Design and Implementation of Real Time Indoor Air Quality Management

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Abstract

Quality of air adversely influences health of humans, livestock and plants. This paper deals with design of an Internet of Things based real time air quality monitoring system in an indoor environment. The system monitors carbon-di-oxide and oxygen levels, temperature and humidity using sensors and the data is sent to the cloud. Temperature 30 C to 15 C, humidity =< 50 RH and carbon-di-oxide > 400 ppm

Key Words: MQ135, MG811, Arduino UNO, IDE, at-mega328p, Cloud

1.0 Introduction

Indoor Air Quality (IAQ) refers to the air quality inside and around buildings and structures. In IAQ microcontroller is interfaced using an integrated development environment. Sensors gather the data of environmental parameters and send the same to the ThingSpeak cloud system using a Global System for Mobile communication (GSM) module on Arduino by accessing the API Key provided by the ThingSpeak cloud service.Thingspeak server displays the data online in 15 seconds intervals. Monitoring of the data is visible through a web page provided by the ThingSpeak cloud service.

Air quality monitoring system is designed using the ESP32 as controller and sensors incorporatedfor measuring the air quality [1]. Temperature, humidity, dust levels and polluting gases (H_2S, NH_3,CO,NO_2, and SO_2) are monitored. IAQ is influenced by level of occupancy and activities such as sweeping, cleaning and cooking. Ventilation improves the air quality [2].F3 class wood planks increasesthe rate of formaldehyde emission and can cause more pollution than that of F1 class [3].An IoT Edge Device was developedwas focused on the design of RnProbe. It was focused on integrated Rendon Risk Management in public buildings which can reduce public health risks due to the exposure to the pollutants.The device collects, aggregates, and transmits indoor

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environmental parameters to the cloud [4].The gateway collects sensor data from each IAQ-D at an interval of two minutesand transmits data to server in the cloud via GPRS/4G [5, 6].Authorized users can access cloud platformvia mobile apps or the web browser.

Metia and Phung [7,8] reported development of IAQ system with periodic alerts and accurate prediction of air quality. Estimation of air quality was performed using fractional-order modelling and control (FOMCON) toolbox. Experiments based on PM2.5 pollution data in the region demonstrated the rationality of the proposed model. Three characteristics of complex network: scale-free, small-world and community aggregation were verified. Characteristic detection and key station mining provided guidance for air protection in reality. Sensing device deployed a genetic algorithm for the selection of location to deploy a limited number of sensing devices[8-9]. Performance of the proposed solutions was evaluated by simulations in cities [9].

2.0 Design of Indoor Air Quality Monitoring System

2.1 Methodology and Workflow

ArduinoUno board was reproduced using AT-mega328P IC and connected with three sensors for IoT. The components were integrated with Sim900a GSM module and a channel was created on the ThingSpeak platform. API or channel code was used to transfer real time sensor data over the cloud. The data collected over time was relayed continuously and graphically presented. Schematics of the IoT module is presented in Fig. 1.

