Real Time, IoT Based Affordable Air Pollution Monitoring with Smart Home Automation

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Abstract. The emergence of the internet of things (IoT) facilitates us to connect all the devices available at home. Also, we can control and access devices and appliances remotely in real time. This article, by taking the advantages of IoT proposes an IoT based affordable air quality monitoring with smart home system that brings controlling and monitoring of devices and appliances, and monitoring of home environment together in real time. The system uses the combination of wireless communication and cloud networking, to remote control various appliances (like Fans, TV), also getting a glimpse of air quality. In order to monitor the home environment, we develop a practical information acquisition model, a network for indoor and outdoor air quality monitoring which can be carried anywhere as a portable device. The portable nodes can sense pollutants like CO, CO2, PM2.5, PM10 with Temperature and humidity and monitor the air quality. The collected data is sent to a cloud service platform like things speak and Firebase for real-time visualization and appropriate forecasting & prediction analytics. Also, a user-friendly Android app and web portal increase the usability of this system. Moreover, when critical conditions occur, an alert is reflected on the android app and on web portal in real-time. Also, system start sending a warning ring on registered mobile.

Keywords: Air Quality Monitoring (AQM), Smart Home, IoT, Raspberry Pi.

1 Introduction

Home automation is a means, that empowers individuals to control and monitor home appliances intelligently and automatically to make life effortless by providing amenity, security, ease and energy efficiency to its occupants. Recent advancement in technologies, boost up the research and development of home automation. Home automation can assist the people who want to access electrical appliances while at a remote location. Also, it very much helps senior citizen and differently abled people. Moreover, over the past quarter-century, the growth of industries has increased

exponentially. These industries badly affect the environment and create serious problems. Stationary and mobile sources are also contributing in it and generating various chemical pollutants. World health organization (WHO) has established guidelines by seeing the significance of air quality in human lives, for reducing the health hazards of air pollution by setting the threshold values of various pollutants. Hence, the demand for air quality monitoring system is increasing with time and becomes the crucial part of the home automation system. Therefore, we need a system that could assist us in home appliances monitoring and controlling along with air quality monitoring. We develop such type of system by considering industrial class air quality monitoring sensors. It's extended version of our previous work [1], in addition, proposed architecture is modified for adding a GSM module so that warning ring could be sent to registered mobile as critical conditions occur. To reduce the overall response time of the system, Honeywell HPMA-115S0 is used over SDS021 for PM2.5 or PM10 values. It takes less than 6 seconds to generate a new value. Moreover, we add our power supply module and display screen in extended version. Eventually, all components are accumulated and connected in a box and packed. Small box of same system is also obtained by replacing Arduino Mega with Node MCU for air quality monitoring.

2 Related Work

Home automation is the need of today's era. Starting from the small home, to the cities having skyscrapers are being inclined towards automation. In this section, we review the various existing approaches, proposed by the authors.

In a paper [2], authors have proposed an IoT base home automation system, in which authors control home appliances by using Node MCU and Arduino UNO. Also, an alert message is transmitted for energy consumed regularly and for the gas level in cylinder goes down the certain limit. [3] The authors have proposed a home application using IoT, they have given one blynk app for controlling the home appliances. Also, they use Node MCU for interfacing the appliances and internet connectivity. [4] Authors have used Arduino Mega along with ESP8266 for interfacing electronic appliances and sensors. Moreover, they have developed a user interface for switching using virtuino. [5] Authors came with a new concept. They are controlling the home appliances using visual machine intelligence. In their project, they use Raspberry Pi along with Intel Galileo for image capturing and appliances interfacing. [6] Authors use EmonCMS platform for visualizing and collecting remote home data and remote controlling the devices. [7] Proposed an architecture, in which near field communication (NFC) is used as a central system to automate the home environment. Also, use general packet radio service along with the mobile application. [8] Authors used Raspberry Pi along with Arduino Uno to interface home appliances and sensors. They also take the service of the real-time database to visualize the status of the devices in real time using android app. [9] Proposed a low-cost home automation system using wifi. In which, they are using ATmega for interfacing home appliances along with various sensors. Also, they gave the Android app for monitoring and controlling the appliances available at home. [10] Proposed an architecture, in which, multiple Arduino Uno based satellite nodes are used to

interface home appliances and sensors. Also, they transmit their data to Arduino Mega based base station for uploading the data on the server. They have also given one android app for monitoring and controlling the home environment. [11] Proposed TI- CC3200 based security and home automation system. In which, CC3200 is used to interface various appliances and sensors. It also sends voice call at phone if the intruder is detected. In a paper [12], the authors explained home automation using Bluetooth in an indoor environment and home automation using Ethernet in an outdoor environment. Authors have used Arduino Uno for interfacing home appliances.

