INDOOR AIR QUALITY MONITORING ON AWS USING MQTT PROTOCOL

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***Abstract*— In Modern world, air pollution is becoming a major concern whose effects if not reduced may lead to major health problems. Indoor air quality has been ignored for a long period of time. Since we spend time indoors major, it is important to monitor the air we breathe. Taking appropriate measures in a timely manner relies on the measurement and analysis of the parameters of the air, which demands the need for the development of real time air quality monitoring. Air quality monitoring module is proposed to deal with this problem. In this Internet of things project, indoor air quality is measured by using various sensors. Data is pushed and stored on cloud and for better visualization of data, graphs of real time data are plotted. User is alerted if the indoor air quality is poor.**

Keywords-- Indoor air quality, real time air quality monitoring, Internet of things, visualization, alert.

I. INTRODUCTION

Environment surrounding us is becoming polluted day by day causing serious health issues. Whenever we talk about air pollution it's usually outdoor and we never think of indoor air quality. Indoor air quality can be more harmful to us as pollutants are in more concentration. There are various sources of indoor air pollution. It should be taken seriously since most of the time we spent indoors say in home, office etc. It is necessary to monitor indoor air quality. The existing air quality monitoring modules either use Raspberry Pi (R-PI) or use Arduino so a separate analog to digital converter (ADC) or Wi-Fi module is required in respective cases [1-6]. Device is designed using RPI and grove gas sensor. Since sensor gives analog output, grove pi+ board is used for analog to digital conversion. So, replicating this module becomes costly. Also, the sensor is not very accurate to tell particular gas content in air. Module becomes bulky. Alert is given to user using application which makes it mandatory to have internet connection for notifications [1]. Arduino mega, Wi-Fi module, Zigbee, MQ series sensors are used for device. Two microcontrollers are used for this module and MQ series sensors are not so accurate [2]. In some cases, Arduino mega is used along with Ethernet shield or Wi-Fi module and MQ series sensors. Data is pushed on Thingspeak [3, 4, 5]. To reduce module size, Arduino nano is interfaced with Bluetooth module and sensor MQ135 [6]. Range of Bluetooth module is less than Wi-Fi module. PIC is used in the device along with the sensors. So, different components like ADC, Wi-Fi module etc. are required additionally. Data is stored on database and shown on webpage [7]. Moving module also called as mobile robot is built using Arduino board and R-PI along with GPS to monitor air quality [8].

The proposed Air quality module measures gases like CO2, O2 and it also measures dust. These three sensors are interfaced with Node-MCU ESP8266 also called as Wi-Fi module. This air quality module is placed at different positions. This is simplified design since it solves problem of using two microcontrollers. O2 and dust sensors give analog value whereas CO2 sensor sends data to Node-MCU using Universal Asynchronous Receiver/ Transmitter (UART). Wi-Fi module collects data and sends this data wirelessly to Raspberry pi. Wi-Fi protocol is used so it solves the problem of range. Message queuing telemetry transport (MQTT) protocol is used to send data wirelessly. Here R-PI acts as a gateway and as a MQTT server. R-PI sends data collected from all the air quality modules to Amazon web services (AWS) IoT core. Elasticsearch links AWS IoT core and Kibana. Kibana is used to visualize the real time data on dashboard. Minimum and maximum value is also shown along with real time data in case user doesn't understand exact value of data from graph. The user can access data from anywhere using a link. It is not possible for user to every time

keep an eye on sensor values. So, it becomes important to set an alert system. User is alerted using an email and SMS as well. Since email requires internet access SMS feature is also added.

II. RELATED WORK

Increase in CO2 level results in adverse effects on health like people might feel drowsy, they may suffer headache, restlessness. High concentration of CO2 has direct effect on productivity. CO2 is a gas which has no colour and it is a odourless gas. Carbon dioxide has different sources like human exhaling CO2, fossil fuel and eruption of volcano. On the basis, of place and duration of time, average gas concentration of CO2 is noted as 387 parts per million [4]. Average value of indoor air in ppm is 300 – 2500. But it might cause headache at 2000 parts per million for some people. The adverse effects of being too much exposed to carbon dioxide are bronchitis, asthma, acute or chronic inflammation of lungs. Significant proportion of people suffer from dust allergy if the dust level increases in the air. Deficiency of O2 causes, mental confusion, loss of judgment, loss of coordination, weakness, nausea, giddiness, fainting, loss of consciousness and death.

