Air Quality Monitoring System Based on IoT using Raspberry Pi

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***Abstract*—Air pollution is the largest environmental and public health challenge in the world today. Air pollution leads to adverse effects on Human health, climate and ecosystem. Air is getting polluted because of release of Toxic gases by industries, vehicular emissions and increased concentration of harmful gases and particulate matter in the atmosphere. Particulate matter is one of the most important parameter having the significant contribution to the increase in air pollution. This creates a need for measurement and analysis of real-time air quality monitoring so that appropriate decisions can be taken in a timely period. This paper presents a real-time standalone air quality monitoring system which includes various parameters: PM 2.5, carbon monoxide, carbon dioxide, temperature, humidity and air pressure. Internet of Things is nowadays finding profound use in each and every sector, plays a key role in our air quality monitoring system too. Internet of Things converging with cloud computing offers a novel technique for better management of data coming from different sensors, collected and transmitted by low power, low cost ARM based minicomputer Raspberry pi. The system is tested in Delhi and the measurements are compared with the data provided by the local environment control authority and are presented in a tabular form. The values of the parameters measured are shown in IBM Bluemix Cloud.**

Keywords—Air Quality Monitoring, Internet of Things, Arduino Uno, Raspberry pi, cloud computing.

I. INTRODUCTION

Air pollution is caused due to the presence of particulate matter, harmful materials and biological molecules in earth atmosphere [3]. It has adverse impact on living organisms such as humans, animals, food crops and can also damage built and natural environment. It may result in allergies, harmful diseases such as cardio vascular diseases, lungs diseases and can also cause death. The environment group Greenpeace in January released a report that has estimated every year nearly 1.2 million Indian die because of air borne pollutants [10].

Particulate matter is liquid or solid matter which is microscopic and suspended in Earth's atmosphere. We are exposed to this particulate matter which is continuously affecting our heart and lungs. Till now several studies have been done in environment monitoring domain using IoT,Researchers have monitored environmental parameters like Temperature, Humidity, Barometric air pressure, carbon monoxide, sulfur dioxide but the least attention is paid to the measurement of particulate matter [5]. Air quality monitoring without knowing the concentration of particulate matter in the atmosphere is incomplete. Thus, to address this problem, a system consisting of DSM501A which is a PM sensor is being used for monitoring the particulate matter along with the sensors employed for sensing carbon monoxide, carbon dioxide, Temperature, Humidity and barometric air pressure using raspberry pi which is a low power, less expensive, highly flexible minicomputer is designed [6]. It is a good platform for interfacing with many devices at the same time.

Internet of Things and cloud computing are the most emerging technologies. Internet of Things is a concept or a paradigm in which without human interruption devices sense, identify, process and communicate with each other [7]. Cloud computing is a practice of consuming the resource of remote servers such as storage, virtual machines, applications and utilities that are hosted on internet rather than building and maintaining infrastructure for computing in house. Internet of Things becomes very powerful when converges with Cloud computing. IoT cloud system provides a view on accessing IoT resources and capabilities in defined API, configuring and operating it on cloud [8]. The data stored at the cloud can be retrieved any time and the scenarios can be analyzed in a better way leading to the solutions for controlling air pollution to some extent.

II. LITERATURE REVIEW

Phala, kgoputjo et al [2] presented an air quality monitoring system (AQMS) which is based on the IEEE/ISO/IEC 21451 standard.Concentrations of CO, CO_2, SO_2 and NO_2, were measured using electrochemical and infrared sensors. Results are saved in the data server.

Xing Liu, Orlando [4] presented a comparative study on smart sensors, objects, devices and things in Internet of Things. The authors have also explained the definition and concepts of IoT in various different ways. The differences and similarities between the smart objects, smart things in IoT are presented in tabular form.

Marinov, Marin B. et al [3] monitors environmental parameters with amperometric sensors and gas sensors (infrared) using the PIC18F87K22 microcontroller. Sensor nodes are set up in different areas for real time monitoring of environment. The results are displayed on the city map.

Baralis, Elena et al [11] proposes a business intelligence engine (APA). The system is designed to aware the public

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about the quality of air being affected by different factors like pollutants, toxic gases etc. Analysis of air pollution from different perspectives like meteorological data, pollutants and traffic data using APA is done. The system helps the people to realize their activities impact on deteriorating air quality.

Jha, Mukesh et al [7] presented a system for monitoring the environmental parameters, modeling and manipulating micro-climate of urban areas. The system is implemented for the adaption of efficient urban infrastructure after analyzing the urban micro-climate.

