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WSN Method of Pollution Monitoring System

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***Abstract*-- Air pollution is one of the environmental issues that have been often discussed. The fast-growing population and urbanization result in the population concentrated in certain areas. Heavy transportation may lead to poor air quality and inhaling pollutants for a long time also causes damages in human health. A traditional air quality monitoring method is to build air quality monitoring stations, but this method is expensive and provides low resolution sensing data. In this paper an industry based quality air monitoring system based on the wireless sensor network technology and integrated with the ZigBee wireless technology is being implemented. The system consists of a sensor node and a back-end platform controlled by the embedded data acquisition system through which sensing data can be displayed. The data can be stored inside a computer based application and could be accessible to those people having the application. This system can also be deployed to the main roads and automobiles to monitor various gases causing pollution. The experimental results show that the proposed system can provide quality of air monitoring in real-time through the WSN technology.**

***Keywords*—WSN,ADC,MQ-2,MQ-3,MAC,ISM.**

I. INTRODUCTION

With fast development of the industrialization and urbanization process in the world, environmental pollution problems become more universal. At present environment contains air pollution, water pollution and soil pollution worldwide. Air pollution is the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects. The World Health Organization states that 2.4 million people pass away each year because of air pollution. Pure air and human health goes hand in hand. Air pollution is harmful for human health. It causes difficulty in breathing, wheezing, coughing and many respiratory problems.

Currently there are two methods to monitor air pollution. First one is non automatic and other is automatic. The advantages of non automatic sampling method are monitoring devices is simple and inexpensive but it monitors the parameters for certain period. It does not provide the real time monitoring. While the non automatic sampling method provides the real time monitoring of harmful substances in the air. The non automatic sampling method uses the sensors to monitor the parameters, and send the data to central control centre. At present, for monitoring air pollution in wireless network the system includes the GSM, GPRS, etc. But these wireless nodes installation and maintenance are costly. That's why wireless sensor network have been rapidly developed. The wireless sensor network has many advantages application in military and industries.

Many air pollution systems which monitor air pollution use MAC medium to access control protocol for monitoring air quality in wireless sensor network. The E-nose electronic nose[6] architecture for real time monitoring of indoor chemical polluted materials such as CO, NO2 is also another approach. These chemical materials are highly toxic and cause respiratory failure. The ARIMA prediction model[10] is used to monitor air quality in wireless sensor network. The ARIMA model predicts the carbon dioxide level in the air in. A conceptual framework for the deployment of wireless sensor network for pollution monitoring system which uses various sensors and ZigBee networks for monitoring air pollution is proposed here.

A. Pollution Parameters

The air pollution means presence of one or more contaminants for temporal duration that can become injurious to human life, vegetable, and animal. The air contaminants include smokes, gases, dusts, paper hashes, poisonous chemical products and many polluted materials. Certain polluted materials react with each other and produces other pollutants. These pollutants called secondary pollutants. Carbon dioxide and nitrogen dioxide produced by automobiles motors, lead to the development of ozone. Air pollution has consequences for human health. It causes respiratory harms and even fatality. It also contributes the acid rain and reduction of ozone layer. The proposed system is able to measuring the following gases in the environment.

1) Carbon Dioxide (CO2) – Carbon Dioxide is a gas essential to life in the planet, because it is one of the most important elements evolving photosynthesis process, which converts solar into chemical energy. The concentration of CO2 has increased due mainly to massive fossil fuels burning. This increase makes plants grow rapidly. The rapid growth of unwanted plants leads to the increase use of chemicals to eliminate them.

2) Alcohol – The burning of alcohol (family of ethanol) can potentially add more smog forming pollution to the atmosphere, however it can also exacerbate the ill effects of such sir pollution. Burning of ethanol can potentially add 22 percent more hydrocarbons to the atmosphere than does burning gasoline and this would lead to nearly two parts per billion increase in tropospheric ozone.

So, development of a system to measure these pollutants have become a basic necessity now a days. The implementation of such a system is discussed in this paper.

II. LPC2148 TRAINER BOARD

ARM is a family of instruction set architectures for computer processors based on a reduced instruction set computing (RISC) architecture developed by British company ARM Holdings. A RISC based computer design approach means ARM processors require significantly fewer transistors than typical processors in average computers. This approach reduces costs, heat and power use. These are desirable traits for light, portable, battery powered devices—including smart phones, laptops, tablet and notepad computers and other embedded systems

LPC2148 is the widely used IC from ARM7 family. It is manufactured by Philips and it is preloaded with many inbuilt peripherals making it more efficient and a reliable option for the beginners as well as high end application developer. Let us go through the features of LPC214x series controllers has 8 to 40 kB of on chip static RAM and 32 to 512 kB of on chip flash program memory. Its 128 bit wide interface/accelerator enables high speed 60 MHz operation. It has single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1ms. Embedded ICE RT and Embedded Trace interfaces offer real time debugging. It has USB 2.0 Full Speed compliant device controller with 2kB of endpoint RAM.