An IoT prototype is designed that can be used in required geographical area. Results achieved are plotted graphically that eases the users with monitoring the relationship both locally and remotely [4]. Polluino, a system that uses Arduino is designed for monitoring the air pollution. Cloudbased platform is developed that manages data coming from air quality sensors [5]. A crowd-sensing based air quality monitoring module is discussed which is used to monitor air pollution for analyzing sensor's values of the city [6]. An efficient approach given for cost-effective measurement of appropriate environmental parameters that relies on a dynamic or measurable sensor array that combines amperometric and infrared gas sensors [7]. A system is developed that includes an autonomous robot to sense surrounding parameters such as temperature, humidity, moisture and air quality with GPS coordinates and save them on the cloud [8]. Objective of system i.e. streaming of media files via media server using the services of AWS is discussed [9]. MQTT based Secured home automation system is made that uses sensors and Raspberry pi B+ model as the network gateway [10]. UART implemented on virtex II pro Field programmable gate array (FPGA) chip mainly because of low cost, high transfer speed, reprogramming ability and faster time to market is discussed [11]. Hence we can say that the indoor air quality needs to be monitored so, as to live in clean environment.

After inspection of the office environment, renovation was required due to improper ventilation. There was a serious need to monitor CO2 content. Also, it is very important to monitor dust content near devices, equipment. So, Air quality monitoring module (AQMM) fulfills both requirements. Seldom O2 content is monitored, which is important factor in our lives. AQMM measures air content like CO2, O2 and dust. There are modules available which detects CO2 content also dust. But generally we don't see O2 content measured. AQMM has this additional feature. For alert purpose, Email as well as SMS are sent to user. If users want to see values of all modules locally and not through website, they can see it on LCD display connected to R-PI where values from AQMMs placed at various positions are received. Also, Oled is connected to each module which displays sensors' values.

III. THEORY

A. UART:

UART (Universal Asynchronous Receiver/ Transmitter) is a programmed microchip which controls computer and serial device interfacing. Also, it provides computer with RS-232C Data Terminal Equipment (DTE) interface to transfer data with modems and other electronic serial devices. Majority of computers and microcontrollers have multiple serial data ports that are used to communicate with serial input/output devices like keyboards and serial printers. By using a modem directly connected to a serial port, we can transmit serial data to and receive from a remote location via telephone line. This form of serial communication interface that receives and transmits the serial data is called a UART (Universal Asynchronous Receiver-Transmitter). RxD is referred as received serial data signal and TxD is transmitted data signal [11]. As shown in fig.1, for transmitting data, parallel data is converted to serial bit stream. And at receiving end, again the serial bit stream is converted to parallel data.

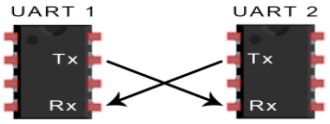


Fig.1 Universal Asynchronous Receiver/Transmitter, UART

It checks parity of incoming bytes and discards parity bits also it adds parity bit on outgoing transmissions. It adds start and stop bits on outgoing transmissions and at receiving end, it is separated. It can do device management by handling speed of operation of computer and device speed. It also handles interrupts from mouse and keyboard.

B. MQTT PROTOCOL:

As shown in the fig.2, this protocol works on publish and subscribe communication method. It performs a crucial role in the applications of internet of things and is used for machine-to-machine i.e., M2M communication [10]. MQTT (MQ Telemetry Transport) is lighter communicating protocol. It gives resource-constrained client a simpler method in telemetry system to distribute data [10]. MQTT protocol works on client-server communication. Client can either publish or subscribe to a particular topic whereas server can publish as well as subscribe. Server receives data from publisher and sends it to all the clients those are subscribed to that specific topic. It works on port 1883 which is default TCP/IP port. MQTT of various types are available like PAHO MQTT, HIVEMQ, MOSQUITTO[10]. In this case, Mosquitto is used.

