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Air Quality Monitoring System based on Arduino Microcontroller

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ABSTRACT: The level of pollution has increased with times by lot of factors like the increase in population, increased vehicle use, industrialization and urbanization which results in harmful effects on human wellbeing by directly affecting health of population exposed to it. In order to monitor quality of air, a Wireless sensor network (WSN) based new framework is proposed which is based on data acquisition and transmission. The parameters of the environment to be monitored are chosen as temperature, humidity, volume of CO, volume of CO2, detection of leakage of any gas - smoke, alcohol, LPG. The values of these parameters are transmitted by using Zigbee Pro (S-2) to a base stationwhere they are being monitored. The value of temperature and humidity are transmitted over Bluetooth also so that every person in the range of the system can check it over their smart phones and laptops as these parameters hold importance to everyone. CO, a dangerous parameter is monitored with an extra precaution. A text message is sent to the base station through GSM module whenever its volume exceeds a particular safe limit intended for a particular application.

KEYWORDS: WSN, Air Pollution, Arduino, GSM-GPRS, Bluetooth

I. INTRODUCTION

I.1 Air Pollution Problem

Air pollution is the biggest problem of every nation, whether it is developed or developing. Health problems have been growing at faster rate especially in urban areas of developing countries where industrialization and growing number of vehicles leads to release of lot of gaseous pollutants. Harmful effects of pollution include mild allergic reactions such as irritation of the throat, eyes and nose as well as some serious problems like bronchitis, heart diseases, pneumonia, lung and aggravated asthma. According to a survey, due to air pollution 50,000 to 100,000 premature deaths per year occur in the U.S. alone whereas in EU number reaches to 300,000 and over 3,000,000 worldwide [1]. Various kinds of anthropogenic emissions named as primary pollutants are pumped into the atmosphere that undergoes chemical reaction and further leads to the formation of new pollutants normally called as secondary pollutants. For instance, according to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), nearly all climate-altering pollutants either directly or indirectly (by contributing to secondary pollutants in the atmosphere) are responsible for health problems [2]. Almost every citizen spends 90% of their time in indoor air [3]. Outdoor air quality of the cities of developed countries improved considerably in recent decades. In contrast to this, indoor air quality degraded during this same period because of many factors like reduced ventilation, energy conservation and the introduction to new sources and new materials that cause indoor pollution [4]. The design of buildings for lower power consumption resulted in decrease of ventilation which further decreases the quality of air inside the building. This increases the need for indoor air quality (IAQ) monitoring Due to this fact and use of new building materials, IAQ often reaches to unacceptable levels [5].

I.2 Air Quality Monitoring Systems

The commercial meters available in the market are Fluke CO-220 carbon monoxide meter for CO, Amprobe CO2 meter for CO2, ForbixSemicon LPG gas leakage sensor alarm for LPG leakage detection. The researchers in this field have proposed various air quality monitoring systems based on WSN, GSM and GIS [6] [1] [7]. Now each technology has limited uses according to the intended function, as Zigbee is meant for users with Zigbee trans-receiver, Bluetooth

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is a short range communication system, GSM notifies through a message only. No such system is present that monitors various gases present in the environment like CO, CO2, smoke, LPG, iso-Propane, iso-Butane as well as the temperature and humidity in the environment at the same time and monitors these parameters at a remote location, provides extra precaution for the most crucial parameter and provides parameters important to all users such as temperature and humidity to every person in the range of the monitoring system**.** This paper proposes such system based on WSN, Bluetooth Technology and GSM/GPRS.

I.3 Wireless Sensor Network

Wireless sensor network (WSN) is a network of large number of programmable mobile and static sensor nodes with communication infrastructure which helps in recording and monitoring parameters like temperature, pressure, humidity, speed and wind direction, sound intensity, illumination intensity, vibration intensity, power-line voltage, vital body functions chemical concentrations and pollutant levels using multi-hop and self-organization method[8]. WSN consists of sensor nodes from dozens to thousands depending upon their usage and every node has essential feature to compute, save and broadcast data [9]. In the era of great technological enhancement, the word wireless is becoming famous in every field and thus WSN will be next technological market for making huge amount of money [6][10]. The technologies used in WSN are time synchronization, network protocol, localization, security administration, data aggregation and power management. Limitations in certain parameters such as processing power, bandwidth, energy and storage makes the task of providing security to the network really difficult [11].

The routing of WSN is implemented in different way than conventional routing of a fixed network; therefore study of routing protocols is a key point to design any wireless networks which are shown in Fig.1.