In summary, most of the authors in their proposed systems are controlling and monitoring the various home appliances. Also, they are monitoring the home environment using various sensors like Temperature, Humidity, Smoke, etc. Only a few of them have used MQ series sensors to keep an eye on air quality, even though its crucial component of home automation. Such type of gap encouraged us to develop a system that could give equal emphasis on air quality monitoring along with controlling and monitoring of home appliances. Moreover, the system must use industrial class air quality sensors so that accurate and stable values could be obtained.

3 Proposed Work

We propose a system that assists in monitoring and controlling the home appliances along with monitoring the home environment in real time. It is unique. Till now, almost all systems are giving high weightage to controlling and monitoring the electronic devices along with temperature, humidity sensors. These systems do not give equal emphasis to air quality monitoring even though its important aspect of home automation. However, separate articles are available on AQM in literature. In our work, we propose an IoT based affordable air quality monitoring with smart home system. In order to monitor air quality, industrial class sensors are used. They give us precise values, long life, high stability, high sensitivity and ability to survive in the worst condition.

As shown in Fig. 1, we use Arduino Mega and Raspberry Pi for interfacing electronic devices and sensors. Here, Arduino Mega is used to monitoring the home environment and Raspberry Pi takes the responsibility of controlling and monitoring the all electronic devices available at home. Although, it is possible to interface all devices and sensors with a single microcontroller, for reducing the complexity and easy troubleshooting, we use a combination of Arduino Mega and Raspberry Pi.

Initially, Arduino Mega reads the values of gas sensors like CO, CO2, along with PM 2.5, PM 10, Temperature and Humidity. Which senses pollutants and by using appropriate readout circuit the signals get extracted and conditioned appropriately using algorithm running on the controller. The collected data is sent to a cloud database like Google Firebase for real-time visualization. Similarly, Raspberry Pi controls all home appliances and upload their status on the cloud database.

Hereafter, for controlling and visualizing the status of the home appliances, and monitoring of the home environment, we develop a user-friendly Android app and web portal. Both types of interfaces fetch/upload the data in real time on the cloud

database. Whenever change comes in the home environment and status of the home appliances, then Arduino Mega/Raspberry Pi update the values in the real-time database. Consequently, the same is reflected in the Android app and web portal. Also, we can change the status of home appliances by android app or web portal.

