitoring the emissions. They are listed below:

1) Fossil fuel estimation and accounting raw material consumption.
2) CO flux measurement in air using IR radiation and
3) Development of wireless sensor node and deployment of Wireless Sensor Networks based on the coverage area and scalability issues.

From above methods, there exist pros and cons but our solution IoT based air pollution monitoring system gives accurate results with minimum errors which are unnoticeable. With the help of results obtained from the proposed model, one can draw the suitable conclusion and to safeguard the environment from air pollution.

Below stated are the health effects caused because of the air pollution. Even healthy people can experience health impacts from polluted air including respiratory irritation or breathing difficulties during exercise or outdoor activities. The actual health risk of human beings depends on current health status, the pollutant type and concentration, and the length of our exposure to the polluted air.

High air pollution levels can cause immediate health problems including aggravated cardiovascular and respiratory illness, added stress to heart and lungs, which must work harder to supply the body with oxygen and damaged cells in the respiratory system.

Long-term exposure to polluted air can have permanent health effects such as:

1) Accelerated aging of the lungs.
2) Loss of lung capacity and decreased lung function.
3) Development of diseases such as Asthama, Bronchitis, Emphysema and possibly Cancer.
4) Shortened life span.

Those most susceptible to severe health problems from air pollution are:

1) Individuals with heart disease, coronary artery disease or congestive heart failure.
2) Individuals with lung diseases such as Asthma, Emphysema or Chronic Obstructive Pulmonary Disease (COPD).
3) Pregnant women.
4) Older adults and the elderly.
5) Children under age 14.
6) Athletes who exercise vigorously outdoors.

People in these groups may experience health impacts at lower air pollution exposure levels, or their health effects may be of greater intensity.

Air pollution also occurs from specific pollutants, one of them is ground-level ozone. Ground-level ozone is formed when volatile organic compounds (VOC) and oxides of nitrogen (NOx) react with the sun's ultraviolet rays. The primary source of VOCs and NOx is mobile sources, including cars, trucks, buses, construction equipment and agricultural equipment. Ground-level ozone reaches its highest level during the afternoon and early evening hours. High levels occur most often during the summer months. It is a strong irritant that can cause constriction of the airways, forcing the respiratory system to work harder in order to

provide oxygen. It can also cause other health problems including aggravated respiratory disease such as Emphysema, Bronchitis and Asthma, Lung damage, Wheezing, Chest pain, Dry throat, Headache, Reduced resistance to infections, increased fatigue, weakened athletic performance.

The other reason for air pollution is particulate matter (PM). It is a complex mixture that may contain soot, smoke, nitrates, dust, sulphates, metals, and water and tire rubber. It can be directly emitted, as in smoke from a fire, or it can form in the atmosphere from reactions of gases such as nitrogen oxides. The size of particles is directly linked to the potential for causing health problems. Small particles (known as PM 2.5 or fine particulate matter) pose the greatest problems because they bypass the body's natural defences and can get deep into our lungs and potentially our blood stream. Exposure to such particles can affect both lungs and heart. Long-term exposure to particulate pollution can result in significant health problems including irregular heartbeat, non-fatal heart attacks, and premature death in people with heart or lung disease including death from lung cancer. Even if you are healthy, because of air pollution you may experience temporary symptoms, such as irritation of the eyes, nose and throat, coughing, chest tightness, shortness of breath. Because of the above mentioned ill effects of air pollution, a monitoring system is must. Hence, we designed a IoT based Air Pollution Monitoring System using raspberry pi.

II. EXISTING SYSTEMS

The first step in air pollutant concentration is to define clearly the objectives of measuring concentrations of air pollutants, and to determine the target substances for measurement. The objectives that are usually intended are as follows: 1) To thoroughly understand the pollution levels and concentration fluctuations when the sources and pollutants are clearly known; 2) when neither the source nor the pollutants are clearly known, to examine the causes of the pollution; 3) when the source is identified, to thoroughly understand the levels of pollution and the types of pollutants emitted; 4) when the pollutant has been identified, to specify the source and to determine the level of its contribution; 5) to easily understand border area concentrations and exposure sites for voluntary periods of time; 6) to thoroughly understand the broad range pollution level and its fluctuations.

