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Implementation of an Efficient Noise and Air Pollution Monitoring System Using Internet of Things (IoT)

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Abstract: The rapid growth in infrastructure and industrial plants creating environmental issues like climate change, malfunctioning and pollution has greatly influenced for the need of an efficient, cheap, operationally adaptable and smart monitoring systems. In this context smart sensor networks are an emerging field of research which combines many challenges of computer science, wireless communication and electronics. In this paper a solution for monitoring the noise and air pollution levels in industrial environment or particular area of interest using wireless embedded computing system is proposed. The solution includes the technology Internet of Things (IoT) which is outcome of merged field of computer science and electronics. Here the sensing devices are connected to the embedded computing system to monitor the fluctuation of parameters like noise and air pollution levels from their normal levels. This model is adaptable and distributive for any infrastructural environment that needs continuous monitoring, controlling and behavior analysis. The working performance of the proposed model is evaluated using prototype implementation, consisting of Arduino UNO board, sensor devices and MATLAB with Arduino hardware support package. The implementation is tested for two or three parameters like noise, CO and radiation levels with respect to the normal behavior levels or given specifications which provide a control over the pollution monitoring to make the environment smart.

Keywords: Internet of Things (IoT); Embedded Computing System; Arduino UNO; MATLAB Software; Smart Environment.

I. INTRODUCTION

Present innovations in technology mainly focus on controlling and monitoring of different activities. These are increasingly emerging to reach the human needs. Most of this technology is focused on efficient monitoring and controlling different activities. An efficient environmental monitoring system is required to monitor and assess the conditions in case of exceeding the prescribed level of parameters (e.g., noise, CO and radiation levels).
When the objects like environment equipped with sensor devices, microcontroller and various software applications becomes a self-protecting and self-monitoring environment and it is also called as smart environment.

In such environment when some event occurs the alarm or LED alerts automatically. The effects due to the environmental changes on animals, plants and human beings can be monitored and controlled by smart environmental monitoring system. By using embedded intelligence into the environment makes the environment interactive with other objectives, this is one of the application that smart environment targets.

Human needs demands different types of monitoring systems these are depends on the type of data gathered by the sensor devices. Event Detection based and Spatial Process Estimation are the two categories to which applications are classified. Initially the sensor devices are deployed in environment to detect the parameters (e.g., noise, CO and radiation levels etc.) while the data acquisition, computation and controlling action (e.g., the variations in the noise and CO levels with respect to the specified levels). Sensor devices are placed at different locations to collect the data to predict the behavior of a particular area of interest. The main aim of the this paper is to design and implement an efficient monitoring system through which the required parameters are monitored remotely using internet and the data gathered from the sensors are stored in the cloud and to project the estimated trend on the web browser.

A solution for monitoring the noise and CO levels i.e., any parameter value crossing its threshold value ranges, for example CO levels in air in a particular area exceeding the normal levels etc., in the environment using wireless embedded computing system is proposed in this paper.

The solution also provides an intelligent remote monitoring for a particular area of interest. In this paper we also present a trending results of collected or sensed data with respect to the normal or specified ranges of particular parameters. The embedded system is an integration of sensor devices, wireless communication which enables the user to remotely access the various parameters and store the data in cloud.

II. EXISTING SYSTEM MODEL

In today's world many pollution monitoring systems are designed by considering different environmental parameters.