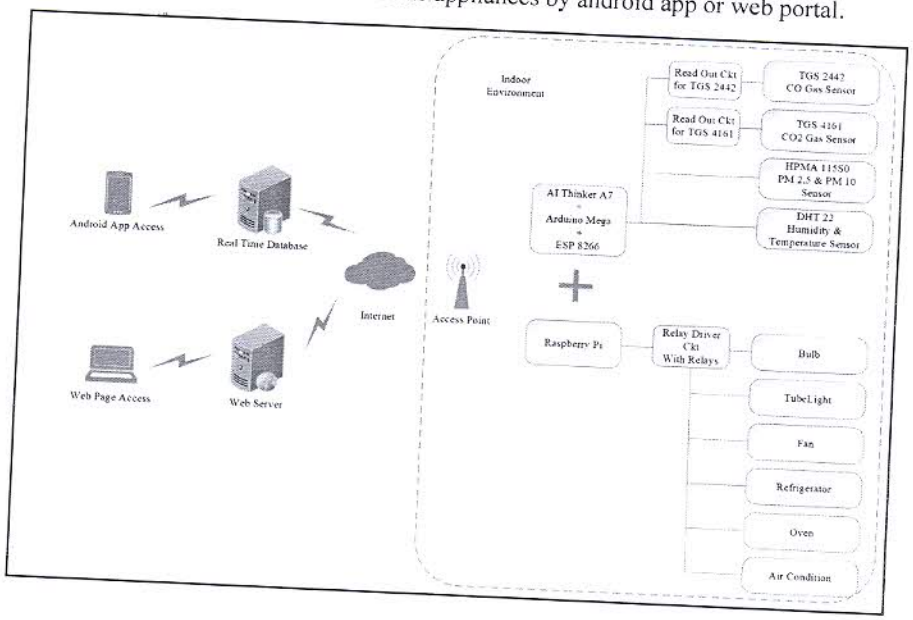

Fig. 1. Proposed Architecture of Intelligent Home with AQM

4 System Implementation

The proposed architecture of the home automation that is used for monitoring and controlling the appliances along with air quality monitoring is implemented. To understand the implementation, we divide the system into three sections by the functionality provided. Initially, home environment monitoring is considered, in which, data is collected from all sensors (CO, CO2, PM 2.5, PM 10, Humidity, Temperature...etc.) continuously and then these values are compared with the predefined threshold values. If values go beyond the permissible limit then alert is reflected in user interfaces as shown in Fig. 2 via red color. Also, system start sending waring ring on registered number. To interface said sensors, Arduino Mega is used. The specifications of all the sensors are available in Table. 1. Moreover, we also develop readout circuit for CO, CO2 sensors. In the second section, home appliances monitoring and controlling is considered, for interfacing various home appliances Raspberry Pi is used. Raspberry pi continuously monitors the status of the appliances and same is uploaded on the cloud database. Also, it controls the appliances as per user instructions. Eventually, interactive web portal and Android app are developed

for controlling and visualizing the status of the appliances along with air quality sensors as shown in Fig. 2.

In addition, all sensors of home environment monitoring are grouped and connected in a box and packed (See Fig. 4(a)) along with its power supply and display screen. In order to reduce the size of box (See Fig. 4(b)), all sensors of home environment monitoring are interfaced with Node MCU by replacing Arduino Mega.

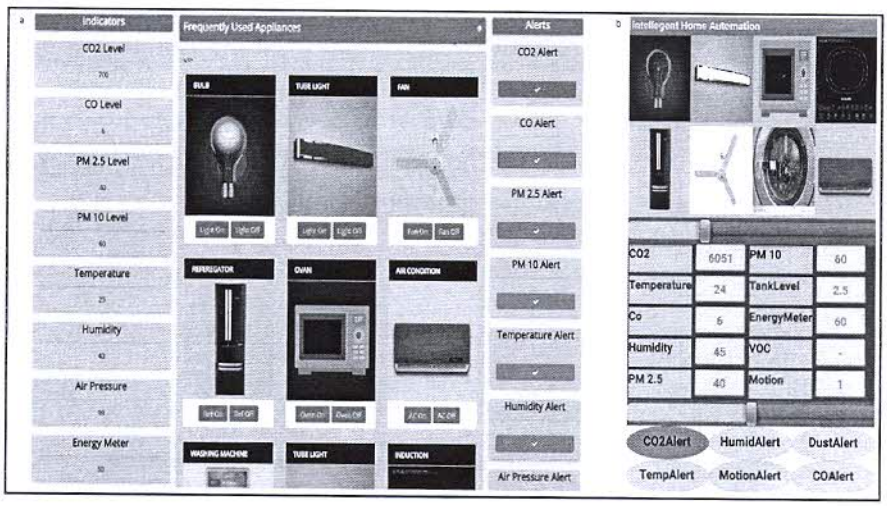

Fig. 2 - (a) Web Portal for Intelligent Home with AQM; **(b)** Android App for Intelligent Home with AQM.

Table 1 – Specifications of the Sensors Used.

Sensor Name	Sensor Model	Nominal Range (ppm)	Accuracy	Response Time (s)	Sensor Type
*CO	TGS 2442	30-1000	-	Approx. 1	MOS
*CO2	TGS 4161	350-10000	Approx. ±20% at 1000 ppm	Approx. 90	Solid Electrolyte
PM 2.5 / PM 10	HPMA 115S0	0-1000 $\mu g/m^3$	0-100 $\mu g/m^3$ (± 15 $\mu g/m^3$), 100-1000 $\mu g/m^3$ (± 15 %)	< 6	Laser
Temperature	DHT 22	-40 - +80 °C	< ± 0.5 °C	Average 2	Capacitive
Humidity	DHT 22	0 - 100% RH	Max ± 5% RH	Average 2	Capacitive

*These sensors have very high selectivity to target gas.

