

# Zigbee Based Wireless Air Pollution Monitoring System Using Low Cost and Energy Efficient Sensors

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**Abstract**— Air pollution is a major environmental health problem affecting the developing and the developed countries alike.

The effects of air pollution on health are very complex as there are many different sources and their individual effects vary from one to the other. These chemicals cause a variety of human and environmental health problems. Increase in air pollution effects on environment as well on human health, so this paper contains brief introduction about air pollution. To monitor this pollution wireless sensor network (WSN) system is proposed. The proposed system consists of a Mobile Data-Acquisition Unit (Mobile-DAQ) and a fixed Internet-Enabled Pollution Monitoring Server. The Mobile-DAQ unit integrates a single-chip microcontroller, air pollution sensors array, and Global Positioning System Module (GPS Module).

The Pollution-Server is a high-end personal computer application server with Internet connectivity. The Mobile-DAQ unit gathers air pollutants levels (CO, NO<sub>2</sub>, and SO<sub>2</sub>), and packs them in a frame with the GPS physical location, time, and date. The frame is transmitted to the Pollution-Server via zigbee module. The Central-Server is interfaced to Google Maps to display the location of hardware unit. We can connect database server to the Pollution-Server for storing the pollutants level for further usage by various clients such as environment protection agencies, vehicles registration authorities, and tourist and insurance companies.

**Keywords**- Air pollution, CO, SO<sub>2</sub>, NO<sub>2</sub> Sensor.

## I. INTRODUCTION

Pollution can be defined as presence of minute particles that disturbs the functioning of natural processes and also produces undesirable health effects.

In other words pollution can affect the natural cycle and also can disturb the health of human being [2]. As industrialization is growing very extensively pollution is also getting introduced at large manner. At present there is Air pollution, Water pollution, Soil pollution worldwide. This thesis only focuses on Air pollution. Air pollution is the presence of contamination or minute particles that interfere with human

health and environment. These pollutants basically result from vehicles, industries [1].

The World Health Organization states that 2.3 million people die each year due to causes directly attributed by air pollution. Based on the fact above mentioned, the human should focus on air pollution monitoring [2].

There are two methods for monitoring air pollution at present. One is passive sampling (non-automatic), and other is continuous online monitoring (automatic). The Passive sampling uses simple equipment but it does not provide the real time values. The procedure of continuous online monitoring uses sensors to monitor the parameters, and then send to control center by network. The way of data transfer includes wired and wireless systems. Even though system is reliable it is having short comings at large and dynamic range, such as complex network cabling, expensive etc.

With extensively developing communication technologies, now a day's air pollution monitoring system is often designed in wireless mode. At present, the wireless mode in air pollution monitoring deals with GSM, GPRS, etc. But these modes are high cost in both installation and maintenance. But on the other hand Wireless sensor networks have been rapidly developed during recent years and used on the large scale at military, industries too. Based on these advantages, it is now being applied in environmental monitoring [4].

In order to implement such system single chip microcontroller along with array of sensors, zigbee module and Global positioning system module (GPS-module) is used. This system measures concentration of gases such as CO, NO<sub>2</sub> and SO<sub>2</sub> using electrochemical sensors. The hardware unit gathers air pollutants levels also pack them into the frame with GPS physical location, time and date. The frame is uploaded to the zigbee modem and transmitted to the central server via zigbee. Central server is interfaced to Google maps to display location of hardware unit. The system is low cost and energy efficient in terms of sensors.

