AirSense : Smart air quality monitoring and reporting tool using IoT devices and cloud service

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***Abstract*— In urban areas, exposure to indoor air pollution is expanding because of numerous reasons, including the construction of more tightly sealed buildings, reduced ventilation, the use of synthetic materials for building and furnishing and the use of chemical products, pesticides, and household care products. Indoor air pollution can start inside the building or be attracted from outside. Other than nitrogen dioxide, carbon monoxide, and lead, there are various different toxins that influence the air quality in an encased space. The most susceptible groups to indoor pollution are women and children because women lung sizes are significantly smaller to male counterparts and lung volume to body volume proportion of children is significantly higher than adults. Indoor air pollution monitoring requires equal attention as outdoor pollution. With advent in sensor technology and studies showing harmful effect of indoor air pollution it is important for us to start monitoring the air quality inside our schools, offices, hospitals, home and other places. The nature of air is influenced by multi-dimensional elements including area, time, and unverifiable factors. As of late, numerous specialists started to utilize the big data investigation approach because of headways in big data applications. Sensors build on powerful Arduino board and wi-fi networking units are tested to monitor air quality of three parameters; suspended particles, organic vapors and humidity. These key parameters are monitored over period of time, the time series data is stored in cloud service, and machine learning is applied to find ways to predict and manage air quality. The paper presents the IoT device architecture, cloud application architecture and sample results for an indoor test environment. Mobile and web-based visualizations were created for the data collected from the sensors. An alarm system is also developed to notify the user when the air quality deteriorates to unhealthy level.**

***Keywords*— Indoor Pollution, IoT, Big Data, Machine Learning, Arduino, Visualization, Mobile Application, Gas Sensors**

I. INTRODUCTION

Indoor air pollution monitoring requires equal attention as outdoor pollution. Indoor air pollution is the spoliation of the air in shut spaces inside homes, workplaces and other work-related spots. The indoor air pollutants distinguished by specialists incorporate NOx, SO2, O3, CO, unstable and semi-volatile natural mixes, particulate matters, and microorganism. Other than nitrogen dioxide, carbon monoxide, and lead, there are various different toxins that influence the air quality in an encased space. Because of the restricted space of indoor conditions accessible for these gases to scatter, indoor pollution has been recognized to be more destructive to people than open air contamination [1]. It is assessed that 70%-90% of the season of a person's life is spent inside [2], so the nature of indoor air impacts a man's wellbeing. The most susceptible groups to indoor pollution are women and children because women lung sizes are significantly smaller to male counterparts and lung volume to body volume proportion of children is significantly higher than adults. Therefore, indoor air quality monitoring (IAQM) is of great importance to human health [3]. Indoor condition incorporates workplace (office) and living condition, for the previous, one may invest 40% of the indoor time in. With the expansion of sensibly precise sensors, Indoor Air Quality (IAQ) can be dictated by estimating different elements through the sensors introduced in a given space. Such estimations can be utilized to identify changes in the climatic state [4]. This paper presents the IoT device architecture, cloud application architecture and sample results for an indoor test environment. Mobile and web-based visualizations were created for the data collected from the sensors. Our IAQM system, 'AirSense' provides real-time monitoring of the pollutants along with a safety level indicator.

II. LITERATURE SURVEY

Many researchers have already studied the issues related to IAQ and including various problems faced by the people across the world. Almost all of these works including the most recent one's state that these studies are still inconclusive, and more study is needed to be carried out to understand the complete health issues caused by the exposure of the harmful pollutants. Different indoor air quality investigations have inspected the air quality in present day vitality productive structures [5]. The parameters estimated have included air temperature, relative humidity and CO_2 concentration. Benammar et al. [3] provides a detail review of the past related works on IAQM.

In the paper, Brienza et al. [6,3] the authors introduced a cost-effective monitoring tool that permits a continuous checking of the convergence of some polluting gases in different regions of a city. In this arrangement, the framework is restricted to open air AQM and at every area singular sensor boards are introduced to post the data estimations specifically through the internet to a server. Their framework is extremely fascinating since it empowers online show of the data estimations. This framework is committed for clients with particular end-client gadgets.

