Indoor Environment Air Quality Monitoring and its Notification to Building Occupants

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***Abstract* – In this article, assistive technology has been developed for Mobile SMS notification and Email which can be used in real time for the indoor environment and provide the information of indoor Air Quality Index (AQI). AQI is generally used to give the severity of pollution level to building occupants. This assistive technology monitors indoor environmental parameters such as temperature, humidity, heat-index, carbon monoxide, and carbon dioxide which are responsible to affect occupant's fitness and indoor workplace if not properly ventilated. This technology consists of AQI monitoring sensor node having electrochemical and non-dispersive infrared gas sensors. ESP8266-01 wi-fi module is being used for AQI data transmission. Toxic gas parameter values will be measured in parts per million (PPM). The environmental information measured by the sensors will be sent to building occupants through Mobile SMS and Email.**

***Keywords* – Indoor Environment, Microcontroller, Gas Sensors, Wi-fi Module, Air Quality Index (AQI).**

I. INTRODUCTION

Indoor air quality (IAQ) is the most important parameter to ensure the health and relaxation level of the human being because working capability might be disrupted by reason of the polluted surrounding condition and poor indoor air quality. N. Sabrani et al. [1] surveyed that 80 - 90% of people spend their time in the indoor environment such as houses, offices, and schools. R. K. Kodali et al. [2] indoor air pollution is a vital reason for the infection, lethal and others, looked by the developed world. Passing the measurements arranged and released by the World Health Organization (WHO), approximately 4.6 Million deaths in the world are caused by the illnesses straightly accelerated via air contamination, for example, Bronchitis, Asthma, lung cancer, Emphysema, Respiratory allergic reaction, and other heart problems. Not just sicknesses and disorders, however air contamination additionally prompts the degradation of nature and living surrounding the word, particularly in urban zones.

Assistive technology-based framework is an innovative approach in the indoor environment monitoring system. Researchers are already studying indoor environment monitoring with numerous methods. Mostly peoples have worked in various harmful gases, for example, CO, CO_2, CH_2O, O_3, SO_2, CH_4, and others. Basically, gas sensors are used to detect the indoor air quality and this information can be introduced to the building occupants.

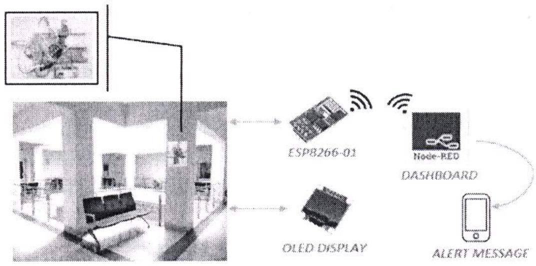

Fig. 1 IAQM proposed framework

USEPA [3] describes the national air quality standards confer to five air pollutants. EPA advises needing the level of seven pollutants like PM, NO_2, O_3, CO, and SO_2 to measure the air quality value. To calculate the air quality index using concentration value, breakpoint and AQI mathematical statement matured by US EPA. Mathematically AQI formula:

$$I_p = \left(C_p - BP_{low}\right) \text{ x } \frac{I_{high} - I_{low}}{BP_{high} - BP_{low}} + I_{low}$$

Where: I_p = The Index for pollutant p, C_p = The pollutant concentration p, BP_{High} = The breakpoint that is greater than or equal to C_p, BP_{Low} = The breakpoint that is less than or equal to C_p, I_{High} = The AQI value corresponding to BP_{High}, I_{Low} = The AQI value corresponding to BP_{Low}

S.Abraham et al. [4] present an indoor air quality monitoring with wireless sensor and low-cost system. It monitors the six parameters from different locations and developed a linear least square estimation method for calibration and data measurement. H.E.Fathallah et al. [5] developed a Real-time IoT based indoor air pollution monitoring system which monitors the temperature, humidity, formaldehyde, and CO_2. J.Y.Kim et al. [6] induced a real-time wireless monitoring technology of toxic gases in the indoor environment and stored data in SD card and database. R.K.Kodali et al. [7] developed IoT based climate monitoring system which monitors temperature, barometric pressure, humidity and additionally light intensity and these parameter values cross the threshold value message will be sent to the users.

Our main focus is to present an indoor air quality monitoring framework design. Our main motive in this work is as follows:

Survey of the harmful gases for the indoor environment which is highly affected by the building occupants. Measured environmental harmful gases (Carbon dioxide, Carbon monoxide) and thermal comfort (Temperature, Humidity, and Heat-Index). Then calculate the concentration value of the toxic gases in Parts Per Million (PPM). All the parameters are compressed into a single value which is called the Air Quality Index and display these parameters on OLED. Measured environmental compounds data are sent to an email notification and mobile SMS using MQTT Broker protocol.