## II. PROPOSED SYSTEM

In this dissertation work it is proposed to carry out response analysis of Air Pollution Monitoring. Zigbee module is used here, over GSM and GPRS as it is having low installation and maintenance cost. Over Passive sampling (non-automatic)

method of pollution measurement, we have chosen continuous online monitoring (automatic) technique. The Passive sampling uses simple equipment but it does not provide the real time values. The procedure of continuous online monitoring uses sensors to monitor the parameters, and then send to control center by network. Here we have used continuous online method so as to get the real time values of concentration of pollutants. Also we have decided to use PIC microcontroller which is having in built ADC, thus it reduces extra circuitry of ADC for signal conditioning. As we have decided to use electrochemical sensors the overall system will be energy efficient and low cost in terms of sensors. System measures the concentration of gases such as CO, SO<sub>2</sub>, and NO<sub>2</sub> using electrochemical sensor.

*Block Diagram-*

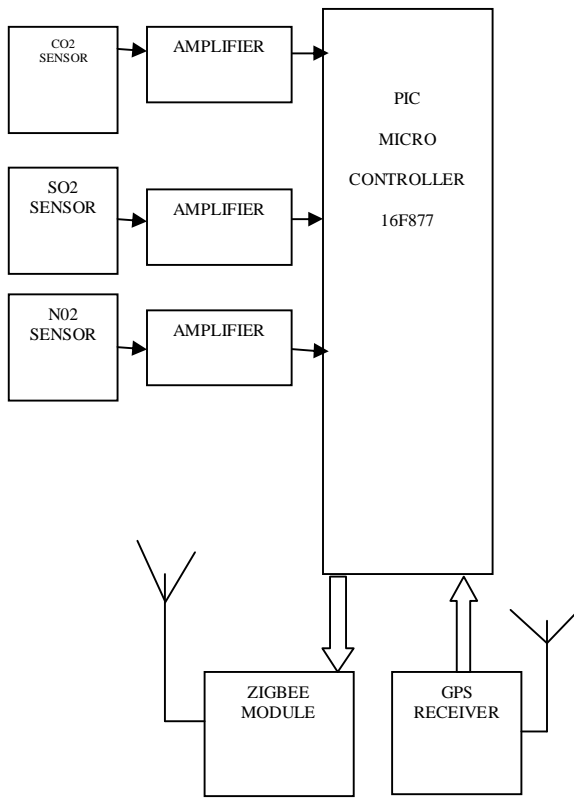


Fig 1 System hardware at transmitter side

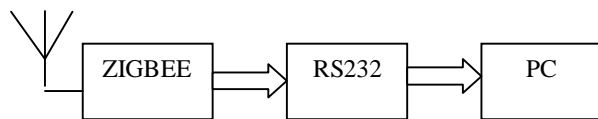
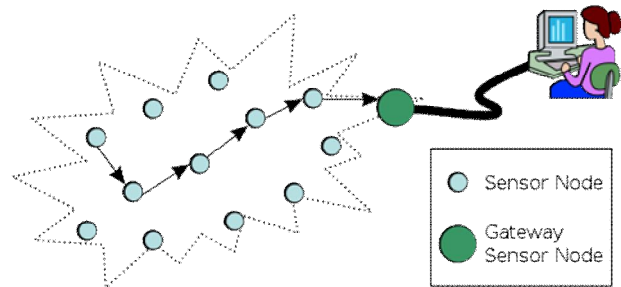


Fig 2 Interfacing of Zigbee at receiver side



III. HARDWARE DESCRIPTION

The sensor platform supports data collection, storage and off-line data retrieval. They may also be used for the streaming of live sensor readings. System can be accessed through a USB cable. This wired interface provides power to the board. And this power can be used for on-line operation and for charging the integrated Li-ion battery. Location and time information is provided by an on-board GPS module at 1 Hz sampling rate. Gas concentration levels are measured by three analog sensors: viz MQ-131, MQ-135, MQ-136. These readings along with GPS information are stored in a serial flash device 2MB. A 16X2 character LCD panel provides immediate visualization of gas concentration; GPS readings. PIC 16F877 microcontroller controls every aspect of the system from battery charging to analog to digital conversions. A single-chip microcontroller PIC 16F877 is device that has built-in resources like digital input/output ports, 16 channels, 8/10 bits analog-to-digital converter, 8 input/output interrupt-driven timers, RAM, EEPROM, FEEPROM memory, RS-232 serial communication ports, and SPI communication ports. The data packet from the GPS-Module includes an RMS Header followed by UTC time, latitude, longitude.. The GPS modem is interfaced with the microcontroller using the RS-232 communication standard. The Central-Server is personal computer with accessibility to the Internet. The Pollution Server is connected to the ZigBee-Modem via RS-232 communication standard. The air pollution information is saved to database of central server