Measurements are taken using collection-analysis (manual analysis), concentration meters, continuous analyzers, and the other simple measuring equipment. Manual analysis is applicable to most of compounds that can be used with ordinary equipment such as spectrophotometers and gas chromatographs, because once has been collected at fields, it has to be carried back to the laboratory for analysis. The concentration meter obtains on-site values in a portable form for the target gas. The simple measuring equipment is inexpensive and easy to operate, and aims to be able to take measurements on-site. The continuous analyzer is used for fixed point observations, and records both the time course and the mean concentrations. In recent years, on-site analytical values have been obtained, and portable continuous analyzers have also been on the market, but the basic patterns of air pollution measurements are these four.

Of the above objectives, 2 and 3 require accurate analysis manually, while 1 and 6 require continuous analysis, and 5 uses simple measuring equipment. For the 4 objectives, both manual and continuous analyses are used continuously. Even with expensive measuring equipment, if the selection of the equipment and the operation employed are wrong, accurate environmental information will not be obtained, whereas even with inexpensive equipment, the above objects can be attained, depending on the approach. If a specific measuring pattern is selected appropriately, rational measurements are entirely possible. There are many different analysis and detection principles that can be used in the above four measuring patterns. These selections are made while considering the sensitivity of the target substance, the selectivity (interference), accuracy, economic viability, ease of use, and so forth. There is a laser remote sensing method, which can measure both airborne aerosols and gas across a wide area directly, without the need for sampling.

In order to learn the pollution level for a given region, samples are taken at points so as to obtain mean concentrations and sites for which the highest concentration can be expected. Ground level of noxious substances emitted from specific chimneys and the side of major roads. On the other hand, because the concentration is governed by wind speed, climate, day of the week, and season, sampling is performed with reference to conditions that indicate both the highest and the lowest concentration in order to obtain an overview of the pollution level with only a small sample, or else measurements are taken continuously throughout the year. Moreover, in order to determine the annual mean concentration, it is necessary to take samples twice a month, each sample being over a 24 hour period.

Manual analysis methods:

This pattern is used for nearly all pollutants and the state in which they are introduced to the analyzing equipment is nearly always either liquid or gas. At this point, the concentration of the samples in the air are determined by the equation C=M/V, where C is concentration, M is target substance amount. Consequently, in order to measure lower concentrations with the same equipment, it is necessary to increase the sample air volume within a range that does not affect accuracy. Measurement accuracy in addition to operational errors and analytical instrument accuracy are governed by collection efficiency and the measurement accuracy of sample air flow rate.

When analyzing air pollutants manually, both spectrometry (absorption spectrophotometry, atomic absorption spectrometry, and ICP emission method), which is widely used, and chromatography (gas chromatography and liquid chromatography) are used.

A. Spectrometry

The responses for the sample solutions and the standard solutions are obtained using a spectrophotometer. The calibration curve is usually prepared for the determination.

B. Chromatography

Chromatography, representative differential analytical method, is to identify over a retention time of the

chromatogram peak, and then determine over the peak area. Both gas chromatograph and liquid chromatograph analyzers are composed of a separating column, a detector and a carrier introducer, and a thermostat. In order to use one, it is essential to set the temperature, the length of the column, internal diameter, packing, species of stational faces liquid, type of detector, flow rate and species of carrier gas, sample injection volume, and other analysis conditions. In particular, the column conditions govern the degree of separation, and the detector sensitivity and selectivity. The standard substance is injected under the set conditions, and the peak retention time is measured. Unknown samples of many kind of volatile organic compound should be identified in parallel with a mass spectrometer because the peak positions may well overlap.

III. ADVANCED TECHNICAL METHODS

There are some advanced methods in order to find out the percentage of gaseous composition in air. Of them, Ardunio based air pollution monitoring is one of the efficient method and the working process is the MQ135 sensor can sense NH3, NOx, alcohol, Benzene, Smoke, CO2 and some other gases, so it is a perfect gas sensor the air pollution monitoring project. When we will connect to it to an arduino then it will sense the gases and we will get the pollution level in the ppm (parts per million). MQ135 gas sensor gives the output in the form of voltage levels and we need to convert it in to ppm. So, for converting the output in ppm, a library of MQ135 sensor is used. The below figure [1] shows the block diagram of existing arduino based air pollution monitoring system.