Shete., R. and Agrawal S. [6] provides the framework for monitoring the city environment. Low cost Raspberry pi is used for implanting the system. Parameters like carbon monoxide, carbon dioxide, temperature and pressure are measured but no emphasis is given on particulate matter which left the environment monitoring incomplete.

Mitar simic, Goran M. et al [16] presented a system for measurement and acquisition of data of water and air quality parameters and results are shown on IBM Watson IoT platform. The system is battery powered with solar panel based charger unit.

Chiwewe, Tapiwa M., and Jeofrey Ditsela [17] collected air quality data from different cities of South Africa. Machine learning technique was applied to the data and prediction models were generated for ground level ozone.

III. SYSTEM DESIGN

The simplified diagram of the proposed system is demonstrated in Fig.1. Raspberry pi is the major node controlling our system. The sensors are being used for detecting different environmental parameters like particulate matter, Carbon Monoxide, Carbon Dioxide, Temperature, Humidity and Pressure. The sensors are connected to Arduino Board and Raspberry pi is interfaced with Arduino Uno through USB cable. The data sensed by the sensors are continuously transmitted through Raspberry pi to the cloud over the internet because of its good network connectivity. The sensors DSM501A is a PM sensor whose output is PWM, used for measuring the particulate matter i.e. smoke and dust present in our environment, DHT22 and BMP180 are having digital outputs used for measuring temperature, humidity and pressure. The sensors, MQ9 (Gas sensor) as well as MQ135(air quality sensor) are analog sensors used for measuring Carbon monoxide and carbon dioxide.

Arduino Uno is a low-cost microcontroller board based on ATMEGA-328P which can be easily interfaced with Raspberry pi and has a very effective ADC. Since Raspberry pi 2 model B does not have built in Wi-Fi adapter therefore Wi-Fi adapter is used for providing the internet to the complete system. The light weight protocol MQTT (Message Queuing Telemetry transport). MQTT plays an important role in establishing communication between the sensors and the clients. The client can access the data that is being displayed on the dashboard by using the device id but the client will be not able to do any modification to the data received.

The schematic diagram of our system has been shown in Fig.1.

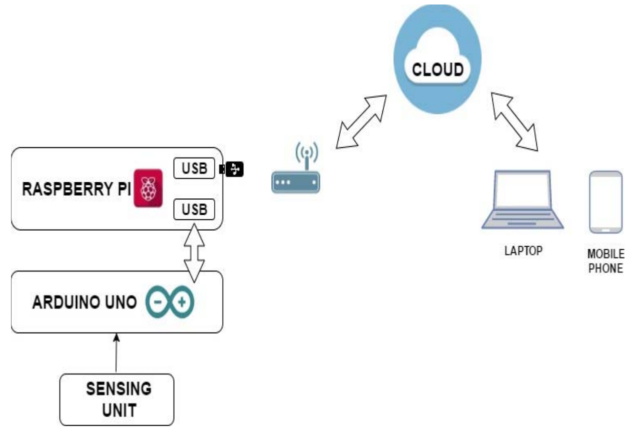

Fig. 1.Simplified diagram of Proposed System

A. *Raspberry Pi*

Raspberry Pi is a single board computer. It has ARM Cortex A7 CPU and 1 GB RAM which makes it a faster and powerful than the previous available models. It has Broadcom BCM2836 quad core processor which is running at 900 MHz but it can be overclocked. It has 4 USB ports, 40 GPIO pins, 1 full HDMI port, 1 Ethernet port, 3.5 mm audio jack and composite video, camera interface (CSI), the display interface (DSI) [6]. It has a separate slot for Micro SD card slot which is used for storing operating system as well as other software's and drivers needed. Raspberry Pi can support different operating systems such as Raspbian, Windows 10, Ubuntu etc. Raspbian operating system is used for implementation of system. Node Red is a visual programming toolfor IoT which is very easy to use. Node Red has an inbuilt library consisting of thousands of flows and nodes which enable the users to connect all kind of devices and services. Once the flow is made it can be deployed and data can be seen on the dashboard.

B. *Sensing Unit*

Sensing Unit comprises of five sensors for monitoring the air pollution. Table 1 shows the technical specifications of the three air quality sensors, Temperature, Humidity and pressure sensors. DSM501A is a low-cost dust sensor module has a very high sensitivity as it can even detect the fine particles having the diameter greater than 1 micron. MQ9 is highly sensitive to carbon monoxide / combustible gases. It has a simple drive circuit and has a prolonged life. With the rise in concentration of the gases in air, conductivity of the sensors also increases. MQ135 has wide scope for detection of NH3, alcohol, CO2, smoke, etc. with a very low response time. DHT22 is a four-pin, resistive type having digital output relative humidity and temperature sensor. BMP 180 is a low-cost sensor used for monitoring barometric air pressure and can also be used as an altimeter as the pressure changes with the variations in altitude.