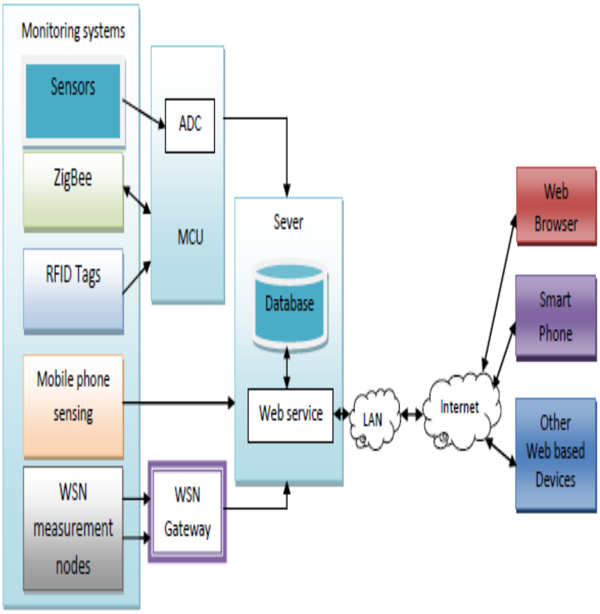

Fig. 1: Existing System Model

Existing system model is presented in figure 1 uses Zigbee [3] based wireless sensor networks to monitor physical and environmental conditions with thousands of application in different fields. The sensor nodes directly communicated with the moving nodes deployed on the object of interest which avoided the use of complex routing algorithm but local computations are very minimal.

RFID [4] is a means of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit. It is usually used to label and track items in supermarkets and manufactories. RFID systems consist of two main components: tags and readers. A tag has an identification (ID) number and a memory that stores additional data such as manufacturer, product type, and environmental factors such as temperature, humidity, etc.. The reader is able to read and/or write data to tags via wireless transmissions. In a typical RFID application, tags are attached or embedded into objects that are in need of identification or tracking. RFID tags can be classified into three major categories by their power source: active tags, passive tags, and semi passive (semi-active) tags.

Mobile phones [5] or smart phones that are enabled with sensors are used for impact on social including how mobile technology has to be used for environmental protecting, sensing and to influence just-in-time information to make movements and actions environmental friendly. Mobile phone sensors were deployed and used on urban areas for monitoring and it was categorized into two major classes, participatory sensing where user is directly involved and opportunistic sensing where user is not involved, but its limitation includes power and static information processing or mobility restrictions.

A Wireless Sensor Network [6] consists of many inexpensive wireless sensors, which are capable of collecting, storing, processing environmental information, and communicating with neighboring nodes. In the past, sensors are connected by wire lines.

The access method of WSN gateway node is convenient because data can be received from a WSN via the gateway at any time and any place. The gateway acts as the network coordinator in charge of node authentication, message buffering where you can collect, process, analyze, and present your measurement data. Wireless sensor network management model consists of end device, router, gateway node and management monitoring center. End device is responsible for collecting wireless sensor network data, and sending them to parent node, then data are sent to gateway node from parent node directly or by router. After receiving data from wireless sensor network, gateway node extracts data after analyzing and packaging them into Ethernet format data, sends them to the server.

A server is an instance of a computer program that accepts and responds to requests made by another program; known as a client. Less formally, any device that runs server software could be considered a server as well. Servers are used to manage network resources. The services or information in the servers are provided through the Internet that are connected through LAN and made available for users via smart phones, web browser or other web browser devices to make the system more intelligent, adaptable and efficient.

III. PREVIOUS WORK

Some of the research works carried out for monitoring the pollution parameters in a particular area of interest for making the environment smart in that area, different techniques and methods which were used in the past discussed in this section.

Smart Environment Monitoring using Wireless Sensor networks [1] - In this work they are mainly focus on the making the city environment smart, by deploying wireless sensor networks in all over the city and moving public transportation system buses and cars. By accessing all the sensor networks, environmental behaviors are collected as a streaming data base to identify the environmental conditions. This methodology gives the monitoring data from stationary nodes deployed in city to the mobile nodes on public transportation buses and cars.

Toward a Green Campus with the Internet of Things - the Application of Lab Management this research work adopts the concept of "Internet of Things" and implements an idea of energy-saving by proper management of computers and air conditioners. The architecture and the prototype of

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the system is explained in [6].Here the objects of Internet of Things are computers and air conditioners.