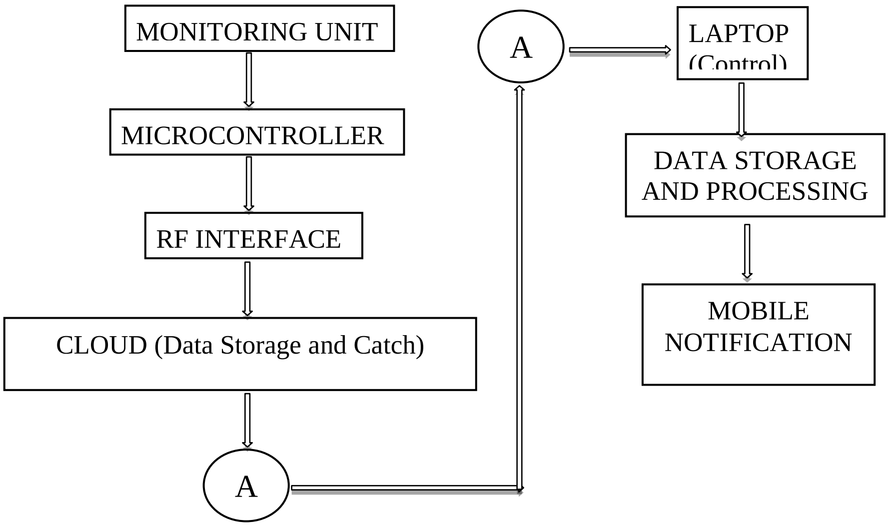

Fig. 1. Schematics of the IoT module

MIX8410 was used to sense oxygen and a Potentiometer on board was used to set the threshold. An LED glows once the threshold is reached and a digital pin gives a HIGH voltage signal[3]. DHT-22 (a capacitive humidity sensor and a thermistor) was used to measure humidity and temperature. The device requires a 3 to 5V power supply. It uses a single data wire to communicate back to the Arduino. Fig. 2 presents the workflow. At-Mega has a fairly slow update rate and should only be sampled every 2 seconds. The MQ-135 gas sensor can detect gases Ammonia (NH_3), Sulfur (S), Benzene (C_6H_6), CO_2, other harmful gases and smoke. Similar to other MQ-series gas sensor, this sensor also has a digital and analog output pin.

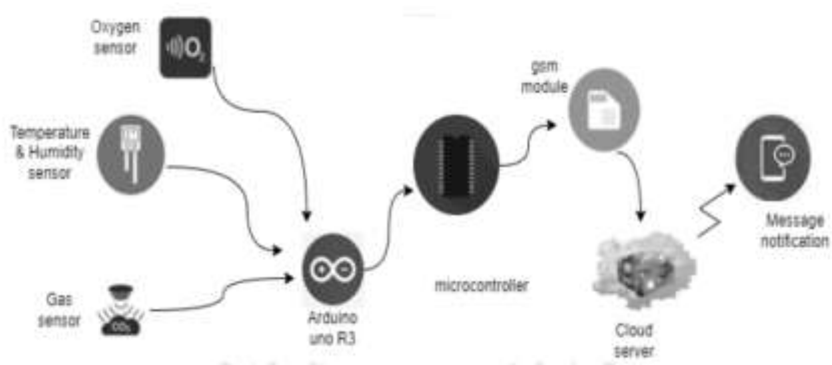

Fig. 2. Workflow of IOT module

2.2 Design Details

ATMEGA328P is a high performance, low power controller from Microchip. It is an 8-bit microcontroller based on AVR RISC architecture. It is the most popular of all AVR controllers as it is used in ARDUINO boards[3,4]. The Arduino Uno R3 is a microcontroller board based on a removable, dual-inline package (DIP) AT-mega328 microcontroller. Table 1 presents the parameters used for air quality monitoring and their threshold values. Temperature, humidity, CO_2/CO and presence of harmful gas is detected [4-5].

Table 1. Parameters of Air Quality Monitoring system and their thresholds

Parameter	Limit/Range	Reference
Temperature	Summer 23-26 Winter 20-23.5	ASHRAE Standard 55
Relative Humidity	30-65%	ASHRAE Standard 55
CO_2	About 700 ppm over outdoor ambient	ASHRAE Standard 62
CO	8-hr TWA 9 ppm 50 ppm	ASHRAE OSHA

Arduino is replicated to on breadboard with the required components. Arduino has 20 digital I/O pins (of which six can be used as PWM outputs and other six can be used as analog inputs). Programs can be loaded from the easy-to-use Arduino computer program. The microcontroller compares the input bits with the coded bits, which are burnt into the microcontroller's program memory and outputs based on these bits. COM3 of the microcontroller is used as the output port. Fig 3 illustrates the workflow of the module. Data collected from the sensor is computed by the microcontroller which in return relays the same over the cloud via GSM 900 module[10].