Table. 1: Air Parameters Sensing

Parameter	Operating Voltage	Measuring Range
Particulate Matter	5 V	10 to 10000 ppm
Carbon Monoxide	1.5 V	10 to 10000 ppm
Carbon Dioxide	5 V	10 to 10000 ppm
Temperature	3.3 V	-40 to +80 degree Celsius
Relative Humidity	3.3 V	0 to 100 % RH
Pressure	5 V	300 to 1100 hPa

C. *Software Architecture*

It involves Node-Red and Integrated Development Environment.

1) Node-RED

Node-RED is an easy to use, fundamental and an open source programming tool for IoT applications. It is highly used visual programming tool which help IoT developers to integrate Hardware devices, APIs and online services in a very interesting and creative manner. Built in Library of Node-Red consist of thousands of flows and nodes that enable the user to connect all kind of devices and services. Flows can be run at the edge of network on the hardware like Raspberry pi or in the cloud since node-red runtime includes node.js. Node-Red provides a simple click mechanism to deploy the flows by the IoT developers to a light weight runtime environment.

2) Integrated Development Environment

Arduino programs can be written in any programming language that has a complier for a conversion of program code into the binary code. IDE is platform independent acting as the base for Arduino hardware. It is a very powerful for programmers, project development professionals and researchers to develop various Arduino projects employing different kind of sensors. Arduino IDE is an open source design/ software which has originated from the integrated development environment for the languages processing and wiring projects. As IDE is platform independent, it can run on Windows, Linux based operating system as well as Mac OS [9]. Some of the key features of IDE include a text console, message area, toolbar for common functions. A program for Arduino using IDE platform is known as sketch, languages like C, C`++ are supported by Arduino IDE for programming.

3) MQTT Protocol

MQTT is extremely light weight connectivity protocol for internet of things applications. It is designed for devices and high latency, low bandwidth, unreliable network. Its mainprinciple is to minimize device resource requirement and network bandwidth. IANA reserved TCP/IP port 1883 for use with MQTT over SSL [12]. Unlike HTTP protocol it does not follow request/response architecture instead it follows publish/subscribe architecture.

IV. METHODOLOGY

Our sensor based Air quality monitoring system measuring the ambient pollution is highly accurate, affordable, easy to use. DSM501A is a PM sensor connected to digital pin 5 of Arduino, DHT22, BMP180 are connected to the Digital pi3 and 4 of the Arduino where as MQ135 and MQ9 are interfaced to analog pin 2 and 3 of Arduino. Arduino is interfaced with Raspberry pi via a USB cable. Raspberry pi is connected to internet with the help of Wi-Fi adapter and the adapter is connected to Raspberry pi at USB port.

Initially operating system has to be installed into Raspberry pi by downloading image from the Raspberry pi official website. The file having .zip extension has to be unzipped to retrieve .img file and write the image to the SD card.
As of November 2015, version of Raspbian Jessie, SD card image is preinstalled with Node-RED and it is necessary to upgrade it. When Pi boots up using the command "sudo systemctl enable nodered.service" Node-RED starts running automatically. In order to use cloud services of IBM, an account is created at IBM Bluemix and at the same time device is to be registered. Once the device is registered, Bluemix IoT platform will acknowledge the user by providing the Auth token which can be used for the communication of data from device to Bluemix IoT platform.

The sensors are already connected to the Arduino board and Raspberry pi is interfaced with Arduino. So, by deploying a flow containing Serial in node to receive the data coming from Serial port to raspberry pi, Serial in node is connected to Watson IoT node for sending the data to the cloud. The data can be seen on the dashboard of IBM Bluemix IOT platform anywhere in the world, only requirement is that device should be connected to internet.

V. EXPERIMENTAL SETUP

As shown in fig.2 the complete setup for the system consisting of sensors, Arduino, Raspberry pi has been shown.