WSN- and IOT-Based Smart Homes and Their Extension to Smart Buildings [8] –This work mainly aims to design and develop reliable, efficient, flexible, economical, real-time and realistic wellness sensor networks for smart home systems. The sensor and actuator nodes based on wireless networking technologies are deployed into the home environment. These nodes generate real-time data related to the object usage and movement inside the home. Further extends the smart home system to smart buildings and models the design issues related to the smart building environment.

IV. PROPOSED MODEL

The proposed embedded device is for monitoring noise and CO levels in the atmosphere to make the environment intelligent or interactive with the objects through wireless communication. The proposed model is shown in figure 2 which is more adaptable and distributive in nature to monitor the environmental parameters.

The proposed architecture is discussed in a 4- tier model with the functions of each individual modules developed for noise and air pollution monitoring. The proposed model consists of 4-tiers. The tier 1 is the environment, sensor devices in tier 2, sensor data acquisition and decision making in tier 3 and intelligent environment in tier 4.The proposed architecture is shown in figure 2.

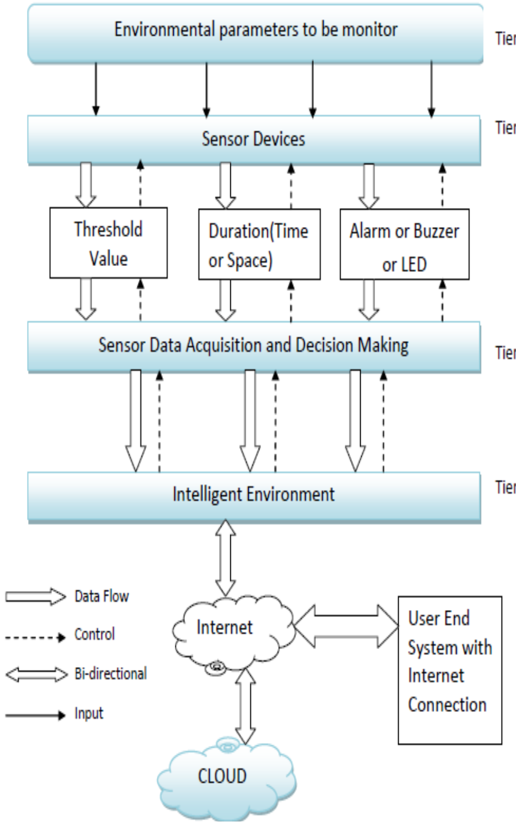

Fig.2: Proposed model

Here, the tier 1 provides information about the parameters under the region which is to be monitored for noise and air pollution control. Tier 2 deals with the sensor devices with suitable characteristics, features and each of these sensor devices are operated and controlled based on their sensitivity as well as the range of sensing.

In between tier 2 and tier 3 necessary sensing and controlling actions will be taken depending upon the conditions, like fixing the threshold value, periodicity of sensing, messages (alarm or buzzer or LED) etc. Based on the data analysis performed in between tier 2 and tier 3 and also from previous experiences the parameter threshold values during critical situations or normal working conditions are determined.

Tier 3 describes about the data acquisition from sensor devices and also includes the decision making. Which specify the condition the data is representing which parameter.

In the proposed model tier 4 deals with the intelligent environment. Which means it will identify the variations in the sensor data and fix the threshold value depending on the identified level of CO or noise levels. In this tier sensed data will be processed, stored in the cloud i.e.in to the Google spread sheets and also it will show a trend of the sensed parameters with respect to the specified values. The end users can browse the data using mobile phones, PCs etc.

IV.I. COMPUTATIONAL ANALYSIS ON ENVIRONMENTAL PARAMETER:

Here we include some basic analytics methods to calculate the pollution parameters, like noise levels and CO levels in the surrounding environment.

The common unit of measurement for sound is decibel, dB and its intensity is measured in Sound Pressure Level (SPL). The noise levels are measured in the A–weighted (low-level sensitivity) SPL, abbreviated as dB (A). Sound of frequencies from 800 to 3000Hz is covered by the A–weighted scale.