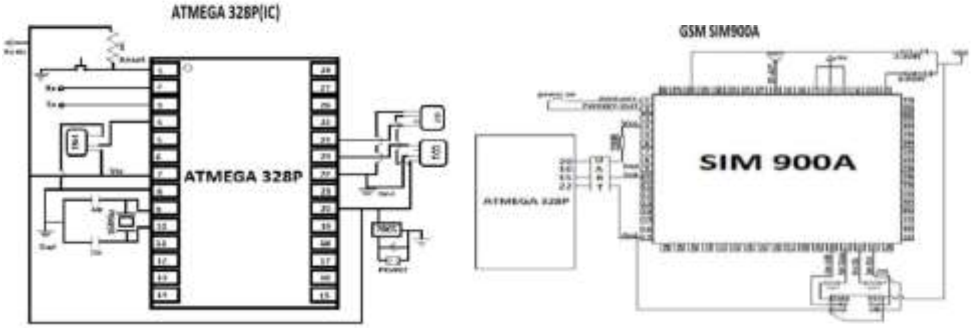

Fig. 3a, b. Block diagram of ATMEGA328p connection along with GSM900A

2.3 GSM 900A Module Integration

GSM900A is built with Dual Band GSM/General Packet Radio Service (General Packet Radio Service (GPRS)) based SIM900A modem from SIMCOM. It works in frequencies 900/ 1800 MHz. GSM900A can search these two bands automatically. The frequency bands can also be set by AT Commands. The baud rate is configurable from 1200-115200 through AT command. [6-7] The GSM/GPRS Modem ishaving internal Transmission Control Protocol (TCP)/Internet Protocol (IP) stack to enable to connect with internet via GPRS. SIM900A is an ultra-compact and reliable wireless module Powered up Microcontroller starts reading the sensor data from the three sensors used [11-12]. Temperature, humidity and Co_2values are recorded. The data is obtained by GSM module (SIM900A) which uses 2G spectrum to transmit and receive real time data. The data is uploaded to ThingSpeak.com as field1 to field 4. A channel is created on Thingspeak platform and the API keys.services, social network and other APIs are used [9,11]. Once created, sending the data to the channel using WriteAPIKey allow ThingSpeak to process it and also retrieve the same (Fig. 6). A channel stores the data that is sent to ThingSpeak. Once channel is created and data retrieved, sensor data is relayed over the phone as SMS notification. Fig 5 shows the block diagram of the module [11-12].

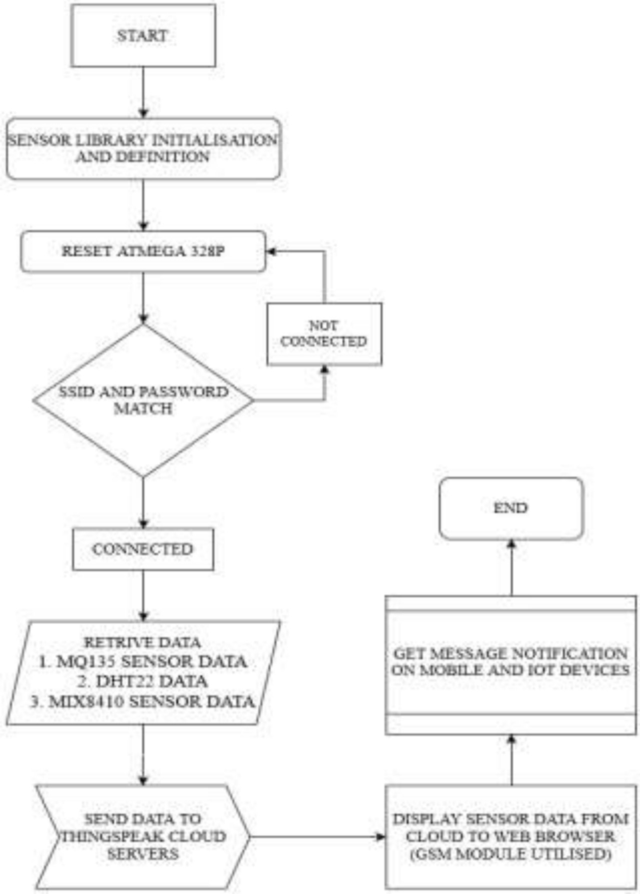

Fig.5. End to end Flowchart of working of module.