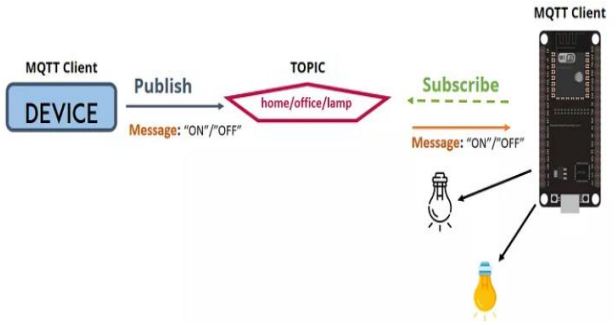


Fig.2 Publish and subscribe using MQTT protocol.

C. CLOUD:

For storing data, it is pushed on cloud. In this project sensors' data is pushed on AWS because of following features:

i) Scalability: In AWS one can increase the number of servers whenever there is an increase in demand for the service. When more users get involved in uploading a particular video, one can easily scale the usage of servers in easy steps. For example: -A particular instance can be scaled from micro instance to small instance.

ii) Flexible capacity: As the number of servers increases it is essential that one needs to increase the memory which can be done in simple easy steps.

iii) Low ongoing cost: There is no upfront cost required or involved in the making of media server. The user is not required to pay for using this system.

iv) Speed and Agility: Speed is high because there are many high-speed network connections within AWS components.

v) Global Reachability: Reaching the people on a global level is as simple and effective with cloud front.

vi) Security: The security of this project is high as one can limit the usage of various users using Identity and Access Management (IAM).

vii) No upfront investment: No investment is required in setting up servers and maintaining them.

viii) Focus on the project and not on architecture: The mentioned features of Cloud made to focus on the project rather than the architecture [9].

D. RASPBERRY PI:

Raspberry Pi is a single board microcomputer which is useful device for embedded and IoT applications. The RaspberryPi3 has an on-board Wi-Fi with which one can directly connect it to internet for sending and receiving data. It also has an Ethernet adapter to connect it to a router which has network connectivity for remote controlling via port forwarding. All Internet of Things applications need internet connectivity so easy access and no separate interfacing for Wi-Fi makes the coding easier.

As shown in fig.3, Raspberry Pi acts as a MQTT broker and the end to end flow of data. The Raspberry Pi is basically like a credit card-sized single-board computer that communicates with the cloud operating system like Open Stack. It is based on the Linux platform that supports the functionality of cloud environment. Once every minute all the sensor readings are stored in the cloud server through wireless communication using a Wi-Fi device and R-PI board [8].

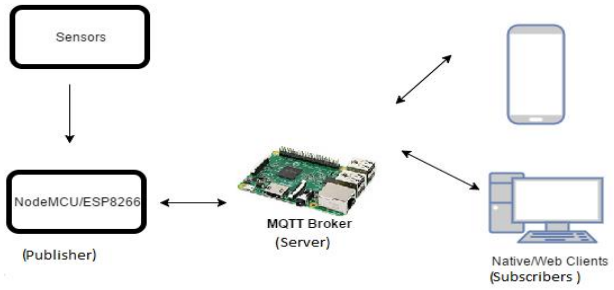


Fig.3 Flow of data

E. SENSORS:

To monitor air quality various factors like CO2 and dust is measured along with O2 content. For this purpose, sensors used are GP2Y20100UF Dust sensor, MH-Z19 CO2 sensor and Gas grove sensor O2. Grove-Gas Sensor (O2) is a sensor deployed to determine the oxygen concentration in air. It uses the principle of the electrochemical cell. MH-Z19 NDIR infrared gas module is a small size sensor which incorporates non-dispersive infrared (NDIR) principle to detect the existence of CO2 in the surrounding air, with best selectivity, long life and non-oxygen dependent. Inside a Dust sensor, an infrared emitting diode (IRED) and a phototransistor are placed diagonal to each other. Incident light of IRED is reflected due to dust particles and is detected by phototransistor. CO2 PWM value can be calculated using following formula:

$C_{ppm} = 2000 \times (T_H \times 2ms) / (T_H + T_L - 4ms)$ ppm

Where, T_H is time for high level during an output cycle;

C_{ppm} is calculated CO2 concentration, unit is ppm; T_L is time for low level during an output cycle.