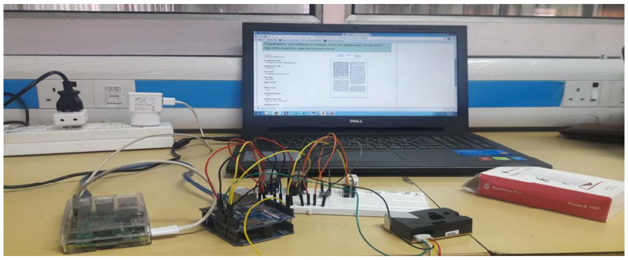

Fig. 2. Experimental Setup

VI. RESULTS

The flow made in our visual programming tool i.e. Node-RED has been shown in Fig. 3. Device Centric Analysis on IBM Watson IOT Platform has been shown in Fig.4

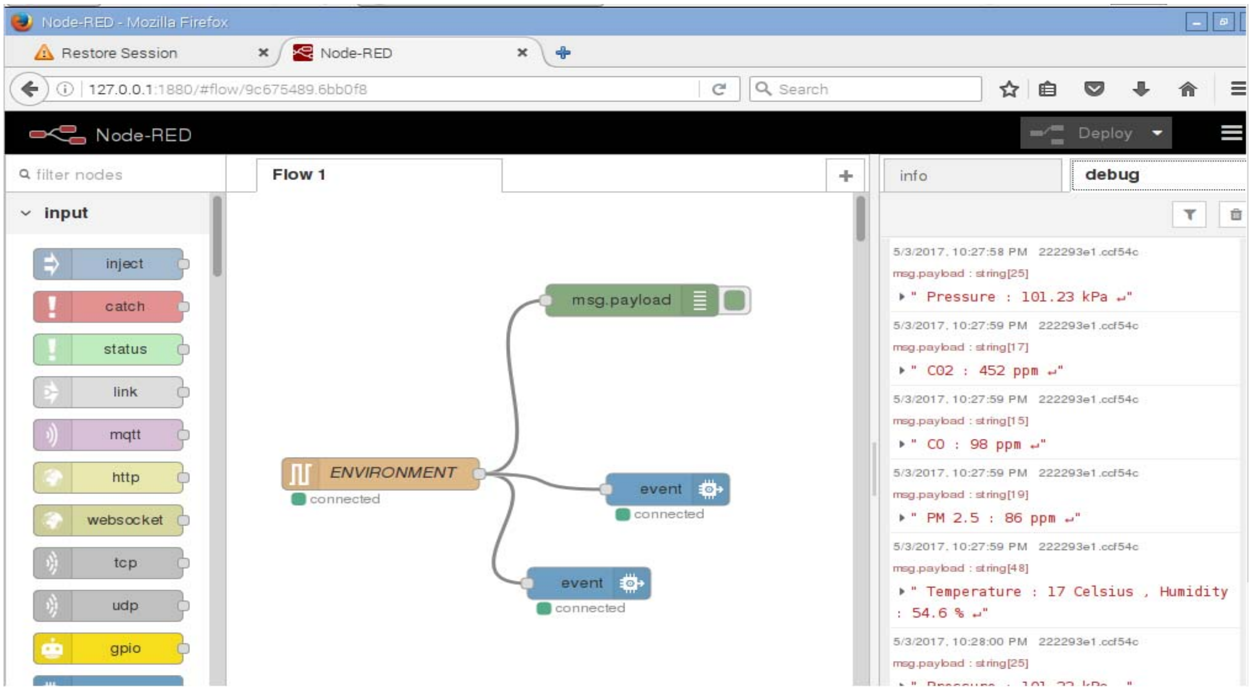

Fig. 3. Node-RED Flow of System

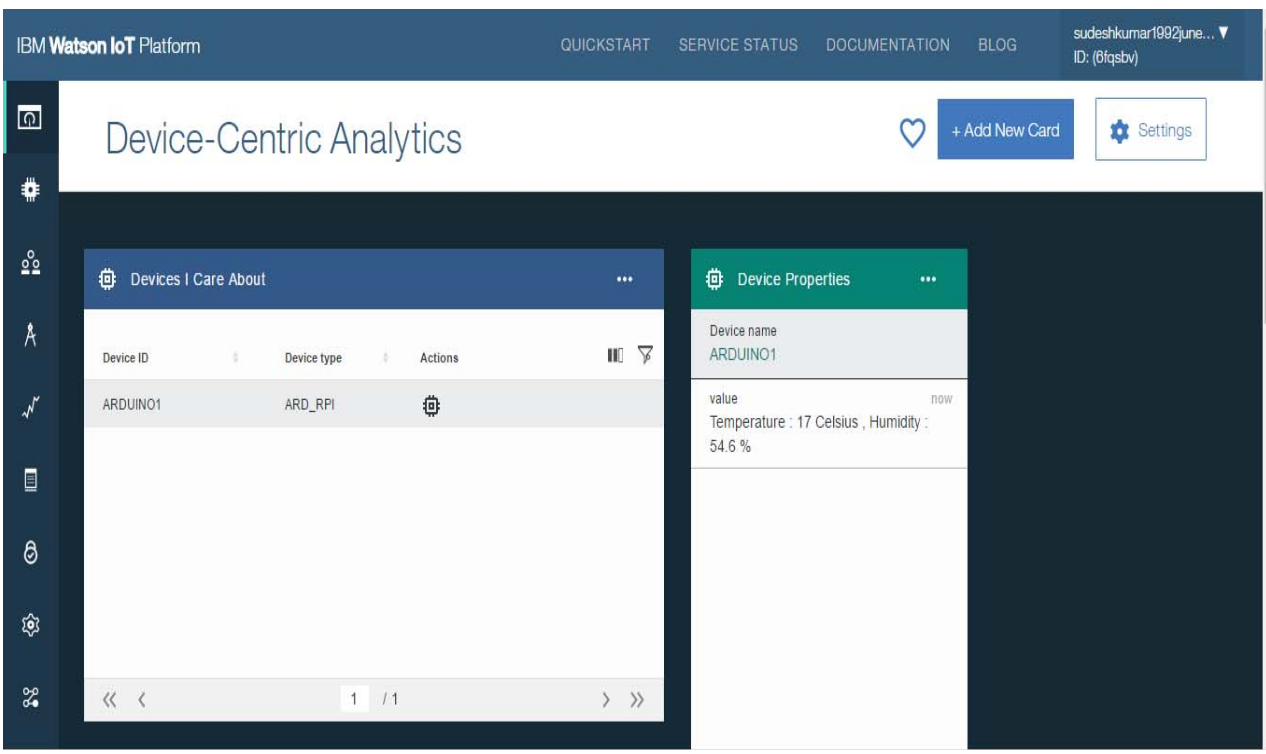

Fig. 4. Device Centric Analysis on IBM WATSON Platform

The parameters being displayed on the dashboard have been shown in Fig.5. Because of the different designs available on IBM Watson platform, the Dashboard presentation looks very appealing.

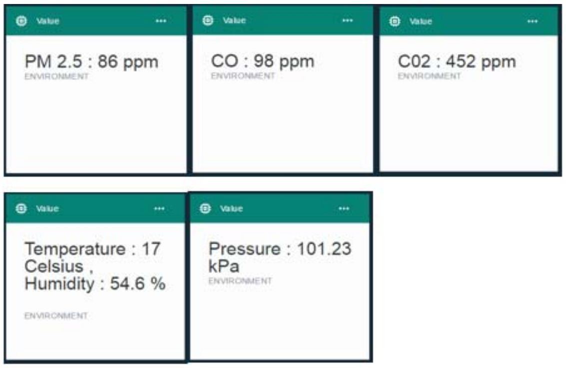

Fig. 5. Dashboard

The values from different sensors are taken in the morning time is shown in Table.2

Table. 2: Results in Morning time

Sensor	Measured Value	Expected Value
PM 2.5 (ppm)	86	90
CO (ppm)	98	104
CO2 (ppm)	452	467
Temperature (Degree Celsius)	17	18
Relative Humidity (Percentage)	54.6	55
Pressure (Kilo Pascal)	101.23	103

The values from differnet sensors are taken in Evening Time is shown in Table. 3.

Table. 3: Results in Evening Time

Sensor	Measured Value	Expected Value
PM 2.5 (ppm)	73	78
CO (ppm)	98	104
CO2 (ppm)	456	470
Temperature (Degree Celsius)	24	25
Relative Humidity (Percentage)	22.4	23
Pressure (Kilo Pascal)	98.3	101

VII. CONCLUSION AND FUTURE WORK

The proposed system provides low cost, low power, compact and highly accurate system for monitoring the environment with the dedicated sensors remotely from any place in this world. A perfect tradeoff between accuracy and cost is achieved by making use of single board minicomputer Raspberry pi and appropriate sensors leading to a well-grounded system. Datasheets available on the dashboard of IBM Bluemix account will help in framing good policies against the increasing level of pollution to ensure healthful environment. Air quality monitoring system can be more advantageous if pollutants like Sulfur dioxide, nitrogen dioxide, ground level ozone etc. are also monitored. Furthermore, long-term pollution patterns can be discovered and certain relationships between the air pollutants can be found.

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