3.0 Results and Discussion

The values of CO_2, O_2, temperature and humidity along with presence of any harmful gas in an interval of one minute was recorded and the same relayed to the cloud along with an SMS alert. Threshold values of temperature 30 C to 15 C, humidity =< 50 RH and CO_2>400 ppm were defined. Fig. 6-8 show the results of the parameters monitored.

Fig. 6a

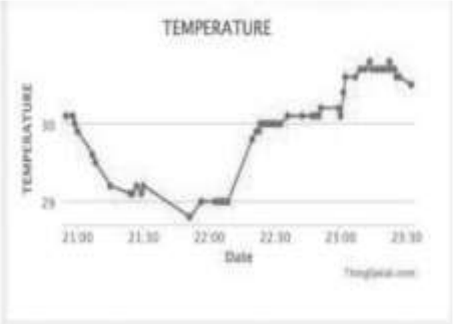

Fig. 6b.

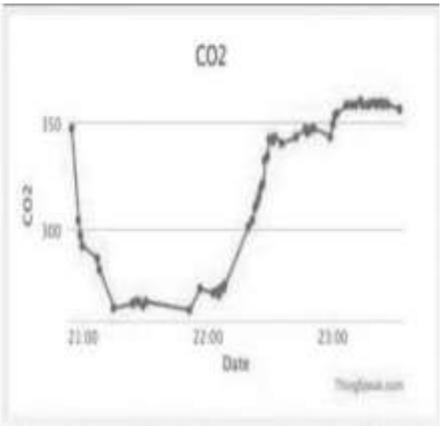

Fig. 6c

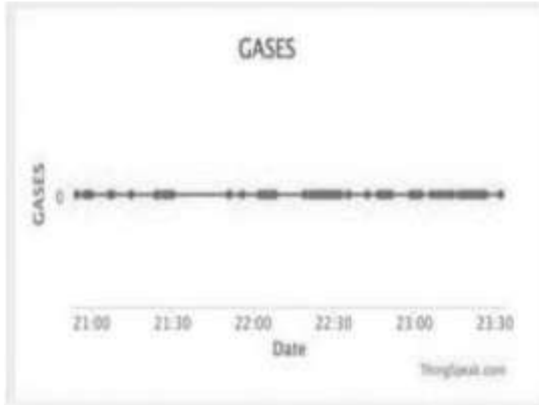

Fig. 6d

Fig. 6. Output of IAQ monitoring system.