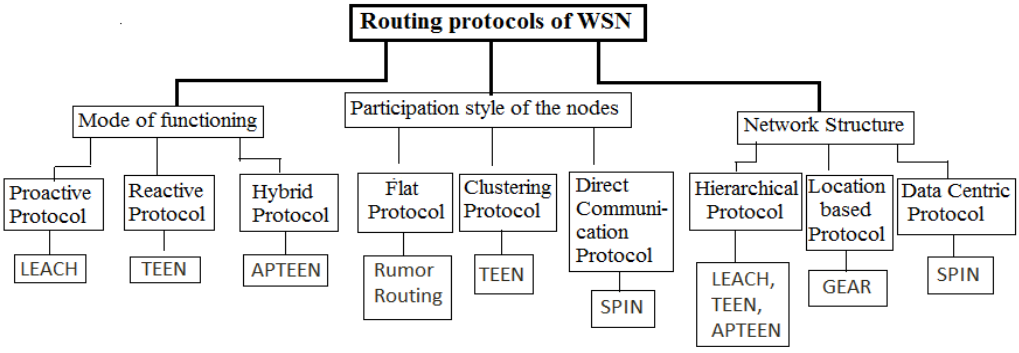

Fig.1 Routing protocols of WSN

II. RELATED WORK

GIS based system is designed, implemented and tested to monitor the pinpoints of air pollution of any area. It consists of a microcontroller, gas sensors, mobile unit, a temporary memory buffer and a web server with internet connectivity which collects data from different locations along with coordinate's information at certain time of a day. The readings for particular location are averaged in a closed time and space. The Global Positioning System (GPS) module is attached to a system to provide accurate representation of pollution sources in an area. The recorded data is periodically transferred to a computer through a General Packet Radio Service (GPRS) connection and then the data will be displayed on the dedicated website with user acceptance. As a result large number of people can be benefited with the large information gathering network [1].

GSM/GPRSbased system for recording environmental data such as temperature and humidity using Arduino Uno Microcontroller is proposed in which values are stored using SD card attached to GPRS module rather than Arduino Uno memory. The GPRS module is used to provide various functions like the transmission of the data, real-time clock functionality, and data storage on a Micro SD card. Hydrologic Information System (HIS) software created by Consortium of Universities for development of Hydrologic Sciences Inc. (CUAHSI). On software side HTTP GET request is generated to transmit data and to provide timestamps over the internet. Info (contains metadata information)

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and readings (contains temperature, humidity and timestamp values) are two parameters which are transmitted using GPRS technique. The data stored in HIS can be categorized in international catalogues such as the Global Earth Observation System of System (GEOSS) catalogue through WaterML encoding [12].
The system is proposed which integrate different technologies like frequency hopping communication technology and virtual instrument technology to fulfil wireless data transmission for monitoring of air quality.The carrier frequency is adjusted according to the result and full radio spectrum is used with the use of a spectrum hole detection sample. The wireless transmission of data is performed without interference with this specimen and real time information can be received by a system effectively. Moreover, this system is useful for non-professional staff also as the data is easy to read and shown clearly [13].
Pollution can be effectively monitored with the use of WSN is capable of providing a real time pollution data. The calibration of gas sensors like CO_2 gas sensors, NO_2 gas sensor is done by using various suitable calibration technologies and then WSN is formed using a multi hop data aggregation algorithm. The pollution data is shown in the form of numbers and charts with the help of web interface and is available on internet as well. Temperature and humidity parameters are measured along with the gases and data is analysed data fusion [14].
The system is deployed in the public transport like buses which have reliable and fixed routes. The model includes Mobile Sensing Box (MSB) which consists of a microcontroller, sensors, GPS system and a cellular modem. The power supply is provided by connecting to the bus battery to operate this model. The concentration of CO and particulate matter is measured in the proposed system. The system consists of various monitoring stations, which are able to communicate wirelessly with the use of backend server, equipped with the metro logical sensor and gas sensor for recording data wirelessly. The real time data which is collected through a backend server is converted to the useful information for the user with the help of web portals [15].

III. PROBLEM STATEMENT

During past decades, as result of civilization and urbanization there is a huge growth in Polluting industries, open burning of refuse and leaves, massive quantities of construction waste, substantial loss of forests and vehicles (particularly diesel-driven cars) on roads that give rise to health endangering pollution. Therefore, it is necessary to regularly monitor and report the hazardous impacts from air pollution.
To monitor the quality of air, a new framework is proposed that monitors the parameters of the environment around us such as CO2, CO, presence of smoke, alcohol, LPG, temperature and humidity with the help of GSM, Bluetooth and WSN.

IV. AIR QUALITY PARAMETERS

The important parameters that are considered in the proposed framework include:

IV.1 Carbon monoxide gas

CO is odourless, colourless, tasteless and highly poisonous gas. It is released when fuel in engine does not burn properly and road traffic is the primary source of 91% of all CO emissions [1]. In addition, after combining with the haemoglobin of blood, it forms carboxyhaemoglobin (HbCo) which leads to reduction in oxygen carrying capacity of blood thus causes hypoxia. Human health is largely in danger with the exposure to 100ppm or more [16]. Continuous exposure of CO even at low levels can cause depression, confusion, and memory loss. Carboxyhemoglobin can be reverted to haemoglobin but the recovery process is slow because of the stability of HbCo complex. The optimum treatment for CO poisoning although remains controversial, but providing hyperbaric oxygen therapy is considered as a treatment whether or not it provides necessary results [17]. Half-life of CO gets shortens from 320 minutes to 80 minutes on normal air by managing oxygen via non-rebreathe mask [18].

IV.2 Carbon dioxide gas

CO2 is colourless, odourless gas and non-combustible gas. Moreover, it is considered under the category of asphyxiate gases that have capability of interfering the availability of oxygen for tissues [19]. It is certified study that if the oxygen

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is unavailable for 3 to 5 minutes, it can cause brain damage or death. Many times, occupant generated CO2 act as a substitute for measurement of IAQ. The requirement of outdoor air can be easily predicted by the content of CO2 and according to the guidelines of ASHRAE CO2 levels must be less than 1000ppm [20]. Generally CO2 levels of outdoor air are under 350ppm.