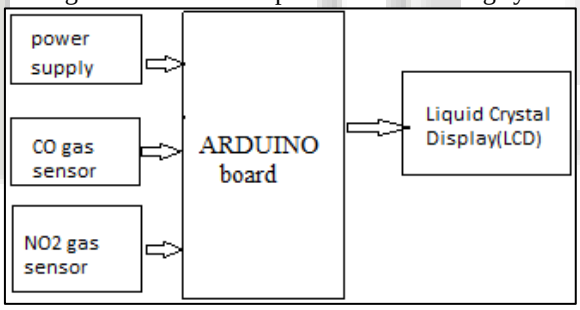

Fig. 1: Arduino based Air Pollution Monitoring System

Whenever the sensor gives the value of 90 then there was no gas near it and the safe level of air quality is 350ppm and it should not exceed 1000ppm. When it exceeds the limit of 1000ppm, then it causes Headache, Sleepiness, and stagnant, Stale, Stuffy air and if it exceeds beyond 2000ppm then it can cause increased heart rate and many other diseases. When the value will be less than 1000ppm then the LCD and web page will display "Fresh Air". Whenever the value increase 1000ppm, then the buzzer will start beeping and the LCD and webpage will display "Poor Air, Open windows." If it will increase 2000 then the buzzer will keep beeping and the LCD and webpage will display "Danger, Move to the fresh air." This Arduino based Air Pollution Monitoring System is one of the advanced method to find out the levels of dangerous gases which causes air pollution.

IV. SYSTEM MODELLING

Owing to the evolution of SBC in the recent trends a miniature and low cost SBC called raspberry pi based on quad-core ARM Cortex-A7 cluster is selected as principle of hardware Plug and play, easy to use type electronic shield called Grove pi+ is piled over Raspberry Pi. The hardware shield consists of controller with ADC and i2c interface. Multiple digital sensors can be interfaced to Raspberry pi. The i2c based sensor can be interfaced to Raspberry Pi can access directly to those sensors via these buses.

The sensor modules like MQ-2(for NO2) and MQ-135(for CO) are interfaced to Raspberry Pi for monitoring air in our proposed system. Each sensor has various levels of concentration towards the corresponding gases present in the atmosphere. The raspberry Pi runs with the operating system called Raspbian, on which the necessary libraries are included and the drivers are developed for accessing the sensors. The drivers and the application scripts are developed using the PYTHON, which is a multi-paradigm programming language that helps in rapid development and integration of the application with the systems. An open source cloud IoT platform called Thing Speak is used as a cloud services for posting the data. Apart from remote data monitoring, the ThingSpeak cloud services also provides facilities for running aggregation, decision making and data analytics services. The ThingSpeak platform also offers other services like data visualisation with MATLAB supports, alerts, scheduling and device communication. In our proposed model, the data from the multiple sensors are uploaded to the desired channels created for posting data. The channels are set to private or public view depending up on the requirement and austereness of the data for analytics, alert and reaction. The block diagram of our proposed model is as shown below.

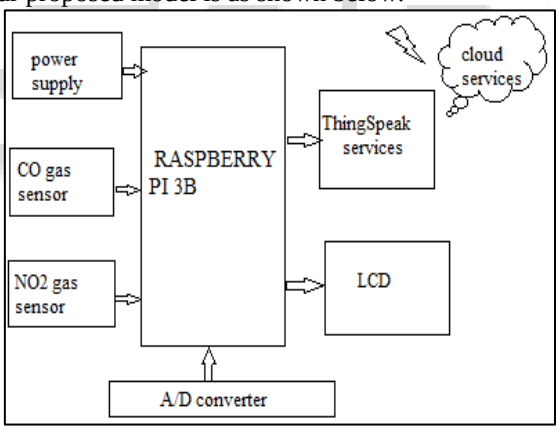

Fig. 2: Block Diagram of IoT based Air Pollution Monitoring System using Raspberry Pi

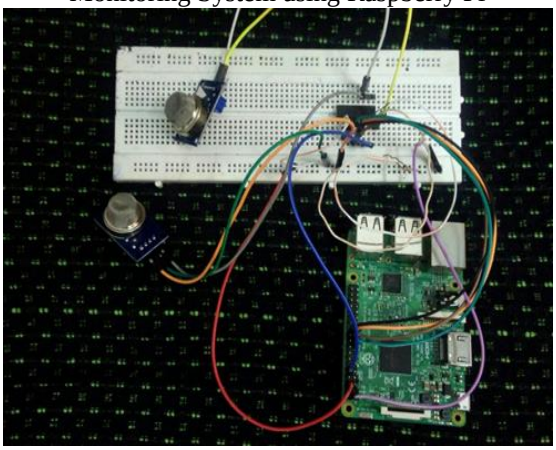

Fig. 3: Working Prototype of IoT based Air Pollution Monitoring System using Raspberry Pi

Here, we need to create the channel in the Thing Speak cloud services in order to post the data. This can be illustrated with the figure4.