IV. MODULE IMPLEMENTATION FOR AIR QUALITY MONITORING

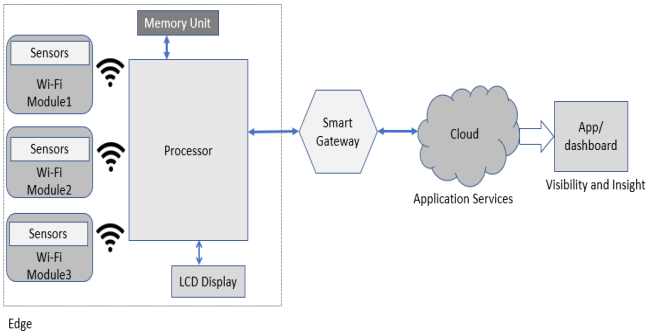


Fig. 4 Schematic diagram of Air quality monitoring module

As shown in the fig. 4, at the edge end, sensors are interfaced with Node-MCU ESP8266 which is also called as Wi-Fi module. ESP8266 allows microcontroller to get

connected to the Internet through Wi-Fi. Moreover, ESP8266 has a full TCP/IP protocol stack integrated on the chip [5]. These modules are placed at different locations in a room and send data to Raspberry pi over Wi-Fi. LCD display is connected to the R-PI to display received values. The sensor data is received using MQTT protocol. Now, data is pushed on cloud through gateway and displayed on app or dashboard. Below fig.5 shows detailed block diagram of air quality monitoring module. O2 sensor and Dust sensor gives analog output. Since the Node-MCU has only one analog pin, MUX is used to increase the analog inputs. CO2 sensor communicates with Node-MCU using UART protocol. LED is also connected to indicate sensor's value exceeding threshold. MQTT client is installed in the Wi-Fi module to communicate with R-PI. Considering the environment as an industry, for each cubicle air quality monitoring module will be deployed.

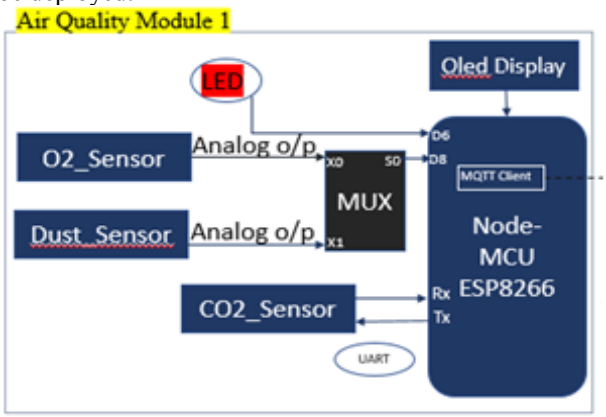


Fig.5 Block diagram of Air quality monitoring module

In this project indoor air quality is monitored and pollutants like CO2, dust are detected along with O2. Sensors are deployed in the house or an industry at various places where human presence is prominent. Sensors send data collected to the raspberry pi wirelessly. Node-MCU ESP8266 Wi-Fi module is used to make the sensor wireless. ESP8266 has in built microcontroller and can be programmed using Arduino IDE. According to the data collected by the sensors, necessary steps will be taken like glowing a LED or buzzing if data found to be above the threshold. Also, the data is sent to the cloud and can be accessed through a webpage. Graph is plotted for better visualization of the status of the air quality. User can get alert through SMS or via email. Oled display is interfaced with Node-MCU ESP8266 to display sensor's values.

V. FLOW OF DATA ON AWS

As shown in below schematic diagram, the sensor data that is collected by R-PI is pushed to AWS IoT, it has MQTT client installed. To visualize this data, Kibana is used. Various graph charts are available. Also, mathematical functions are applied on the data and then it is plotted. Sensor data received by AWS IoT is sent to Kibana through Amazon Elastic Service.

Fig.6 Schematic diagram of data flow on AWS

VI. COMPARISON OF IOT COMMUNICATION PROTOCOLS

MQTT has very short message header also smallest packet size whereas HTTP has got lengthy headers and messages. MQTT has various benefits like it is easy to use, power consumption is less, bandwidth usage is low, response time is less and its throughput is high. So, for above reasons MQTT is selected over HTTP for IoT development.