In the paper, Lambebo and Haghani [7,3], the authors implemented a real-time temperature and greenhouse gas concentration monitoring system using Wireless Sensor Network (WSN). The gateway is an open source hardware based on Arduino Uno Microcontroller and radio module XBee IEEE 802.15.4 for the ZigBee communication. The gateway guarantees the relay of data to WiFi network and the procurement of data estimations from all the local sensor nodes.

In the paper, Fioccola et al. [8,3], the authors portrayed a framework in light of Arduino board and a cloud-based stage that oversees information got from AQ sensors. An examination between two distributed computing administration models and between two IoT correspondence conventions has been performed. In any case, the displayed framework depends on wired innovation, which restrains the portability of the sensors and their situating.

In the paper, Tsang et al. [9,3], the authors outlined a ZigBee network for IAQ monitoring framework. They presented an energy sparing ZigBee WSN network with low inertness and high throughput. In their work, the authors have proposed a recreation of WSN for IAQM without usage and arrangement of embedded devices.

In the paper, Postolache et al. [10,3], the authors exhibited a WiFi-based network for IAQM. The framework consolidates sensor information preparing in light of neural networks for the identification of air contamination occasions and sensor's abnormal task. Their system is still in laboratory.

In the paper, Jelicic et al. [11,3], the authors presented a WSN for IAQM that highlights individual's presence detecting and action recording [12]. The authors constrained their investigation to simulate the power utilization of a small WSN in an IAQM situation.

In the paper, Kim et al. [13,3], the authors dissected the issues, framework, data processing, and difficulties of outlining and executing an integrated sensing framework for continuous IAQM. The sensor hub depends on the MPU MSP430 small scale controller, the RF chip CC2500 and a few gas sensors. The arrangement did not handle the issue of data unwavering quality when there is no Internet connection.

In the paper, Firdhous et al. [14,3], the authors proposed an IoT-based IAQM framework restricted to checking O3 concentrations near photocopy machines. The IoT gadget speaks with an entryway hub over Bluetooth, which in turn communicates with the preparing hub by means of Wi-Fi. The framework proposed by the authors is restricted to the observing of ozone delivered in workplaces by the photocopier machine.

In the paper, Hassan et al. [15,3], the authors designed a wireless electronic nose to identify wellbeing imperiling gases in indoor conditions. Their work concentrated on the gas distinguishing proof utilizing encoding models. In spite of the fact that the approach offers a lessened computational power and memory necessity, the work was restricted to some mathematical tools, which were not approved against AQ information from any site.

In the paper, Chen et al. [16,3], the authors depicted a framework for checking CO_2 in indoor conditions. The fundamental spotlight was on furnishing individuals in these conditions with data on CO_2 levels through their cell phones, which read brisk reaction (QR) codes.

III. BLOCK DIAGRAM AND SENSORS

The proposed air pollution monitoring is based on the block diagram as shown in Fig. 1. The data of IAQ is recognized by MQ135, MQ7 Gas Sensors and DHT11 Temperature and Humidity Sensor. When the gas sensors are connected to ESP8266 Module, it senses all the gases and it gives the Pollution level in PPM. Both the gas sensors give the output in the form of voltage levels and we have to convert it into PPM. For this conversion, we have used a library for MQ135 sensor.

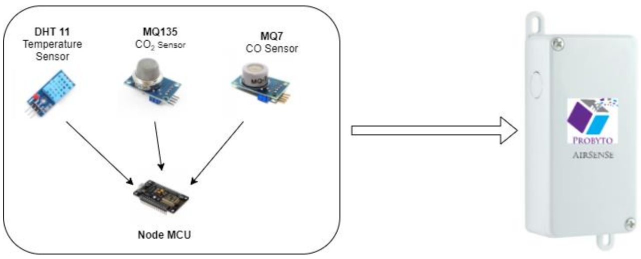

Fig. 1. Block Diagram of the proposed architecture

The different components of the equipment along with their intended purpose are discussed below.