The structure of the article is organized as follows: Section II highlights System Design and Implementation consisting Node Design for System, Software Implementation, Wireless Communication, and Flowchart for proposed prototype framework. Section III demonstrates the result and discussion and Section IV describes the conclusion and future scope.

II. SYSTEM DESIGN AND IMPLEMENTATION

A) Node Design for System

In this section, three different sensors are integrated to calculate Temperature, Humidity, Heat-Index, CO, CO_2 values with Arduino mega 2560. AQI and Heat Index values are being displayed on OLED, which is interfaced with Arduino mega 2560, an open-source development microcontroller board. In addition, to accomplishing greater probability in applications, remotely communication (ESP8266-01 module) will be used for data transmission in our architecture.

Arduino mega2560 is processing unit, it is open source development board based on Atmega2560. It has an 8-bit microcontroller with RISC (Reduced Instruction Set Computer) architecture. This microcontroller has 54 GPIO pins, 15 pins can be used for PWM signal. It also consists of 16 analog pins each pin provides 10-bit ADC (analog to digital converter) resolution, 4 UARTs, and 16MHz oscillator frequency, flash memory is 256 KB of 8 KB used for the boot loader, EEPROM 4 KB, SRAM 8 KB.

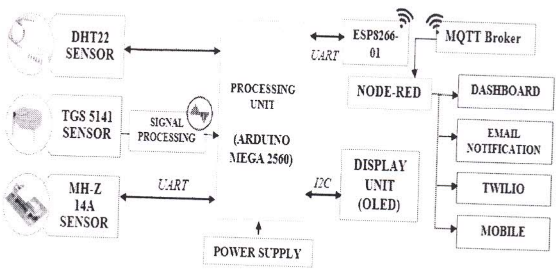

Fig. 2 Block Diagram of Indoor air quality measuring node

Sensors interfaced with Arduino mega2560 microcontroller are:

i) DHT22 Sensor module gives the digital output signal. It mainly measures temperature, humidity, and heat-index. Operating range for humidity is 0-100% and the temperature is -40 to 80 °C and operating voltage is 3.3V to 6V DC.

ii) TGS5141 is a carbon monoxide gas sensor in electrochemical technology, which has high sensitivity, low power consumption. Detection range is 0 to 5000 PPM and the sensitivity of this sensor is 1.2 to 3.2 nA/PPM [8].

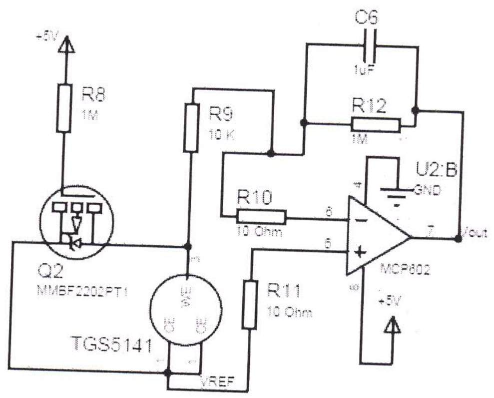

Fig. 3 Readout Circuit Diagram for the TGS5141 Sensor

Electrochemical Sensor produces the output signal in the form of current which corresponds to the gas concentration. The sensor's output must be amplified since computing the result by cause of output current (micro level) that must be converted into voltage using a trans-impedance amplifier. Basic functionality of the trans-impedance amplifier is to convert the current into voltage along with a feedback resistor which set the gain of the amplifier.

Then,

$$\frac{\text{Swing Voltage}}{\text{Max Current}} = R_f$$

Where, R_f is the feedback register.

CO concentration value in PPM (parts per million) is calculated by this formula:

$$\frac{\text{Sensor Current}}{\text{Sensitivity Changes in PPM}} = \text{Gas Concentration (PPM)}$$

iii) MH-Z14A is a CO_2 gas sensor module in Non–Dispersive InfraRed (NDIR) technology. Its output signal can be determined by UART, PWM and analog voltage. Detection range 0-10000 PPM and the operating voltage range is 4.5 to 5.5V DC [9].