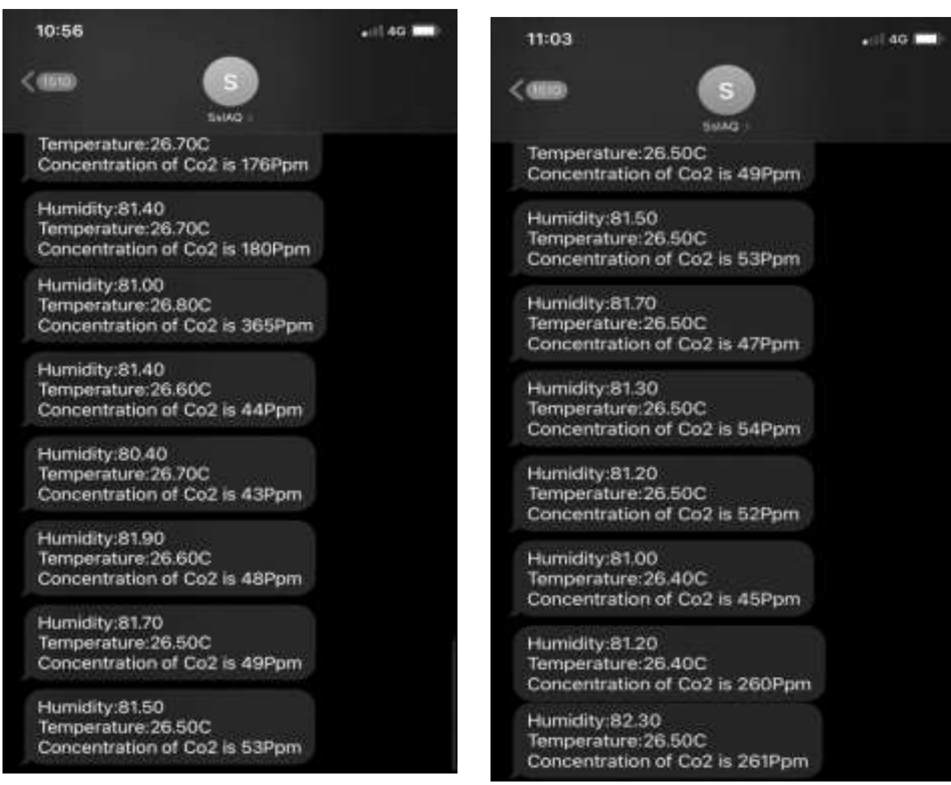

Fig. 7. Pollutant parameters

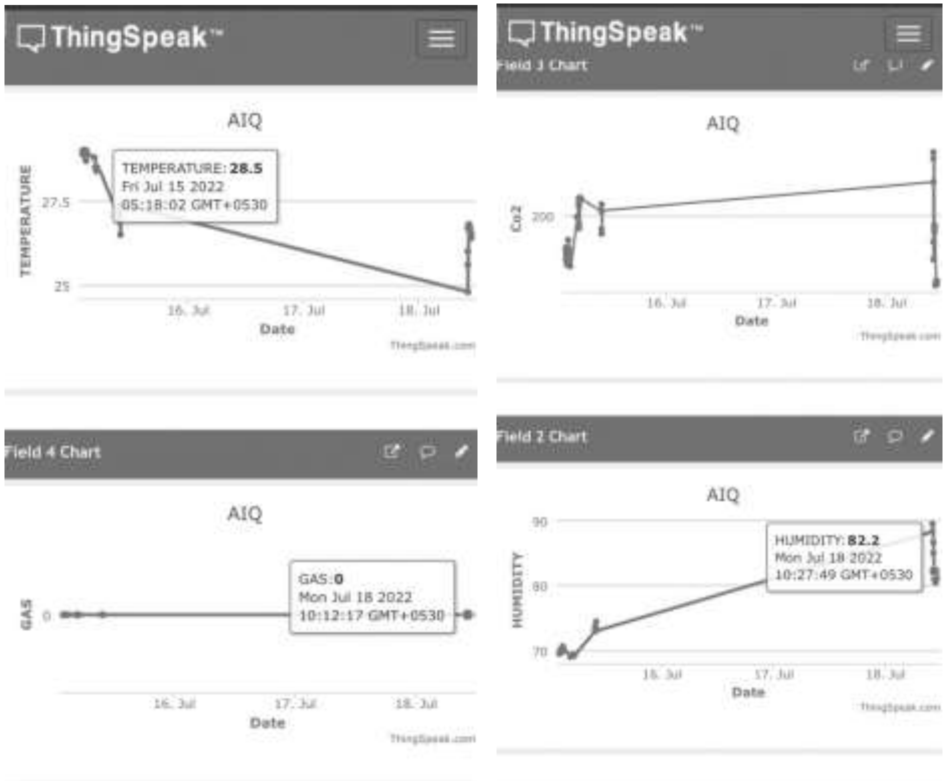

Fig. 8. Notification of pollutant parameters on a Smartphone/IOT device

4.0 Conclusion

Indoor Air Quality Monitoring system was designed by combining IoT and cloud computing technologies. Initially, the Arduino Uno R3 was replicated by ATMEGA328P using the pinout connections for the ATMEGA328P. The data from the three sensors was acquired. The mean temperature 26 C to 27 C, CO_2 70 ppm (40 to 190 ppm)and humidity 80 to 90 RH was recorded. The replicated ATMEGA328P with Arduino Uno R3 was interfaced with the sensors. The data acquired from the replicated microcontroller was interfaced using a Radio Frequency (RF) interface device i.e. GSM 2G module which acts as a medium of communication (mobile phone with 2G SIM) between the Arduino UNO IDE and the cloud. Average data obtained are presented in Table 2. The IAQ system findswide applications in different environments.

Table 2. Mean values of parameters recorded

Temperature (C)	Carbon dioxide ppm	Harmful gases (1/0)	Humidity Levels
26.5	44	0	81.4
26.7	49	0	81.4
27	53	0	81

References

01. T H Nasution, A Hizriadi, K Tanjung, and F Nurmayadi, Design of indoor air quality monitoring systems, *3rd International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*,238–241. 2020, doi: 10.1109/ELTICOM50775.2020. 9230511,

02. H Gokozan, Real-time monitoring of indoor air quality with internet of things-based e-nose, *Applied Sciences*, (9), 16, 2019

03. CY Chang, SJGuo, SS Hung, and Y TLin,Performance analysis of indoor smart environmental control factors , Using temperature to control the rate.