IV.3 Smoke

About 1 million people are in habit of tobacco smoking globally of which majority population is from developing countries [21]. Every year nearly 4.9 million people died due to smoking according to 2007 report [22]. In addition, second hand smoke is serious threat to the health of people of all age's causes 41000 deaths each year.

IV.4 LPG

Liquefied petroleum gas (LPG) is an odourless and colourless liquid which evaporates readily into a gas. Leakage is normally detected by adding an odorant into it. It is considered under the category of highly flammable gases and it can be classified as a carcinogen and mutagen if Butadiene content is more than 0.1%. LPG may leak in the form of a gas or a liquid. If it leaks in the form of a liquid it evaporates quickly and will eventually form large cloud of gas in air which is relatively heavier than air thus drops to the ground. Whereas, LPG vapours travel along the ground for a long distance and gets collected in drains or basements. Gas leads to burn or explode after getting in touch with a source of ignition.

IV.5 Temperature and humidity

Measurement of temperature is important for safety of people and affects our life skills. Greenhouse effect can be monitored by measuring temperature and comparing temperature changes from historical to present time especially since the industrial revolution using climate data.

Humidity is a type of gas that protects us from UV rays from the sun and helps trap heat on Earth, thereby making the climate on Earth, a pleasant one for living. But as humidity increases, the warmth on Earth also increases which makes our life uncomfortable. Humidity is essential for various storage and food processing facilities.

V. BLOCK DIAGRAM AND WORKING

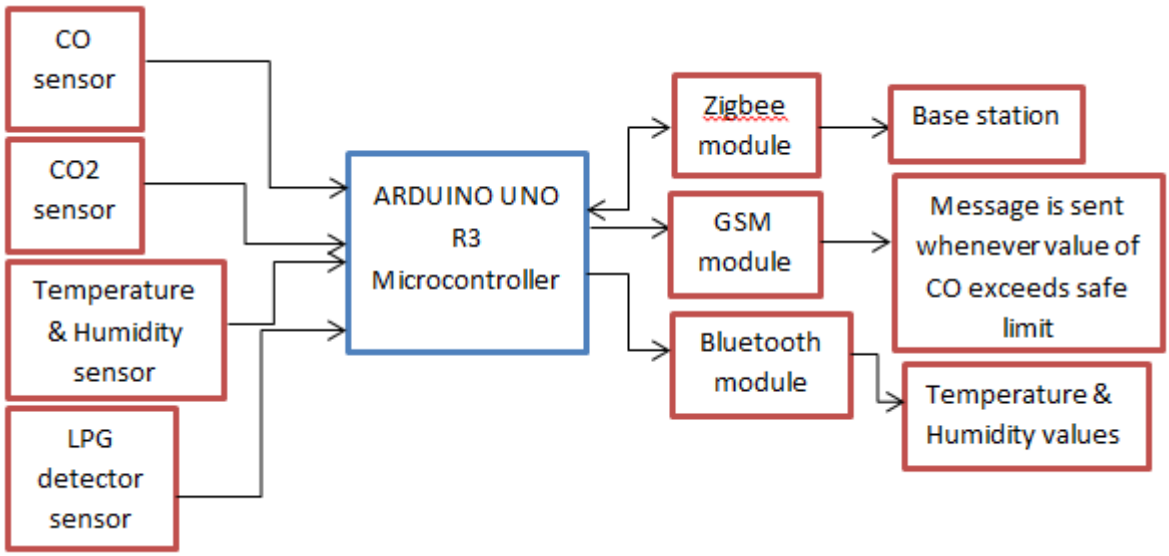

Fig.2 Block Diagram of Proposed System

The proposed air quality monitoring is based on the block diagram as shown in Fig.2 the data in air is acquired by CO2 sensor, CO sensor, gas leakage detection sensor and temperature and humidity sensor. After the data acquisition stage, the pre-processing stage comes in which the Arduino processes the information received from the sensors and

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changes it into more viable form to be accessed at the base station and by the user. Zigbee S2 acts as a gateway for the communication between Arduino and the base station. The text message though GSM module marks an extra precaution for the level of CO in air. Temperature and humidity values are also transmitted via a short range communication with the Bluetooth module.

VI. PROPOSED AIR QUALITY MONITORING SYSTEM DESIGN

The proposed Air Quality Monitoring System is a 2 tier system as shown in Fig.3.

Fig.3 Setup of Monitoring System

VI.1 Air Quality Monitoring Equipment

The equipment shown in Fig.4 helps in the acquisition of the data for the various parameters of the environment in which the system is installed.