VII. RESULTS AND DISCUSSION

Following images show casing, PCB of AQMM and the data that is pushed on AWS IoT core. Also, data discovered by Kibana and data shown on dashboard. Alert sent to the user by Email and SMS is shown in the below figures.

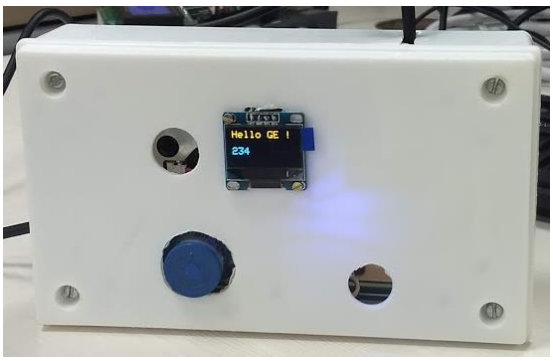


Fig. 7 Casing of AQMM

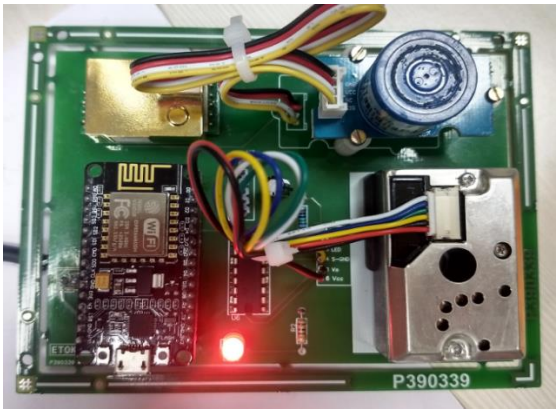
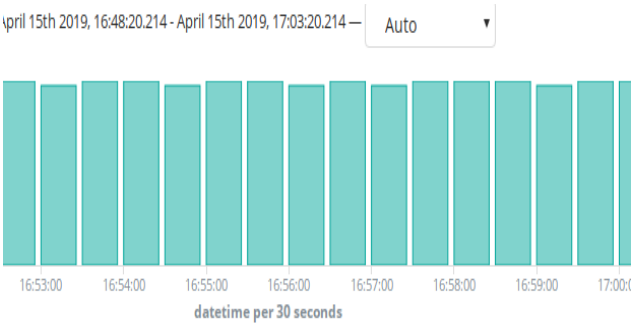