04. K.-FTsang, C K Wu, et, An adaptive indoor air quality control scheme for minimizing volatile organic compounds density, *IEEE Access*, 8(22) 357–365, 2020, doi: 10.1109/ACCESS.2020. 2969212,

05. FPereira, SI Lopes, N B Carvalho, and A Curado, Rnprobe: A lora-enabled iot edge device for integrated radon risk management, *IEEE Access*, 8(203), 488–502, 2020. doi: 10.1109/ACCESS.2020. 3036980.

06. Z Liu, G Wang, L Zhao, and G Yang, Multi-points indoor air quality monitoring based on internet of things, IEEE Access, 9(70), 479–492, 2021, doi: 10.1109/ACCESS.2021.3073681,

07. Q S Metia, and M DPhung, Sensing data fusion for enhanced indoor air quality monitoring, *IEEE Sensors Journal*, 20(8), 4430–4441, 2020, doi: 10.1109/JSEN.2020.2964396,

08. C Song, G Huang, B Zhang, B Yin, and H Lu, Modeling air pollution transmission behavior as complex network and mining key monitoring station, *IEEE Access*, 7, 121 245–121 254, doi: 10.1109/ACCESS.2019.2936613,2019

09. A RAl-Ali, I Zualkernan, and F Aloul, A mobile gprs-sensors array for air pollution monitoring, *IEEE Sensors Journal*,10(10),1666–1671, doi: 10.1109/JSEN.2010.2045890,2010

10. Z Chen, T Zhang, Z Chen, Y Xiang, Q Xuan, and R P Dick, Hvaq: A high resolution vision-based air quality dataset, *IEEE Transactions on Instrumentation and Measurement*, 70,1–10, doi: 10.1109/TIM.2021.3104415,2021

11. Z Hu, Z Bai, K Bian, T Wang, and L Song, Real-time fine-grained air quality sensing networks in smart city, Design, implementation, and optimization, *IEEE Internet of Things Journal*, 6, (5), 7526–7542, 2019, doi: 10.1109/JIOT. 2019.2900751,
12. K Chen, C Ding, G Wang, Q Liu, and X Liu, An adaptive kalman filtering approach to sensing and predicting air quality index values, *IEEE Access*, 8, 4265–4272, doi: 10.1109/ACCESS.2019. 2963416,2020