If the SPL, L1 in dB is measured at r1 meters, then SPL, L2 in dB at r2 meters is given by

$$L2 = L1 - 20 \log_{10} (r2/r1)$$

Day – Night equivalent noise levels (Ld_n) of a community can be expressed as

$$Ld_n, dB(A) = 10 * \log_{10}[\ 15/24(10^{L_d/10}) + 9/24(10^{(L_n+10)/10})\ ]$$

Where,

L_d = day- equivalent noise levels (from 7AM – 10PM), dB(A)

L_n = night-equivalent noise levels (from 10PM – 7AM), dB(A)

Based on intensity, the sound intensity I may be expressed in decibels above the standard threshold of hearing I_0. The expression is

$$I(dB) = 10 \log_{10}[I/I_0] \text{ intensity in decibels}$$

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Table I: Standard for noise values

Night (10pm-7am) Unit in decibels	Day (7am-10pm) Unit in decibels	Type of region
45	55	Residential
40	60	Residential - commercial
55	65	commercial
60	70	Residential-industry
65	75	industry

The usual reference method for the measurement of carbon monoxide concentration in air is based on the absorption of infrared radiation by the gas in a non-dispersive photometer. This method is suitable for stable installations at fixed-site monitoring stations.

More recently, portable carbon monoxide analyzers [9] with automated data-logging have become available for personal exposure monitoring. These measurements are based on the electrochemical reactions between carbon monoxide and de-ionized water, which are detected by specially designed sensors. Nowadays the resolution, stability and sensitivity of the electrochemical analyzers are within the specifications of the reference method and, together with the data-logging systems, they fit into a small rucksack or even a pocket.

Conversion factors

$$1 \text{ ppm} = 1.145 \text{ mg/m}^3$$
$$1 \text{ mg/m}^3 = 0.873 \text{ ppm}$$

Using the Table 1 and values obtained from above calculations, the threshold value can be set to the requirements dynamic nature of the environment and to monitor the parameters data through sensors.

V. IMPLEMENTATION

Based on the framework shown in figure 2, we have identified a suitable implementation model that consists of different sensor devices and other modules, their functionalities are shown in figure 3.In this implementation model we used Arduino UNO board with Wi-Fi module is as embedded device for sensing and storing the data in cloud. Arduino UNO board consist of analog input pins (A0-A5), digital output pins (D0-D13), inbuilt ADC and Wi-Fi module connects the embedded device to internet. Sensors are connected to Arduino UNO board for monitoring, ADC will convert the corresponding sensor reading to its digital value and from that value the corresponding environmental parameter will be evaluated. The Wi-Fi connection has to be established to transfer sensors data to end user and also send it to the cloud storage for future usage. Before sending the sensed data to cloud, the data will be processed in MATLAB for analyze and visualize data to end user. The data analysis in MATLAB makes easier to us to set threshold level and to perform necessary controlling actions.