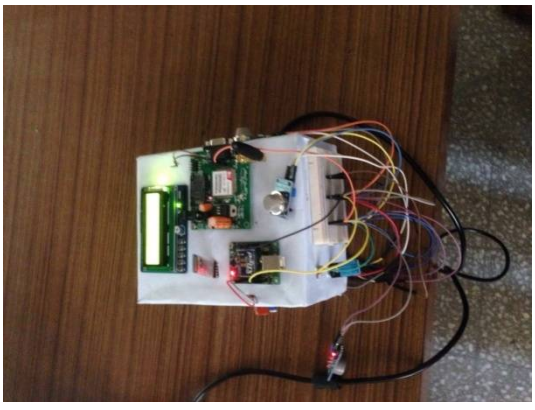

Fig.4 Air Quality Monitoring Equipment

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

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VI.1.1 Arduino Uno R3 microcontroller:It is the most flexible hardware platform used based on ATmega328P which can be programmed according to the function where it is to be used. It has 6 analog inputs, 14 digital input/output pins (6 pins of these can be used as PWM outputs) , a USB connection, a 16 MHz quartz crystal, SPI, serial interface, a reset button, a power jack and an ICSP header as shown in Fig.5

Fig.5 Arduino Uno R3 microcontroller

The Arduino microcontroller is not only for technical audience but is intended for designers and artists as well because of its focus to usability based on its design which helps to achieve the intended goal [23].
It is the primary component of the framework. In addition, it is an open source microcontroller device with easily accessible software/hardware platform and is compatible with many sensors available. Everything needed for its working is present on the board; we only require a USB cable to directly connect it to the computer or give power using battery source or AC to DC adapter to get started. Also, it is not expensive and can be assessed with free authoring software i.e. IDE (integrated development environment). With the availability of a large no. of source codes over the internet, the programming of Arduino becomes easy. The online growing community backing Arduino consists of programmers like us that share their examples for others to make it a more reliable platform.

VI.1.2 CO2 Gas Sensor*:* The Sensitive material used in MQ135 sensor is SnO2. The conductivity of this material is lower in clean air. The sensor conductivity increases with the increasing concentration of target pollution gas. MQ135 can monitor different kinds of toxic gases such as sulphide, ammonia gas, benzene series steam and CO2. The detection range is 10-10,000 ppm with the voltage rate of about 5.0V±0.1V AC or DC. The important features are long life span, low cost, simple driver circuit and good sensitivity to toxic gases. MQ 135 gas sensor is widely used in industrial gas alarm, portable gas detector and domestic gas alarm [24] as shown in Fig.6.

Fig.6 MQ135 Gas Sensor

MQ-135 is used in this framework for monitoring CO2 in air. The amount of CO2 present in the atmosphere is 400.7 ppm [25] according to which the sensor is calibrated.

VI.1.3 Gas Leakage Detection Sensor*:*It is basically used for detection of LPG, Hydrogen, i-butane, propane, alcohol, smoke and methane in houses and industries. The resistance value of MQ2 sensor varies for various kinds of gases; therefore the sensitivityadjustment isnecessary which uses this component. The sensor is calibrated with a load resistance of about 20 KΩ and the concentration of the gas to be detected is selected as: 1000 ppm Liquefied Petroleum

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Gas (LPG), 1000 ppm iso-butane <i-C4H10> in clean air. Moreover, the influence of temperature and humidity is to be considered while determining proper alarm point for gas detector for accurate [26] as shown in Fig.7

Fig.7MQ2 Gas Sensor

In the proposed framework, MQ2 is used for detecting of leakage of gases. Depending on the gas, the system can be used for detection of LPG gas at home, i-butane, propane, and methane in industries or smoke at places where there is a danger of fire. As soon as a particular gas is detected, buzzer attached to the microcontroller turns on indicating the presence of that gas.

VI.1.4 CO Gas Sensor*:* MQ-7 gas sensor is a low cost device that is very sensitive to CO and thus helps in the detection of this gas. The detection range is 10-10,000 ppm and heater voltage rate is about 5.0V±0.2V DC or AC (High) and 1.5V±0.1V DC or AC (Low) [27]. The average response time is less than 150 seconds [28]. The sensor conduction becomes higher with rising concentration of gas to be detected. The main characteristics are high sensitivity to combustible gas and natural gas, simple drive circuit, long life and low cost as shown in Fig.8

Fig.8 MQ7 Gas Sensor

In this proposed framework, CO is an important aspect. The dangerous effect of CO makes it an important thing to keep an eye on. The CO measured is displayed on the LCD attached to the microcontroller to be easily viewed by anyone present near the setup. An extra precaution is a text message that is sent to the person monitoring the presence of CO whenever the volume of CO2 exceeds a particular safe limit according to the purpose to which the system is intended.

VI.1.5 Temperature and Humidity Sensor: DHT11 is featured to measure temperature and humidity sensor complex by using temperature & humidity sensing technology and digital-signal-acquisition technique with output in the form of calibrated digital signal [29]. The sensor consists of NTC (Negative Temperature Coefficient) component for temperature measurement and resistive type component for measuring humidity as shown in Fig.9

Fig.9 DHT11 Sensor

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Temperature and humidity are the two basic parameters that for all intended purposes need to be monitored. Technical as well as non - technical persons need a check on temperature and humidity in a room to work in effectively. The value of temperature and humidity is transmitted in this proposed system with the help of Bluetooth module due to this reason only so that each and every person with a smart phone or a laptop can view the value of these parameters.