Fig.8 PCB

Fig.9 Data pushed on AWS



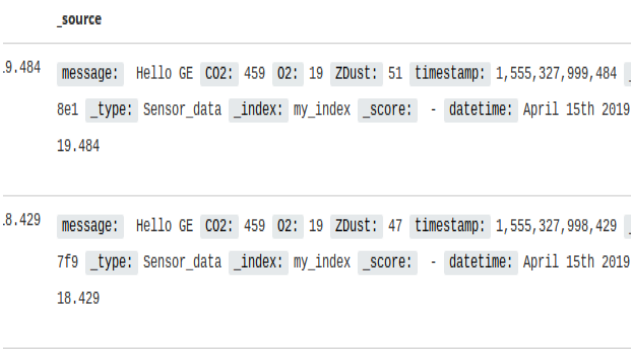


Fig.10 Data discovered by Kibana

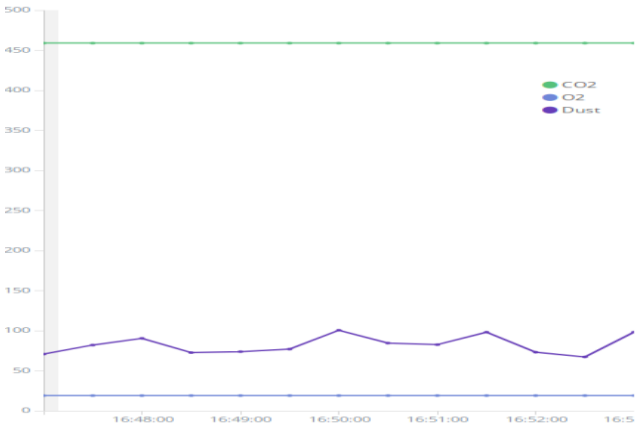


Fig.11 Line chart on Kibana

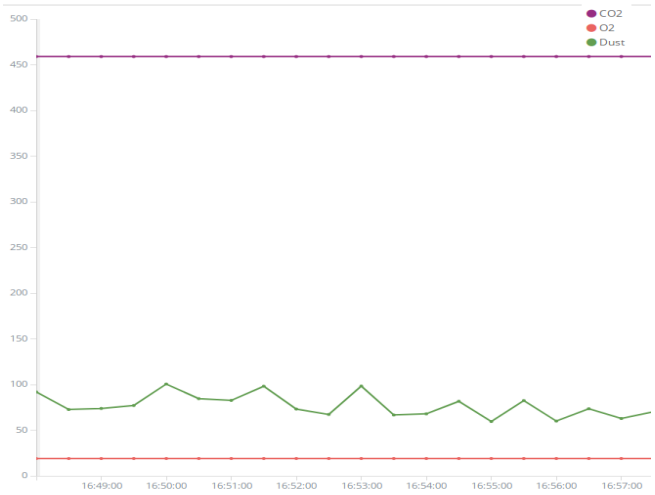


Fig.12 Visualization using Kibana

Average CO2	Max CO2	Min CO2
459	459	459

Average O2	Max O2	Min O2
19	19	19

Average ZDust	Max ZDust	Min ZDust
77	80	72

Fig.13 Table on Kibana showing Avg., Max. and Min. value

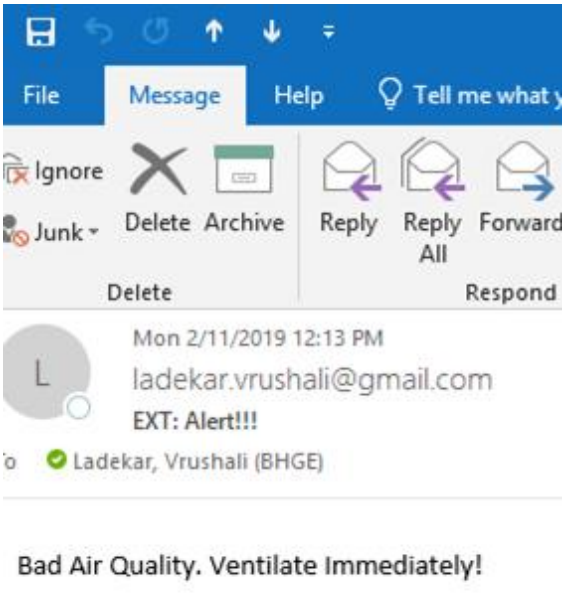


Fig.14 Alert sent to user via email

Fig.15 Alert sent to user via SMS

Field Protocol (Wi-Fi) and cloud protocol (MQTT) are chosen. Mosquitto for R-PI is installed and tested by publishing and subscribing to MQTT Topic. Sensor data is successfully sent to R-PI wirelessly using Wi-Fi module. Data received is shown on LCD. Later it is sent to AWS IoT Core. Using Kibana, graph is plotted for better visualization. Sensors which can be used further are listed. Out of which three are finalized (MH-Z19, Grove Gas sensor, GP2Y2010AU0F). Power Consumption of module is estimated. Alert is sent via SMS or email.

CONCLUSION & FUTURE SCOPE

In this paper, air quality monitoring module is implemented using various sensors interfaced with NodeMCU ESP8266. This device monitors indoor air quality. Parameters like CO2, O2 and dust are measured. Data from various modules is received successfully by Raspberry pi and is pushed on cloud. Alert is also generated promptly if the data hits threshold level. Email and SMS is sent to alert the user. Communication between the air quality sensors with the Cloud platform is made based on IoT principles. Based on the results and easy implementation, the air quality monitoring module is promising in terms of cost and performance. This module is useful in various indoors places like IIOT, Indoor air quality monitoring in houses, schools, offices, banks, hospitals etc. Mines or working area where oxygen level might go low. Range of the air quality monitoring module is confined to smaller area. So, multiple modules will be required for larger area to monitor indoor air.

The scope of air quality monitoring module can be expanded by using more sensors of different kind. Actuators can be used to take some action when air quality is poor. Module can work in active mode and rest at sleep mode using switch for efficient power use. Based on data collected future value can be predicted using ML and AI.

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