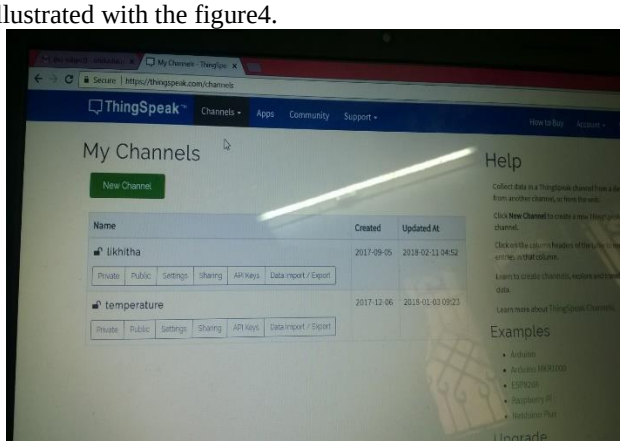

Fig. 4: Channels in Thing Speak Cloud Services.

The results were shown in Fig 4 to Fig 7 and are self-explanatory.

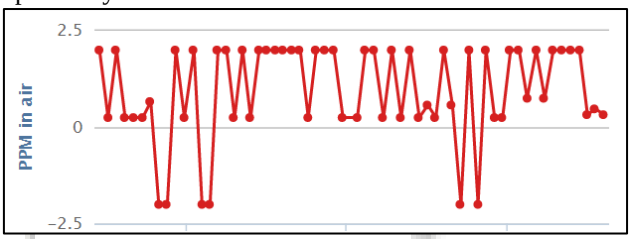

Fig. 5: CO (MQ-135) and NO2 (MQ-2) Gas Sensors Displaying Results in PPM.

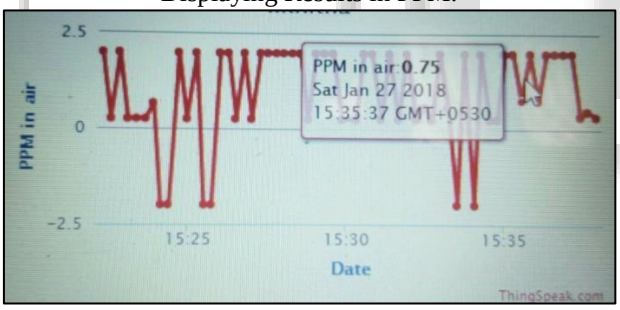

Fig. 6: CO Gas Sensor displaying 0.75 PPM

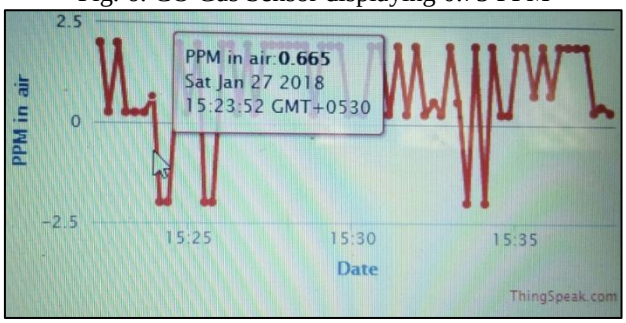

Fig. 7: NO2 Gas Sensor displaying 0.665 PPM

As shown from the above figures, we can monitor the carbon monoxide (CO) and nitrogen dioxide (NO2) parts per million (ppm) levels at any point of time. In this project, we are using channels in the Thing Speak cloud services for posting the data.

V. Conclusion

We have designed IoT based Air Pollution Monitoring System using Raspberry Pi for knowing the Parts Per Million (PPM) levels of dangerous gases that causes severe environmental issues which in turn shows adverse effects on health. With the help of our system we can know the concentration of dangerous gases and to take the necessary steps for reducing it. Since, we give utmost importance to health hence, we designed this system to monitor our atmosphere. With the help of present technology called Internet of Things, it is easier for us to solve the problems from home and this becomes an inspiration for us to design this system and thus we are safeguarding our environment in a wise way.

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