VI.1.6 GSM SIM 900A: Radio modem by SIMComm is used in the shield. Communication with the shield can be done easily with the shield by using AT commands. It Supports features like Data, Voice, GPRS, SMS and integrated TCP/IP stack. The connections of GSM module are done directly to PC through serial port/to microcontroller through serial interface with the use of MAX232. In addition to this, In GPRS mode, it can be connected to internet to run various applications for recording data over the time and to any remote FTP server to upload files for the data to be saved. For different applications particular specifications are required which are mentioned in datasheet of GSM module [30] as shown in Fig.10.

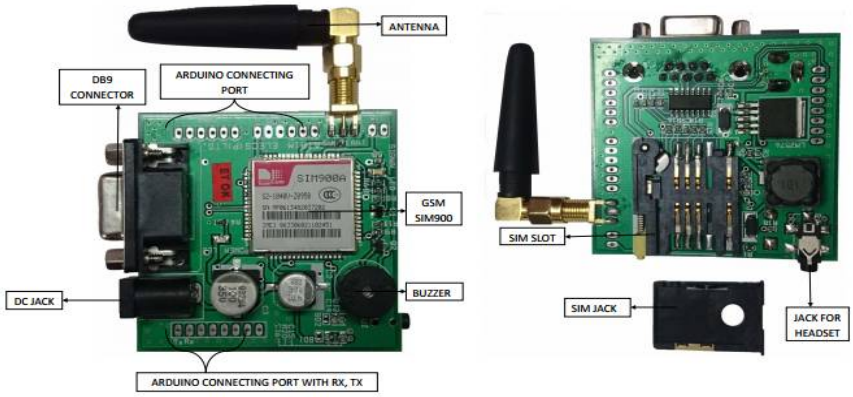

Fig.10 GSM module

In this system, SMS application is used which is intended for the person who is monitoring the value of CO in a room or an industry whenever it exceeds a particular safe limit chosen according to a particular application. The threshold safe limit as well as the mobile number of the person to which the text message is to be sent is programmed in the Arduino which can be changed for any specific purpose.

VI.1.7 Zigbee Transmission module:The ZigBee Series 2 Modules operate using Zigbee protocol There is a requirement of mainly four number of connections- power of 3.3 V, ground, data in and data out(UART) with two other mentioned lines being sleep and reset [31][32]. It operates in the ISM 2.4 GHz frequency band. Moreover, it is easy to use Zigbee S2 as for out of box RF communication no configuration is necessary, for configuring module parameters AT and API Command Modes are used. It has Small form factor and extensive command set. Zigbee operates over DSSS (Direct Sequence Spread Spectrum) technique and has over 65,000 unique network addresses available each direct sequence channel [33] as shown in Fig.11.

Fig.11 ZigBee Module

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The transmission of the data from the sensors can be done by using Internet, GPRS technology as well as WSN. The use of Zigbee Technology in this proposed framework is because it is a cost effective solution to the data transmission problem with minimal power requirement. As data monitoring is a continuous process, large amount of data is required to be transferred over the communication channel which adds to the operating cost of the system if GPRS or internet is used as a transmission tool. This is an advantage in Zigbee technology as no data cost is required for communication.

VI.1.8 Bluetooth module: HC-05 module intended for wireless serial communication is based on Bluetooth Serial Port Protocol. This module supports Bluetooth V2.0 with Enhanced Data Rate. It operates in 2.4 GHz frequency band and has physical dimensions as small as 12.7 mm ×27 mm. Hardware features include -80dBm sensitivity, RF transmitted power of Up to +4dBm, PIO control, UART interface with programmable baud rate, integrated antenna and edge connector [34] as shown in Fig.12.

Fig.12 HC-05 Module

In this framework, Bluetooth acts as a gateway for technical and non-technical persons for transmitting values of temperature and humidity.

VI.2 Control Station

At the control station the various parameters monitored are stored and analysed. The X-CTU simulation environment helps to display the values from the X-Bee Pro transmitter by using a Zigbee Pro receiver attached to a computer placed at the control station. The most crucial parameter in the proposed system is CO. An increase above a certain level is notified through a text message with the help of GSM Module to the person at the control station.

VII. RESULTS

The air quality monitoring system involving gas sensors for monitoring of various parameters has been successfully implemented. The data received from the sensors is displayed on the serial monitor of IDE is shown in Fig.13 and the data received on the console log of X-CTU software at control station is shown in Fig.14.

The proposed system has been used to test the quality of air in PEC University of Technology, Chandigarh. The serial monitors of IDE displays values of temperature in Celsius, humidity in percentage, volume of CO2 and CO in ppm received from the sensors is displayed on the serial monitor of IDE. The values received for the parameters shows that the quality of air in the University environment is good as the value of CO is very less and the value of CO2 is also not a very big value. There was no presence of smoke and the value of temperature and humidity was the same as predicted on the internet.

The coding in C language is performed in the simulation environment of Arduino (IDE).