A. MQ135 SENSOR

MQ-135 gas sensor applies SnO_2 which has a lower conductivity free air as a gas-detecting material. In an environment where there might be pollutants, the conductivity of the gas sensor raises alongside the concentration of the contaminating gas increments. MQ135 has numerous highlights like wide identifying range, quick response, high sensitivity, steady and long life. It can sense NH3, NOx, alcohol, Benzene, smoke, CO_2. So, it is a dynamic gas sensor for our IAQM system.

B. MQ7 SENSOR

This is an easy to-utilize Carbon Monoxide (CO) sensor, reasonable for detecting CO concentrations noticeable all around. The MQ7 can distinguish CO-gas fixations somewhere in the range of 20 to 2000ppm. It has a high sensitivity and quick reaction time.

C. DHT11 SENSOR

DHT11 Temperature and Humidity Sensor guarantees the high dependability and fantastic long-haul solidness. This sensor incorporates a resistive component and a sensor for wet NTC (Negative Temperature Coefficient) temperature estimating gadgets. It has amazing quality, quick response.

D. NODE MCU ESP8266 (WI-FI MODULE)

The ESP8266 Wi-Fi Module is an independent SOC with integrated IP protocol stack which gives any microcontroller access to a Wi-Fi network [17]. Each ESP8266 module comes pre-modified with an AT order set firmware. The ESP8266 module is a to a great degree financially savvy Board. This module is ground-breaking for on-board processing and storage ability that enables it to be incorporated with the sensors and other application particular devices through its GPIOs with negligible advancement in advance and insignificant stacking amid runtime [17]. It has high level of on-chip integration that takes into account for minimal external circuitry, including the front-end module, is intended to possess negligible PCB area. The Wi-Fi module underpins APSD for VoIP applications and Bluetooth co-existence interfaces, it contains a self-aligned RF enabling it to work under every working condition and needs no external RF parts. There is a relatively boundless wellspring of information accessible for the Wi-Fi module, all of which has been given by astonishing community support.

IV. PARAMETERS AND STANDARDS

The motivation behind the IAQM system is the current importance of factors like temperature, relative humidity, CO_2 and CO in closed server rooms with machines generating a lot of heat, hospitals, laboratories, factories and also normal homes. In industries it is very important to maintain a certain level of temperature and relative humidity for a slight change in them might lead to drastic consequences.

The different effects are discussed below with their respective standards and consequences. The standards are taken from the association named The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

A. TEMPERATURE

Temperature directly impacts on perceived comfort and, in turn, concentration and productivity. According to ASHRAE Standard 55, the suggested temperature ranges apparent as "comfortable" are 73 to 79°F (22.8 to 26.1°C) in the summer and 68 to 74.5°F (20.0 to 23.6°C) in the winter.

B. HUMIDITY

Too high RH can add to the development and spread of organic contaminants and individuals think it feels 'sticky'. RH beneath 25% builds distress and drying of skin and mucous layer. According to ASHRAE Standard 55, indoor humidity levels ought to be kept up between 30 percent and 65 percent for ideal comfort..

C. CARBON DIOXIDE (CO_2)

CO_2 gives great sign of ventilation rates. It produces in indoor fundamentally through human metabolism. CO2 develop in indoor is credited to inefficient or non-functioning of ventilation system. According to ASHRAE, over 1000 ppm CO_2 – requires alteration of building's ventilation framework. Building indicates Sick Building Syndrome (SBS) side effects if CO_2 focus > 1000 ppm.

D. CARBON MONOXIDE (CO)

Carbon Monoxide (CO), is often called the “Silent Killer”. It is an odorless, colorless gas formed by the incomplete combustion of fuels. According to ASHRAE, maximum recommended indoor CO level is 10 ppm.

The risk of higher concentration levels of pollutants, for e.g. CO_2 and CO, are given in detail in the below tables.