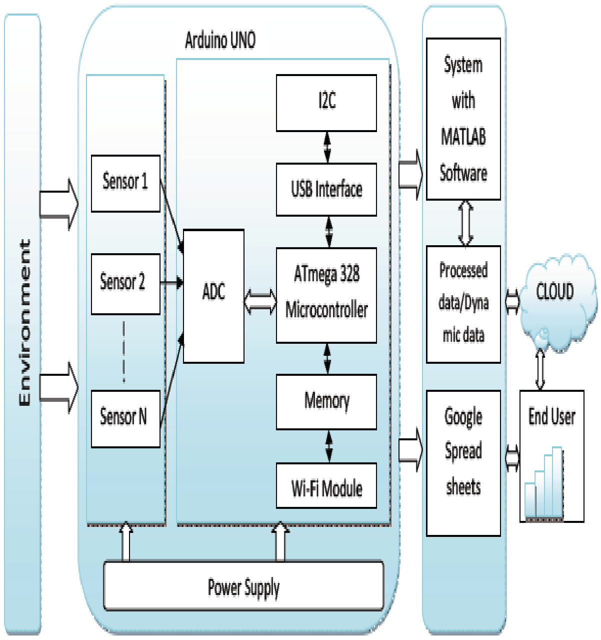

Fig. 3: Schematic diagram of implementation model

An embedded system designed for environmental monitoring and its components are shown in figure 4.The embedded device is placed in particular area for testing purpose. The sound sensor detects sound intensity levels in that area and Carbon Monoxide (CO) sensor MQ-9 will record the air quality in that region, if the threshold limit is crossed the corresponding controlling action will be taken (like issuing message alarm or buzzer or LED blink).All the sensor devices are connected to internet through Wi-Fi module.

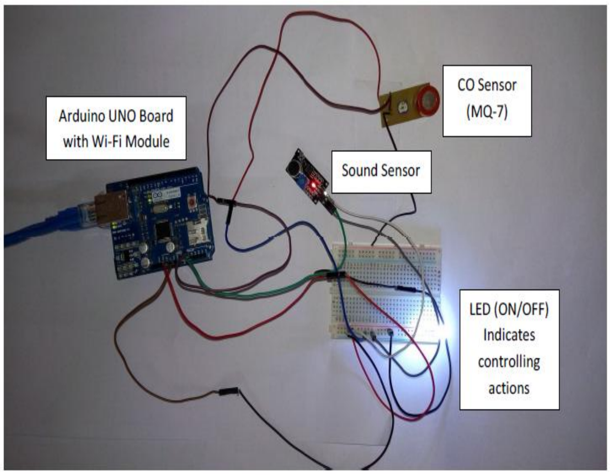

Fig. 4: Noise and air pollution monitoring embedded system with its components

Figure 4 shows the embedded system with its components for reading and to store the pollution parameters in cloud. After successful completion of sensing, the data will be

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processed and stored in database for future reference. After completing the analysis on data the threshold values will be set for controlling purpose.

VI. SIMULATION RESULTS

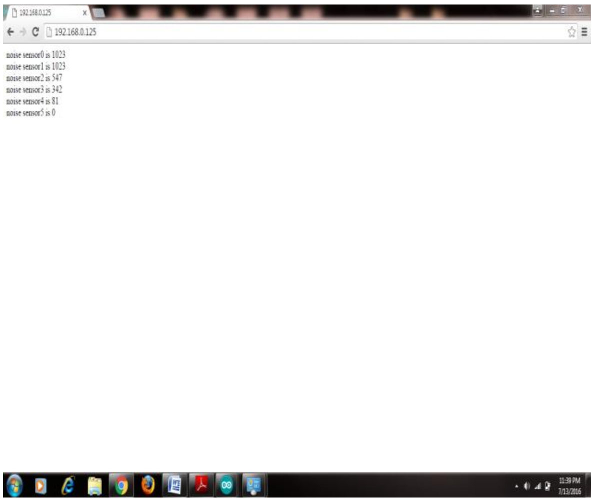

Fig. 5: web server page

After sensing the data from different sensor devices, which are placed in particular area of interest. The sensed data will be automatically sent to the web server, when a proper connection is established with sever device. The figure 5 shows the web server page which will allow us to monitor and control the system. By entering IP address of server which is placed for monitoring we will get the corresponding web page. The web page gives the information about the intensity of sound and the CO level variations in that particular region, where the embedded monitoring system is placed.