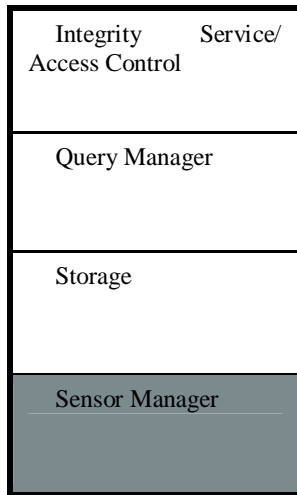
IV. SOFTWARE DESIGN

The system software architecture is having five different functions. This function is responsible for acquiring the real-time data from the sensors-array and the physical location, time and date of the sampled pollutants from the GPS module. This information is then encapsulated into a data frame by the microcontroller. The microcontroller then sends each frame to

the GPRS-Modem through the RS-232 interface. The GPRS Modem, in turn, sends each data frame to the Pollution-Server using the publicly available mobile network and the Internet. Software operating system can be shown as follows

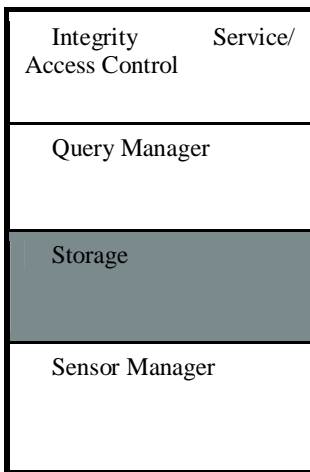
*A. Sensor Manager*

The function of sensor manager is to manage the delivery of sensor data. It provides and manages the resources provided to a sensor.



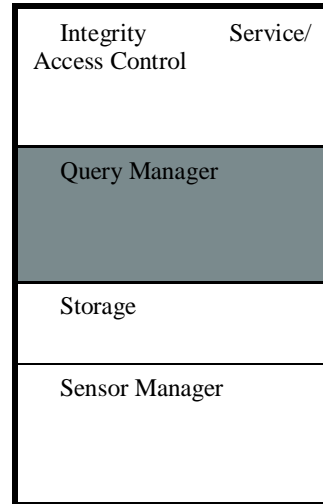
*B. Storage*

It receives the data from all nodes and persistently stores data streams from all the nodes.



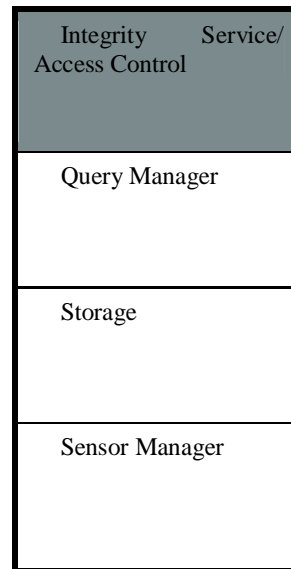
*C. Query Manager*

It manages active queries, it also provides query processing and delivery of events ,query results to registered, local or remote consumer.



*D. Access control and integrity service*

TinyOS: when an event occurs, it calls the appropriate event handler to handle the event.



**V. SYSTEM IMPLEMENTATION AND RESULTS**

The designed sensor array consisting of CO, SO<sub>2</sub>, and NO<sub>2</sub> was interfaced through a signal conditioning circuit to the PIC16F877A microcontroller.