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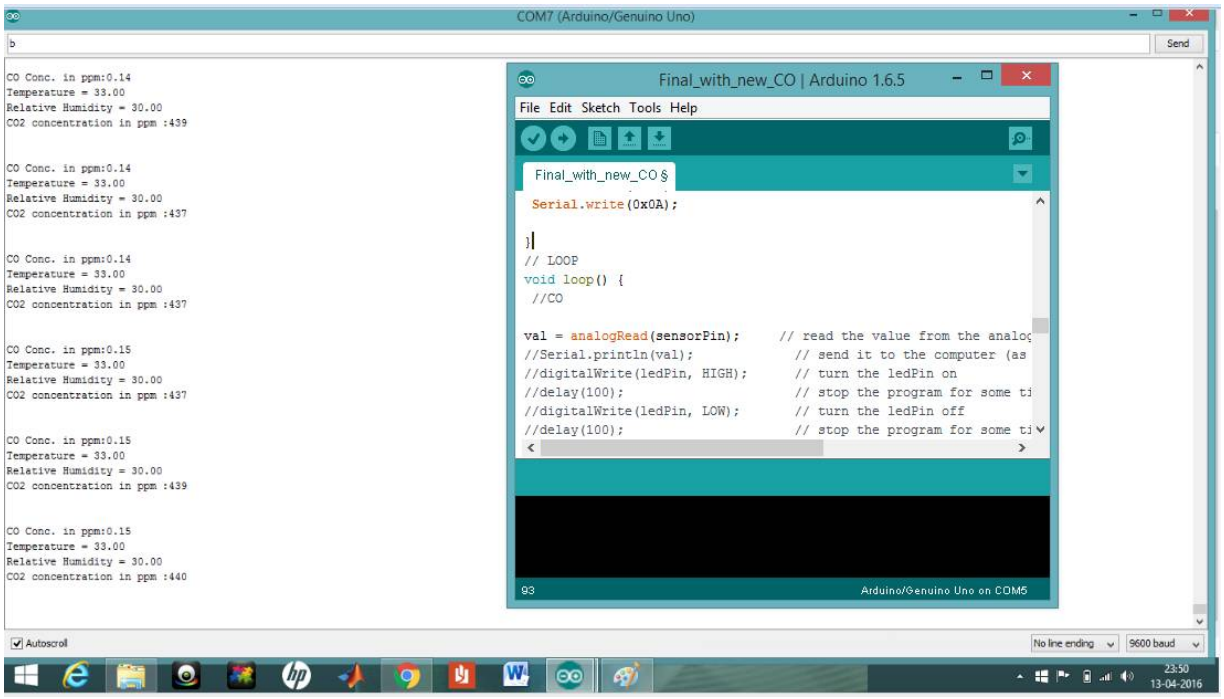

Fig.13 Serial Monitor of IDE

The values received at the control station when the system was implemented have been shown the Fig.14. The Fig.14 shows the console log of X-CTU simulation software which shows values received from various sensors attached to the monitoring equipment. ASCII codes for the received information are also shown in the right hand side of the console log.

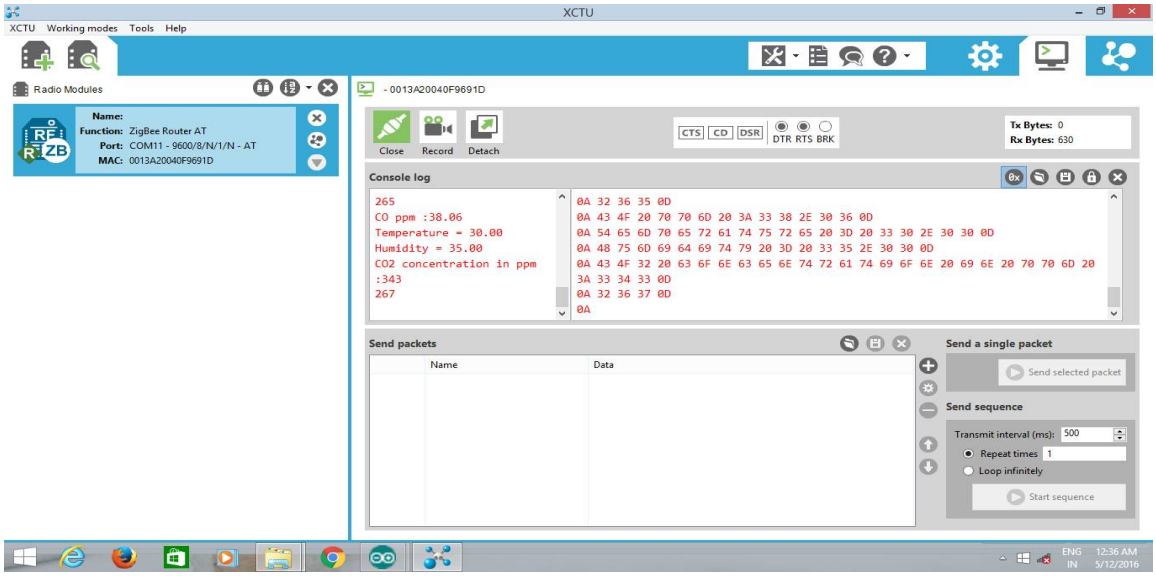

Fig.14 Console log of X-CTU software

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TERA TERM software provides a virtual terminal serial communications. The selected port for serial communication is Port 4 as shown on the top of software window. The values are received at the serial port through Bluetooth communication is shown in Fig.15.The displayed value of temperature is in Celsius and the value of humidity is in percentage.