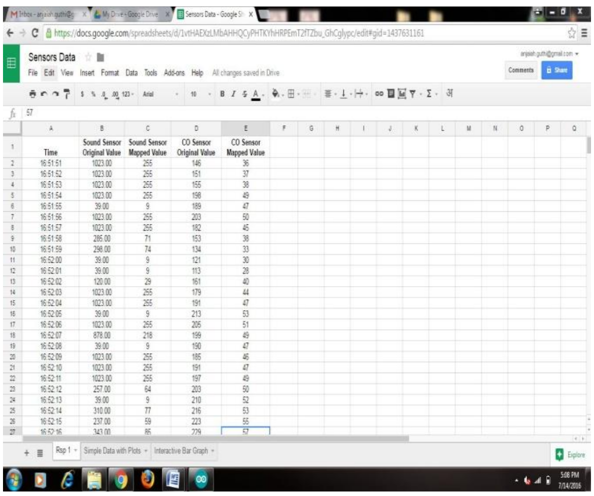

Fig. 6: Cloud storage (Google Spread Sheets) for sensors data.

The sensed data will be stored in cloud (Google Spread Sheets). The data stored in cloud can be used for the analysis of the parameter and continuous monitoring purpose. The figure 6 shows the noise intensity levels and CO levels in air at regular time intervals. All the above information will be stored in the cloud, so that we can provide trending of noise intensity and CO levels in a particular area at any point of time.

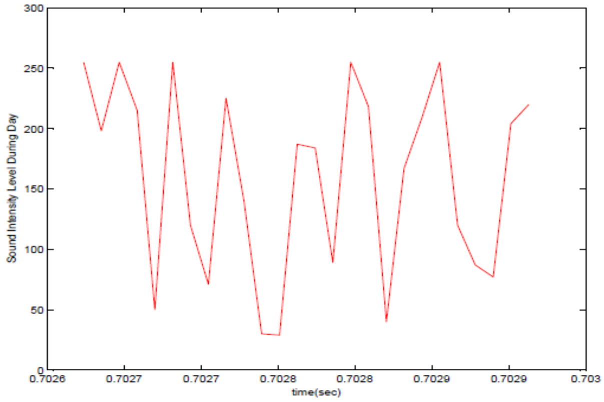

Fig. 7(a)

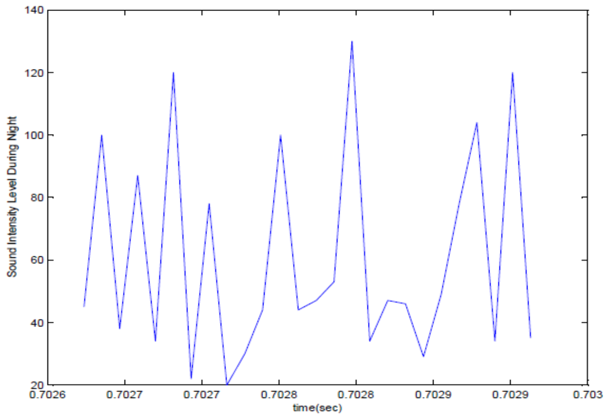

Fig. 7(b)

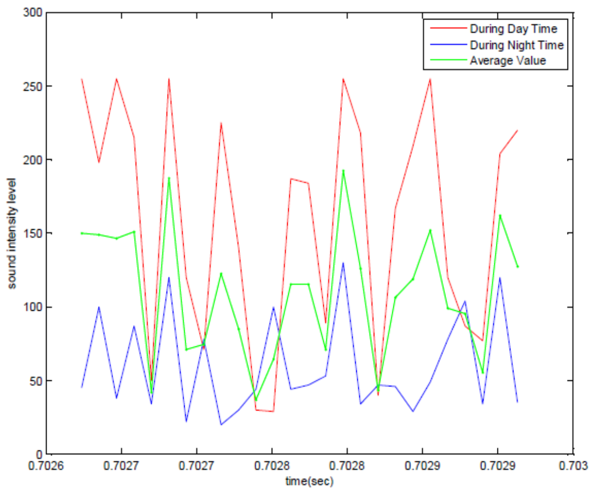

Fig. 7(c)

The graph in figure 7 (a) shows the sound intensity levels during day time at regular time intervals. The graph 7 (b) shows the sound intensity levels during night time. The graph 7(c) shows the average sound intensity levels during entire day. Depending on the average value, threshold value will be decided.