A. Sensor

Fig.3 shows the schematic diagram of CO sensor. The sensor needs a supply voltage of 5V to operate and its resistance changes with gas concentration. The output of the sensor is collected at pin 2 as in the Fig.3.

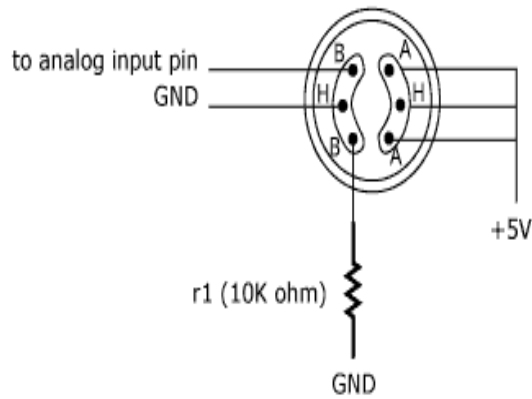


Fig.3 Gas sensor schematic

$V_{cc}$	5v
$R_L$	47KΩ
$R_s$	10KΩ - 90KΩ
$R_0$	32.8KΩ - 39.6KΩ
$R_s/R_0$	0.3-0.6
PPM	4-80

Table1 .CO sensor specification

Table 1 lists the sensor specification which used as reference to calculate the CO concentration. Gas sensor is measured in term of the ratio between sensor resistance in real measurement and sensor resistance in fresh air ( $R_s/R_0$ ).  $R_0$  is in the range of 32.8- 39.6 kΩ.

B. Sensor Reading Conversion

PIC16F876A is 8 bit microcontroller and based on the hardware, the real input voltage of CO sensor taken from voltage regulator is 5.032 V. Since the binary is 10-bit, it is equal to  $2^{10} - 1 = 1023$  steps or levels of resolution. 5.032V are then divided into 1023 and multiply by the adc value to get the  $V_{out}$  as in equation (1).

$$V_{out} = \frac{5032}{1023} (adc) \quad (1)$$

The next step is to calculate  $R_s$  value using equation (2):

$$R_s = \frac{V_{cc}(R_L)}{V_{out}} - R_L \quad (2)$$

Then  $R_s$  value obtained from equation (2) is then divided with chosen  $R_0$  which is 32.8KΩ to get the ratio value. Finally  $R_s/R_0$  value then will be calculated to get corresponding PPM value. The program written in this project is based on the mathematical modelling of the CO sensor.

The modelling is important to get the equation that best fit the sensor sensitivity graph provided in the sensor datasheet. Fig.4 is the curve fitting graph for the sensor sensitivity to find the CO concentration in PPM value. From the graph, the equation best fit to the curve fitting is given in equation (3).

$$y = (9.71 / ((x)^{2.5})) - 8.498 \quad (3)$$

And  $y$  is the PPM value as shown in equation (4).