In this work, To calculate the CO_2 concentration value using UART communication protocol and CO_2 concentration formula is as written below:

$$\text{High pulse} * 256 + \text{Low pulse} = \text{Gas Concentration (ppm)}$$

iv) ESP8266-01 is a wi-fi module which establishes the communication between Arduino mega2560 and Node-Red. It supports Wi-Fi 2.4GHz, 10 bit ADC and UART communication protocol.

v) OLED Module is used to display the measured value and its operating voltage range is 3.3V. Basically, it gives the two type communication protocol i.e. SPI and I2C but we have used I2C communication protocol.

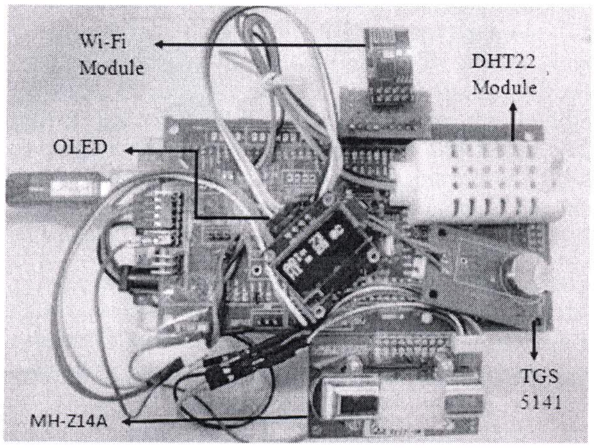

Fig. 4. The image of a developed prototype framework node

B) Software Implementation

This section describes the software used and the framework of the system prototype.

1) Programming Software:

Arduino is an open-source development platform, which works on a different operating system such as Windows, Linux, and MAC. C and C++ programming language are used in Arduino IDE.

2) Node-Red:

Node-Red was developed as a graphical and visualization programming tool. It supports the node.js platform and the JavaScript programming language is used in nodes. Nodes are essential components which actually represent the objects. The set of instruction is done over the internet browser. The primary purpose behind this was simple connection and visualization of MQTT protocol for IoT purpose. This platform allows a measured data visualization facility. So we have used Node-Red dashboard which is a combination of essential components for data visualization [10]. 'My dashboard' is accessible at http://ip:1880/ui.

C) Wireless Communication

The measured sensor data is transferred between ESP8266-01 wi-fi module and Node-Red with MQTT server. The purposeful information is changed into a readable structure on the developed application in Node-Red.

1) MOSQUITTO Broker:

MOSQUITTO is a convention for sending message between IoT gadgets over the local hub. The MQTT Broker by default utilizes 1883 port and information is moved from and to a different server inside the LAN or by means of the Internet. Components joined to this server are one is the publisher and the second one is subscriber, the client as a public. A number of IoTs communication protocols exits. In this framework, MQTT protocol is being used because of its light-weight, easy to implement, asymmetric client-server relationship, and perfect for live data.

2) JSON Parsing Design:

The capture input data are deserialized in JSON design. Consolidate all sensor data into a single hub in JSON design and send it in a single string.

Fig. 5. Converted String into a JSON object

3) Twilio:

Cloud Communication platform is used in Twilio for sending the SMS and Web Service APIs used to a receive phone call and SMS [11].

D) Flow Chart of the proposed prototype framework

The proposed prototype framework is described in the following flow.

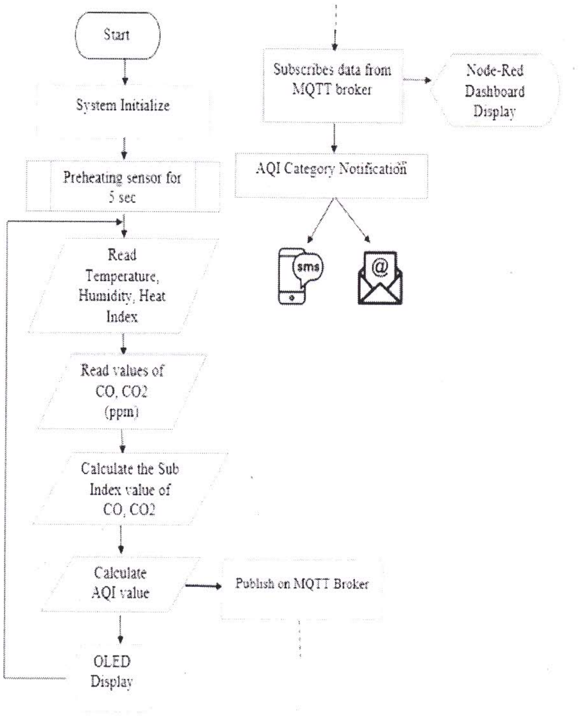

Fig. 6. Flow Chart of the proposed prototype framework

III. RESULT AND DISCUSSION

Fig. 7. (a) shows the live data monitoring for environmental parameters including Humidity, Temperature, and Heat-Index on Nod-Red dashboard. These parameters are important elements when it comes to breathability in indoor rooms. To maintain a healthy environment, monitoring for good air quality is important.