5 Result

This section displays real-time images produced by the system. Fig. 3 (a) (b) displays CO and CO2 concentration on sampled data respectively; (c) demonstrate the humidity, temperature vs. time graph. Android app, a web portal for visualizing and controlling the appliances and home environment are shown in Fig. 2. In case of unusual conditions, an alert is reflected in user interfaces as shown in Fig. 2 by red color.

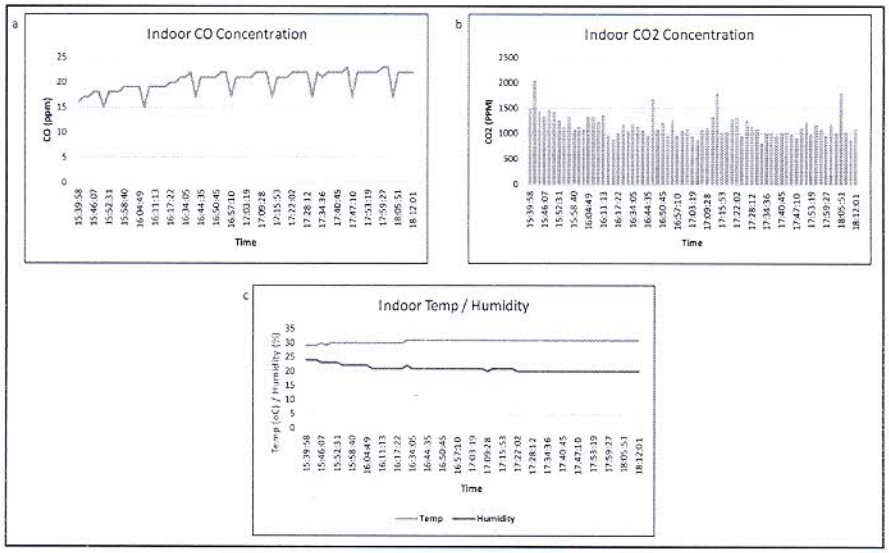

Fig. 3 - (a) CO Concentration on Sampled Data; **(b)** CO2 Concentration on Sampled Data; **(c)** Temp, Humidity Vs Time.

We also packaged our edge node in two boxes of size 17 X 6 X 12 cm and 6.5 X 6.5 X 6.5 cm (See Fig. 4). Fig. 4 (a) is displaying an edge node in action and Fig. 4(b) displays small edge node of same system, obtained by replacing Arduino Mega with Node MCU, packaged in blue box.

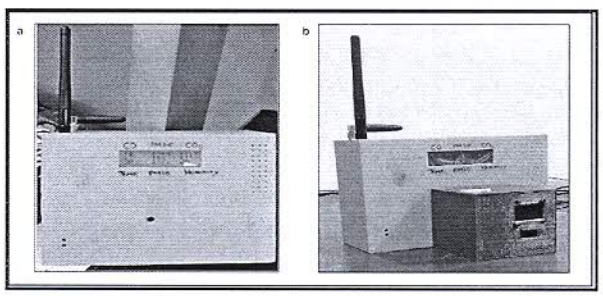

Fig. 4 - (a) Portable Edge Node with Display; **(b)** Small Edge Node with Display.

6 Conclusion & Future Scope

A proposed system integrates various aspects of home automation using IoT, and it gives us a good understanding of environmental conditions in the home along with keeping an eye on appliances in real time. Moreover, the system also comes with good quality user interfaces, i.e., web portal, an android app that gives a glimpse of air quality available at home and assists in controlling and visualizing the status of appliances. Eventually, the system can generate an alert, whenever unusual conditions occur, and the same is reflected on user interfaces. Also, it starts calling a registered number. In the future, we would like to deploy more standard sensors like VOC, NH3, Alcohol (TGS 2602), Methane, and LPG (TGS 2612) at different locations of home and predict the air quality using machine learning.

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