TABLE I. DIFFERENT TYPES OF POLLUTANTS AND ITS EFFECTS [18]

POLLUTANTS	SYMPTOMS
NO_2 Type	Irritation to the skin eyes and throat, cough, etc.
CO Type	Headache, shortness of breath, higher conc. May cause sudden deaths.
Formaldehyde Type	Irritation to the eyes, nose and throat, fatigue, headache, skin allergies, vomiting etc.
SO_2 Type	Lung disorders and shortness of breath

TABLE II. CO_2 AND ITS EFFECTS [18]

CONCENTRATION CO_2 (IN PPM)	SYMPTOMS
350 - 450	None
600 - 800	Acceptable indoor air quality
1000-2000	Drowsiness and poor air
2000-5000	Average exposure limit over 8 hours then headaches, sleepiness, loss of attention, increased heart rate and slight nausea may also be present.
> 5000	Toxicity or oxygen deprivation, permissible exposure limit for daily workplace exposures
> 40,000	Sudden unconsciousness, death

TABLE III. CO AND ITS EFFECTS [18]

CONCENTRATION CO (IN PPM)	SYMPTOMS
< 30	None
30-60	Slight headache, nausea
60-90	Dizziness, Slight increase in respiratory rate, drowsiness
90-150	Impaired judgement, increasing drowsiness, stomach pain
150-200	Confusion, Blurriness, Shortness of breath, Memory loss, Chest pain
> 200	Seizure, Unconsciousness, Death

E. WORK ARCHITECTURE

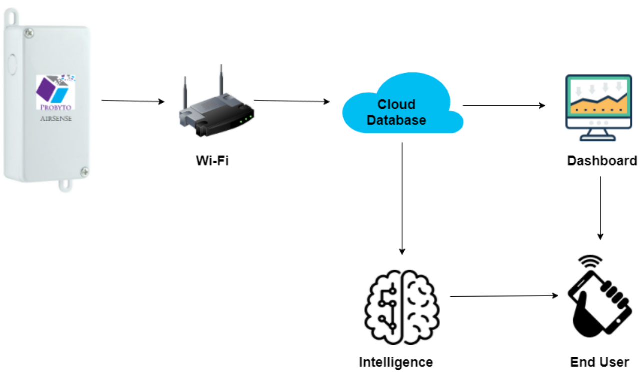

Fig. 2. Flow chart of the Work Architecture

The initial arrangements are made by installing the ESP8266 Module with the Arduino IDE. ESP8266 runs at 5V applied by the power supply. If the supplied voltage exceeds 5V, the module has a high probability of getting damaged. ESP8266 builds access to Wi-Fi network and can communicate with any microcontroller, being one of the most leading devices in the IoT platform. A brief description of the architecture has been shown in the Fig. 2.

As mentioned above, in this paper we are presenting the working principle of three different sensors. We begin with the Temperature and Humidity Sensor, DHT11 by connecting it with the ESP8266. The data pin of this sensor (DHT11) is connected to GPIO-02 of the Wi-Fi module. This highlights a calibrated digital signal output with the temperature and humidity sensor capability. Another two sensors, MQ135 and MQ7 are also connected to the same Wi-Fi module.

These three sensors are then calibrated, so as to increase its efficiency. The calibration was done in an indoor environment for almost 24 hours. However, MQ135 sensor was again calibrated in an outdoor environment for an additional 10 minutes. The integration of the circuit was initialized after the successful calibration of the sensors.

Two different sensors are integrated in a single ESP8266, using its same analog pin A0. Therefore, we have provided a delay between them, so that the data collected from both these sensors maintains high efficiency. The respective VCC and GND pins of these three sensors are connected to the VCC and GND pins of ESP8266 Module. Fig. 3 describes the detailed circuitry of the IAQM system.

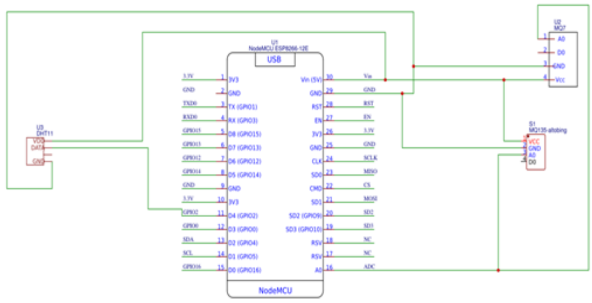

Fig. 3. Circuit Diagram of IAQM using ESP8266

Once the circuitry is in the saddle, the Wi-Fi network is connected to the arrangement via the Arduino IDE Serial Monitor. Considering the device will collect large amount of data in long run we can't choose relational database model. Hence the data is dumped into the cloud as JSON files. These files are retrieved to have a real time visualization with powerful BI tools. In this paper, we have presented four different plots showing temperature (degree Celsius), humidity (%), CO_2 (in ppm), CO (in ppm) values in real-time.