Fig. 7. (b) shows the live data monitoring for Toxic gases which are harmful such as carbon monoxide and carbon dioxide as health affects when a person exposes to CO or any burning fuels. Monitoring such parameters is very necessary. Whereas fig. 7. (c) represents the Air Quality index for the indoor environment so as to keep a track of how clean and polluted the air is.

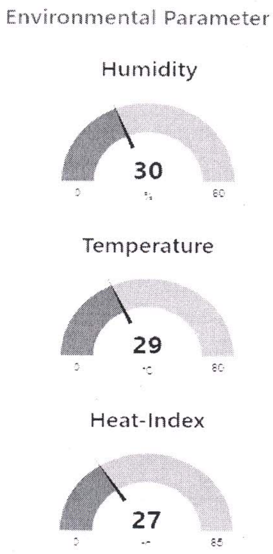

Fig. 7. (a) Live data monitoring for Environmental Parameters on the dashboard

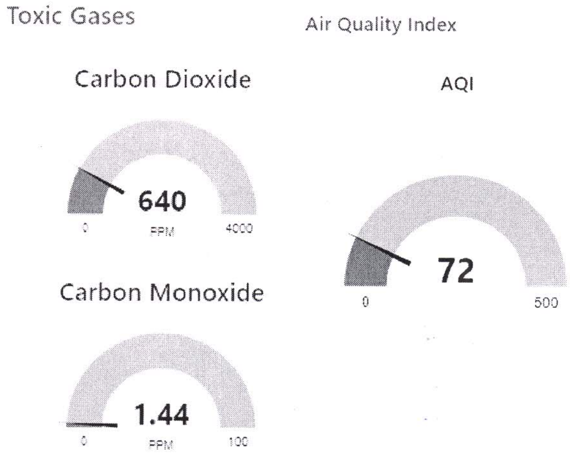

Fig. 7. (b) Live data monitoring for Toxic gases and (c) Air Quality Index on the dashboard

Fig. 8. (a) shows the air quality index notification sent to the building occupants through the help of Twilio about the environmental condition.

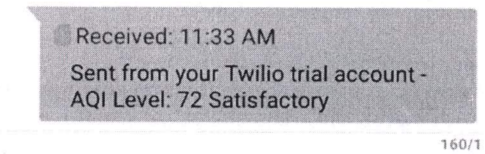

Fig. 8. (a) SMS notification of AQI level

Fig. 8. (b) shows the air quality index level and health impact notification over the Email to building occupants.

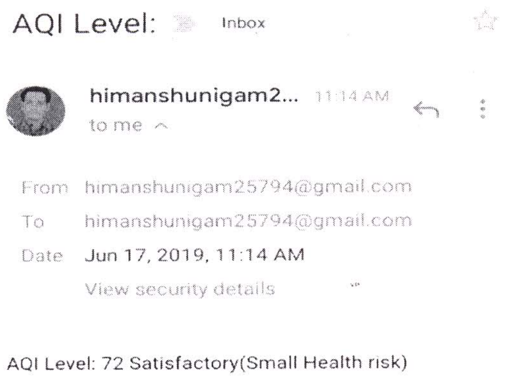

Fig. 8.(b) Email Notification of AQI Level and Health Impact

The sensor data is being uploaded using IoT data protocol and monitored at one's convenience on Node-Red dashboard. Notification is sent to the building occupants at a specific time period.

IV. CONCLUSION AND FUTURE SCOPE

The proposed framework is successfully designed and implemented for indoor environmental monitoring. This system is a compact gadget which makes it convenient and can be moved anywhere. This system is more beneficial in the urban zone because there is much of air contamination. This gadget is completely capable of capturing the Temperature, Humidity, Heat-Index, CO, CO_2 concentration data of the indoor environment. The captured data is transmitted smoothly to the Node-Red dashboard over MQTT protocol and as well as it gives the air quality notification to the building occupant through the Mobile SMS and Email. AQI and Heat Index values are being displayed on OLED. Captured data is automatically updated with the next live data.

In the near future, this system can be modified to add a lot more features by increasing highly sensitive, selective sensors. Also, measured sensor data can be stored in a database, and cloud server.

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