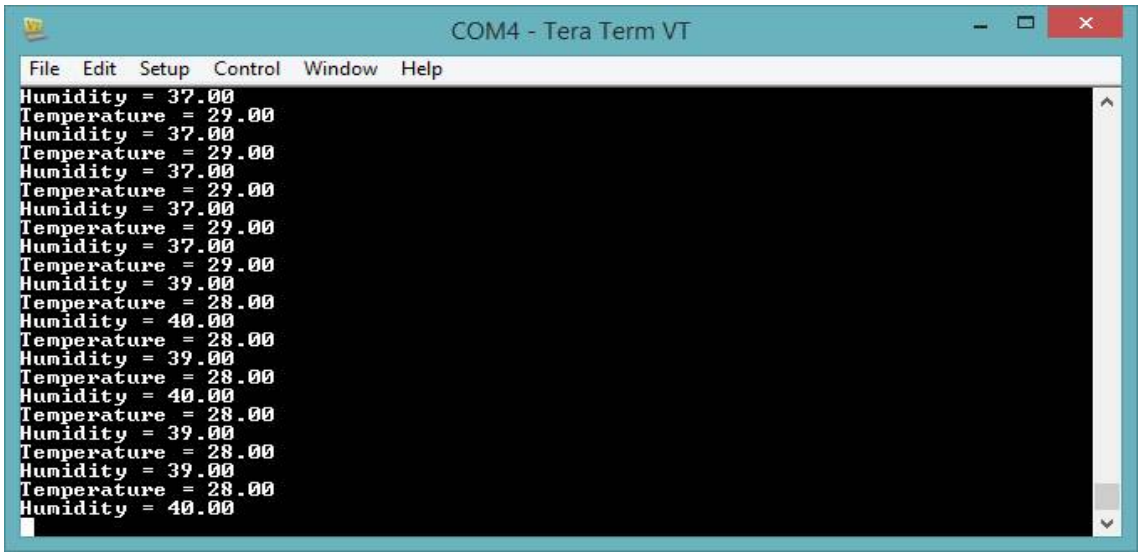

Fig.15 Display Screen of TERA TERM Software

VII. CONCLUSIONS AND PERSPECTIVES

The system to monitor various parameters of environment using Arduino microcontroller, WSN and GSM Technology is proposed to improve quality of air. With the use of technologies like WSN and GSM enhances the process of monitoring various aspects of environment such as air quality monitoring issue proposed in this paper. The detection and monitoring of dangerous gases is taken into account in a serious manner and related precautions have been considered here in the form of an alert message and a buzzer so that the necessary action may be taken. It is estimated that this system will have a great acceptance in the market as it is a centralized system for a complete monitoring function.

This monitoring system can be enhanced by adding wireless network card for storage of values from sensors attached to microcontroller as well as more gas sensors could be used like Nitrogen dioxide (NO2), Ammonia (NH3), Sulfureted Hydrogen (H2S), alcohol etc. Another aspect of measuring particulate matter can be introduced to make it more advanced.

REFERENCES

[1] Tudose, D. Ş., Pătraşcu, N., Voinescu, A., Tataroiu, R., and Ţăpuş, N. , "Mobile Sensors in Air Pollution Measurement.", in Positioning Navigation and Communication (WPNC), IEEE , pp. 166-170, 7 Apr 2011.

[2] TERI. 2015. Air Pollution and Health. Discussion Paper by The Energy and Resources Institute: New Delhi by Rinki Jain (Associate Fellow, TERI), KarnikaPalwa (Research Associate, TERI)

[3] João Ramos Maria, João Dias, "Analyses of Indoor Environmental Quality and Ventilation in a Building of a School of Higher Education in Portugal", in the 4th Advanced Research in Scientific Areas conference, pp. 273-278, 1 Nov 2015.

[4] Dias, M. J. et al., (2010). "Indoor Air Quality Evaluation in School Buildings Ventilated by Natural and Mechanical Systems". Clima pp. R6-TS62-0P02, Turkey: REHVA. ISBN Code of the CD 978-975-6907-14-6, 2010.

[5] Olesen, B. W., &Brager, G. S., "A Better Way to Predict Comfort: The New ASHRAE Standard 55-2004", ASHRAE Journal, pp. 20-26, 8 Aug 2007.

ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 6, June 2016

[6] Al-Haija, Q. A., Al-Qadeeb, H., & Al-Lwaimi, A.,"Case study: Monitoring of air quality in king Faisal University using a microcontroller and WSN", Procedia Computer Science, volume 21, pp. 517–521, 31 Dec 2013.
[7] Sricharan, K. S., Shrivasan, M. A., & Kumar, S. S., "An Intelligent Automated Emission Quality Monitoring System Designed to Test the Vehicles in the Signal", in Green Computing, Communication and Conservation of Energy (ICGCE), International Conference on IEEE , pp. 590-593, 12 Dec 2013.
[8] Zhang, S., & Zhang, H., "A Review of Wireless Sensor Networks and its Applications", in Automation and Logistics (ICAL), IEEE International Conference on pp. 386-389, 15 Aug 2012.
[9] Mahmoudzadeh, B., &Faez, K., "HCTT&R: A Complete Scheme for Object Tracking and Recovery of Lost Objects in Cluster-Based Wireless Sensor Networks", in Telecommunications (IST), Sixth International Symposium IEEE conference, pp. 691-696, 6 Nov 2012.
[10] Qasem Abu Al-Haija, "Toward Secure Non-Deterministic Distributed Wireless Sensor Network Using Probabilistic Key Management Approaches", Journal of Information Assurance and Security, Vol-6, issue-1, pp. 10-18, 2010.
[11] Polastre, J., Szewczyk, R., Sharp, C., & Culler, D., "The Mote Revolution: Low Power Wireless Sensor Network Devices", in Hot Chips, Vol. 16, pp. 22-24, 22 Aug 2004.
[12] Jeffrey M. Sadler, Daniel P. Ames, RohitKhattar, "Open-Hardware Meets Open Software for Environmental Monitoring", in International Environmental Modelling and Software Society (iEMSs) , San Diego, CA, USA, 2014
[13] Wang, H., Wu, T., & Wu, G., "Air Quality Monitoring System Based on Frequency Hopping System", in Intelligent Control and Information Processing (ICICIP), IEEE Conference, pp. 641-64, Aug 2010.
[14] Raja Vara Prasad Y, Mirza Sami Baig, Rahul K. Mishra, P. Rajalakshmi, U. B. Desai5 And S.N. Merchant,, "Real Time Wireless Air Pollution Monitoring System" Ictact Journal On Communication Technology: On Next Generation Wireless Networks And Applications, Vol. 2, Issue 2, June 2011.
[15] Devarakonda, S., Sevusu, P., Liu, H., Liu, R., Iftode, L., &Nath, B., "Real-time Air Quality Monitoring Through Mobile Sensing in Metropolitan Areas", in Proceedings of the 2nd ACM SIGKDD International Workshop on Urban Computing, pp. 15, Aug 2013.
[16] Prockop, L. D., &Chichkova, R. I., "Carbon Monoxide Intoxication: an Updated Review", Journal of the neurological sciences, Vol. 262, Issue 1, pp.122-130, 15 Nov 2007.
[17] Buckley, N. A., Isbister, G. K., Stokes, B., &Juurlink, D. N, "Hyperbaric Oxygen for Carbon Monoxide Poisoning: a Systematic Review and Critical Analysis of the Evidence", Toxicological Reviews,Vol. 24, Issue 2, pp. 75-92, 1 Jun 2005
[18] Weaver LK, "Clinical practice. Carbon Monoxide Poisoning". The New England Journal of Medicine, Vol. 3601, Issue 12,pp. 1217-1225, Mar 2009.
[19] Asmi, A., Putra, J. C. P., &Rahman, I. B. A., "A Study of Indoor Air Quality of Public Toilet in University's Building", in Humanities, Science and Engineering (CHUSER), IEEE Colloquium ,pp. 403-408, 3 Dec 2012.
[20] Raza A. Khan1 et al, "Impact of HVAC Systems on IAQ in Building Environment" International Journal of Advance Research, in Science And Engineering, IJARSE, Vol. 3, Special Issue1, Sep 2014
[21] "Tobacco Fact Sheet N°339". May 2014. Retrieved on 13 Mar 2016.
[22] West, Robert and Shiffman, Saul, "Fast Facts: Smoking Cessation. Health Press Ltd." pp. 28. ISBN 978-1-903734-98-8, 2007.
[23] Diakopoulos, D., &Kapur, A., "HIDUINO: A Firmware for Building Driverless USB-MIDI Devices Using the Arduino Microcontroller", in NIME, pp. 405-408, May 2011.
[24] Technical Data for MQ135 Gas sensor
https://www.olimex.com/Products/Components/Sensors/SNS MQ135/resources/SNS-MQ135.pdf. Retrieved on 10 Jan 2016.
[25] Technical Data on MQ135 Gas sensor
https:// www.co2.earth. Retrieved on 3 May 2016.
[26] Technical Data for MQ-2 Gas Sensor
http://www.seeedstudio.com/depot/datasheet/MQ-2.pdf. Retrieved on 15 Jun 2015.
[27] Technical Data for MQ-7 Gas sensor
https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf.
[28] K SrinivasaSricharan et al., "An intelligent automated emission quality monitoring system designed to test the vehicles in the signals", IEEE conference on Green Computing, Communication and Conservation of Energy (ICGCE), 2013.
[29] Technical Data for DHT11 Sensor
www.micro4you.com/files/sensor/DHT11.pdf. Retrieved on 4 Oct 2015.
[30] Technical Data on GSM SIM 900 module
http://extremeelectronics.co.in/datasheets/gsm_shield_sim900a.pdf. Retrieved on 12 Feb 2016.
[31] Technical Data for Arduino and XBee
http://cs.smith.edu/dftwiki/index.php/Tutorial:_Arduino_and_XBee_Communication. Retrieved on 5 Dec 2015.
[32] Ali Al-Dahoud et al., "Monitoring Metropolitan City Air-quality Using Wireless Sensor Nodes based on ARDUINO and XBEE", International Conference on Circuits, Systems and Signal Processing, communication and computers, pp. 121-125, Mar 2015.
Technical Data for X-Bee Communication http://www.farnell.com/datasheets/27606.pdf. Retrieved on 20 Nov 2015.
Technical Data on HC-05 bluetooth module http://www.robotshop.com/media/files/pdf/rb-ite-12 bluetooth_hc05.pdf.Retrieved on 20 Jan 2016.