V. RESULTS

Our IAQM system monitors four parameters in real-time, such as CO, CO_2, Humidity and Temperature. We have visualized the parameters using a web application which gives us the real-time data of the parameters along with a safety level indicator as seen in Fig. 4.

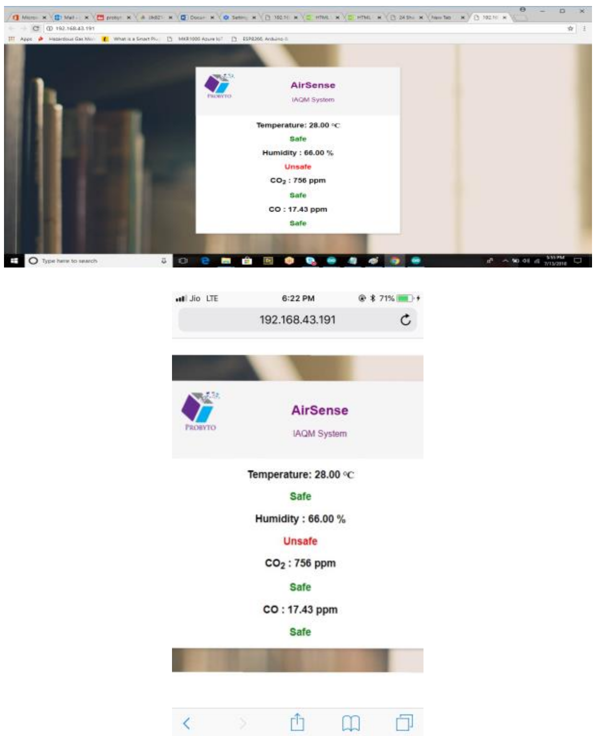

Fig. 4. AirSense's web-based UI in both PC and Mobile Phone

The real-time concentration level and variations of the pollutants, for a duration of almost 3.5 hours are shown in Fig. 5, 6, 7 and 8. The parameters were obtained in an indoor environment after calibration. A certain change in the nature can be seen as the data was varying with time, due to the several factors like Air Conditioner, Fan, Number of persons present in the room, Ventilation etc.

Moving Average tells us how the overall movement of CO_2 level is expected in next 30 mins by averaging out previous 30 mins of CO_2 level. On top of the average values, we mask a 95% confidence interval by measuring variance in last 30 mins and using that as variance in prediction as well.

The 95% Upper Limit is defined as Prediction + 1.96*SD and Lower Limit is defined similarly as Prediction - 1.96*SD. The two limits show what the best possible air quality levels inside house in the next following hours.