$$ppm = (9.71 / ((R_s/R_0)^{2.5})) - 8.498 \quad (4)$$

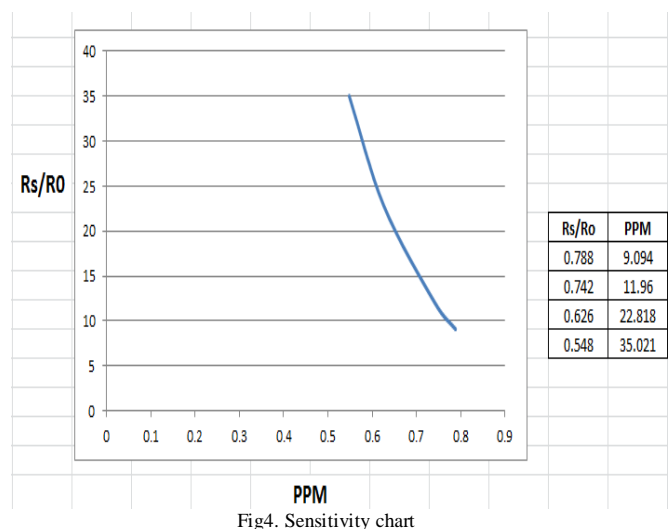
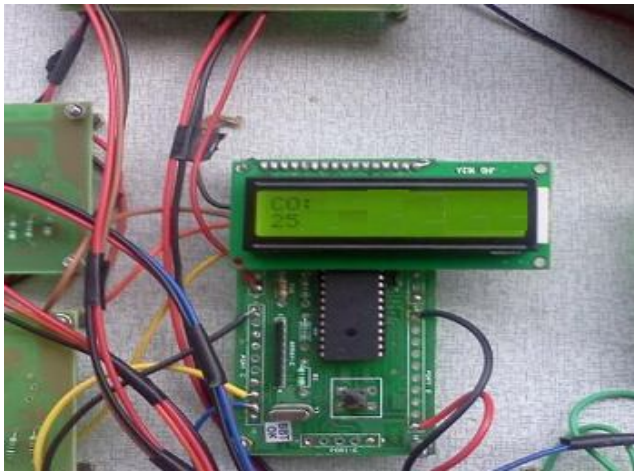


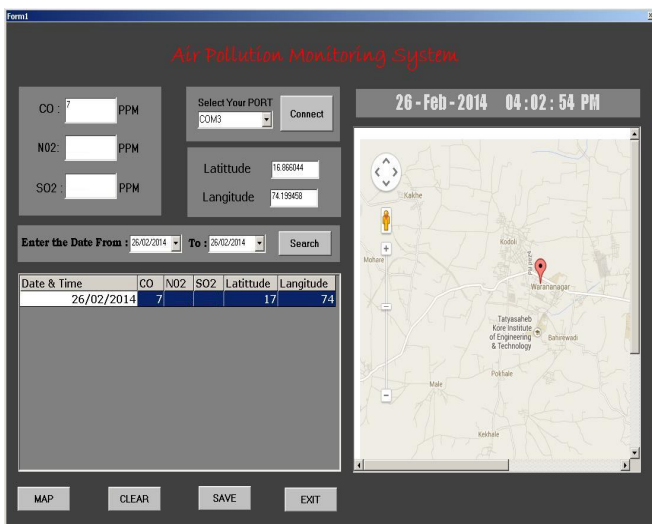
Fig4. Sensitivity chart

The sensor output voltages representing the level of gas for each pollutant were converted to a ppm value for each gas and simultaneously displayed on the LCD display of the hardware.



Snap1 pollutant level on LCD

The Zigbee modem connected to the central server receives the transmitted frame via RS-232 interface and the pollutant data was displayed on the central server as shown in snap 2. The output was displayed in Visual Basics of latest version. In snap 2 the gases levels are shown in terms of percentage of particular gas in the atmosphere. The left window in the snap2 shows the COM PORT selected, Baud Rate, location that is latitude and longitude of the hardware as well as the gas concentration levels also it shows the history of the gas pollutants measured and stored previously. User after entering a particular date in the search option can retrieve pollutant levels on that particular date. The central server is interfaced to Google Maps to display the location of hardware in large metropolitan areas. The system reports real time pollutants level on a 24-h/7-day basis.



Snap2 pollutant level on LCD

## VI. CONCLUSION

The proposed Wireless Air Pollution Monitoring System provides real-time information about the level of air pollution in these regions, as well as provides alerts in cases of drastic change in quality of air. This information can then be used by the authorities to take prompt actions such as evacuating people or sending emergency response team. wireless distributed mobile air pollution monitoring system was implemented using the GPRS public network along with GPS. The system utilizes city buses to collect pollutant gases such as CO, NO<sub>2</sub>, and SO<sub>2</sub>. The pollution data from various mobile sensor arrays is transmitted to a central server that make this data available on the Internet through a Google Maps interface. The data shows the pollutant levels and their conformance to local air quality standards.

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