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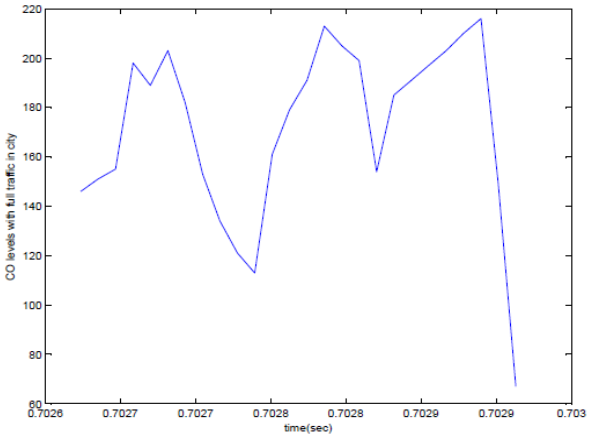

Fig. 8(a)

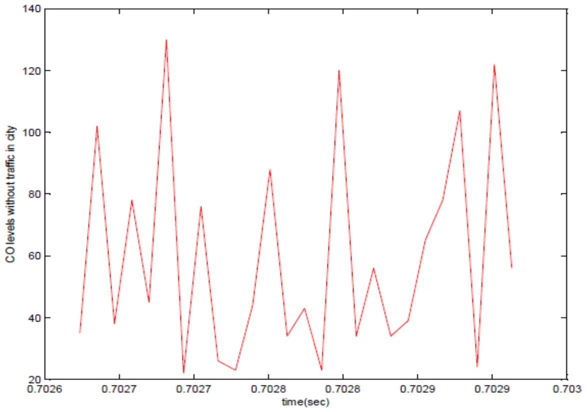

Fig. 8(b)

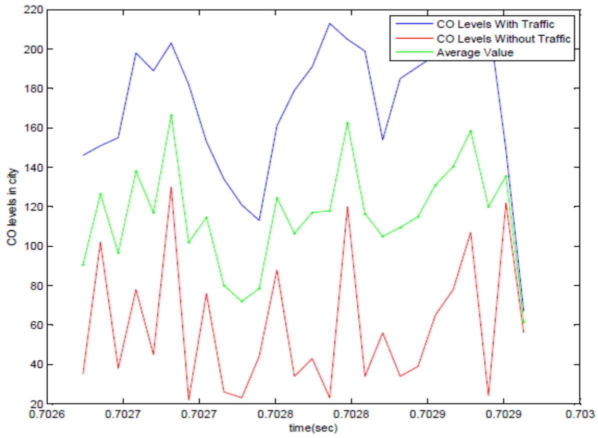

Fig. 8(c)

The graph in figure 8 (a) shows the CO levels in city environment with full traffic at regular time intervals. The graph 8 (b) shows the CO levels in city environment without traffic. The graph 8(c) shows the average CO levels during entire day. After completing the analysis on sensed data, the threshold value will be set for necessary controlling actions.

VII. CONCLUSION

By keeping the embedded devices in the environment for monitoring enables self protection (i.e., smart environment) to the environment. To implement this need to deploy the sensor devices in the environment for collecting the data and analysis. By deploying sensor devices in the environment, we can bring the environment into real life i.e. it can interact with other objects through the network. Then the collected data and analysis results will be available to the end user through the Wi-Fi.

The smart way to monitor environment and an efficient, low cost embedded system is presented with different models in this paper. In the proposed architecture functions of different modules were discussed. The noise and air pollution monitoring system with Internet of Things (IoT) concept experimentally tested for monitoring two parameters. It also sent the sensor parameters to the cloud (Google Spread Sheets). This data will be helpful for future analysis and it can be easily shared to other end users.

This model can be further expanded to monitor the developing cities and industrial zones for pollution monitoring. To protect the public health from pollution, this model provides an efficient and low cost solution for continuous monitoring of environment.

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