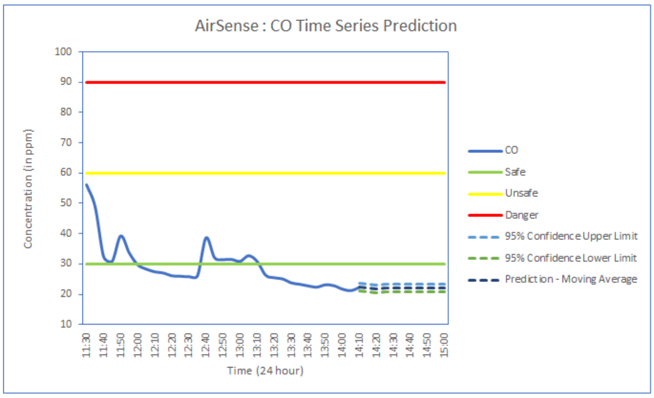

Fig. 5. AirSense's time-series prediction of CO

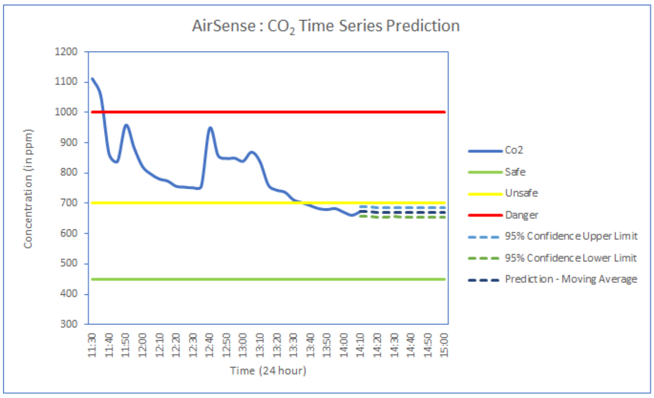

Fig. 6. AirSense's time-series prediction of CO_2

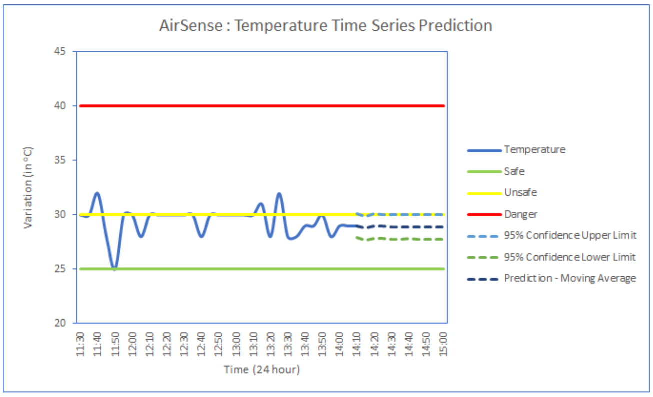

Fig. 7. AirSense's time-series prediction of Temperature

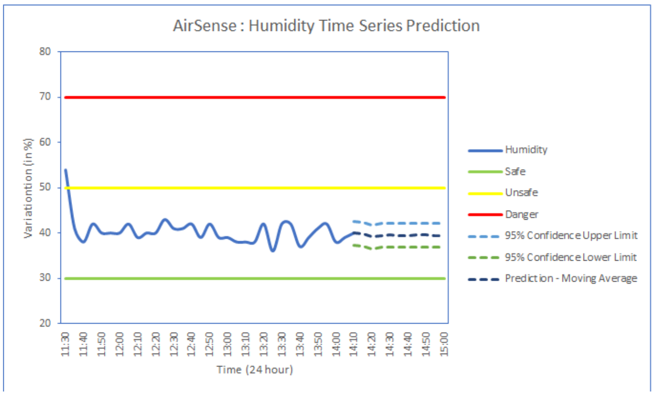

Fig. 8. AirSense's time-series prediction of Humidity

VI. Conclusion

The complete Indore Air Quality Management System is developed combining sensors, technology backbone and cloud to allow Machine Learning for in-depth insights. The whole system is a developed in-house as a ready to go unit. The data collected from various installations will be shared with research community and data scientists for developing Machine Learning algorithms and understand in-house environments dynamics.

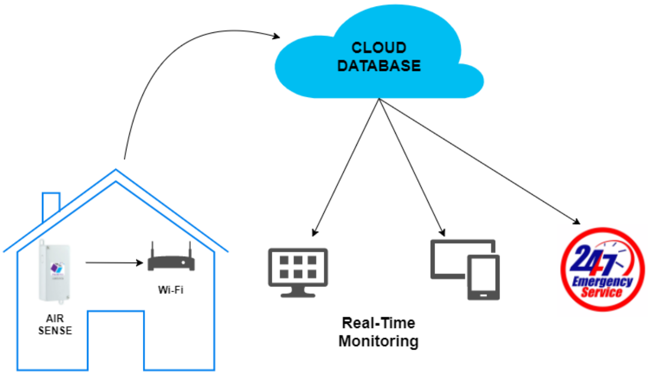

Fig. 9. AirSense Complete IAQMS System

The applications deliver to three key users of the real time monitoring; monitoring at public places by display, online/mobile notifications to users, and for extreme cases directly connect to emergency services for alarm.

AirSense deployed in real situation will allow the team to collect real time data and do further improvements in the features of the whole system.

Acknowledgment

This work is supported by PROBYTO Data Science and Consulting Pvt Ltd and is being developed during Data Science Summer Camp 2018.

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