In addition, the LPC2146/8 provides 8 kB of on chip RAM accessible to USB by DMA. Two 10bit A/D converters provide a total of 6/14analog inputs, with conversion times as low as 2.44 us per channel. Single 10bit D/A converter provides variable analog output. Two 32bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog is also present. There is a low power real time clock with independent power and dedicated 32 kHz clock input.

Multiple serial interfaces including two UARTs, two fast I^2Cbus (400kbit/s), SPI and SSP with buffering and variable data length capabilities is also present with vectored interrupt controller with configurable priorities and vector addresses. Power saving modes include idle and power down. Individual enable/disable of peripheral functions as well as peripheral clock scaling for additional power optimization and processor wakeup from power down mode via external interrupt, USB, Brown Out Detect (BOD) or Real Time Clock (RTC) is also found in LPC2148. It has CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %).

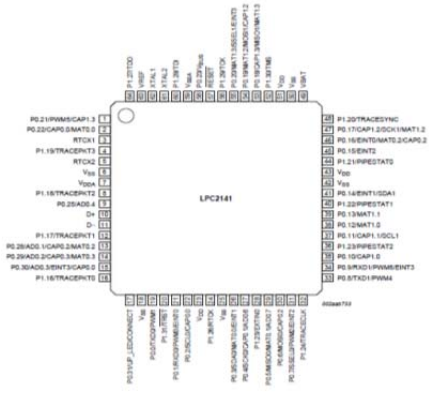

Fig. 1 LPC 2148 ARM board

A. LCD DISPLAY

Liquid crystal displays (LCD's) have materials which combine the properties of both liquids and crystals. Rather than holding a disappearing point, they experience a temperature range within which the particles are near as mobile as they would be in liquid, but are grouped together in an ordered form similar to a vitreous silica. The LCD's are lightweight with only a few millimetres thickness. Since the LCD's consume less power they are compatible with low power electronic circuits and can be powered for long durations. The LCD's are used extensively in watches, calculators and measuring instruments is the simple seven-segment displays, having a limited amount of data. The accompanying form depicts a general purpose alphanumeric LCD, with two lines of 16 bits.

Fig. 2 LCD display

III. ZIGBEE AND SENSORS

A. ZIGBEE

The ZigBee is the small range, low power, and low data rate wireless networking technology for many wireless applications. It is present at the bottom three layers i.e. physical, data link, and network layer. This is the recently published IEEE 802.15.4 standards for personal area networks. ZigBee is embattled at radiofrequency (RF) applications that require a low data rate, extended battery life, and secure networking. ZigBee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power, wireless sensor networks.

ZigBee network layer supports star, mesh and tree topologies. The ZigBee coordinator is responsible for initiating and maintaining the devices present in the network and other end devices directly communicate with the ZigBee coordinator. The IEEE 802.15.4 (ZigBee) standard provides three frequency bands for operation: these are 868MHz, 916MHz, and 2.4GHz for ZigBee. 868MHz band used in only Europe and has the 20Kbps data rate of transmission and contain only one channel with BPSK modulation technique.

916MHz band is used in Americas having the 40Kbps data rate of transmission and contain 10 channels with BPSK modulation technique. 2.4GHz frequency bands used throughout the world because of ISM (Industrial, Scientific, Medical) band. It has 250Kbps data rate of transmission and 16 channels with O-QPSK modulation technique. Transmission distance is within the range from 30 meters in an indoor non-line of sight of environment and 100 meters in line of sight environment. The range problem can be solved by using various routing algorithms at the network layer.

Fig. 3 Zigbee Module

The data is transferred in packets. These have a maximum size of 128 bytes, allowing for a maximum payload of 104 bytes. Although this may appear low when compared to other systems, the applications in which 802.15.4 and ZigBee are likely to be used should not require very high data rates. The standard supports 64 bit IEEE addresses as well as 16 bit short addresses. The 64 bit addresses uniquely identify every device in the same way that devices have a unique IP address.

The zigbee network layers supports star, tree and mesh topology with each node having capability of transmitting and receiving data over communication links. The zigbee network has zigbee cocoordinator is responsible for initiating and maintain the device on the network and network may be external through the use of zigbee routers which move data and control message through the network using hierarchical routing strategy.

B. MQ-2 Gas Sensor

It has a wide detecting scope, fast response and high sensitivity. The stable long life and simple drive circuit makes it more easy to use. The main applications are that they are used in gas leakage detecting equipments in family and industry, are suitable for detecting of LPG, i-butane, propane, methane ,alcohol, hydrogen, smoke etc.

1)Sensitivity Adjustment: Resistance value of MQ-2 is difference to various kinds and various concentration gases. So, when using this components, sensitivity adjustment is very necessary. The value is calibrated by the detector for 1000ppm liquified petroleum gas<LPG>, or 1000ppm iso-butane<i-C4H10> concentration in air and value of load resistance (R_L) about 20 KΩ(5KΩ to 47 KΩ). When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence. Some modules have a built-in variable resistor to adjust the sensitivity of the sensor.

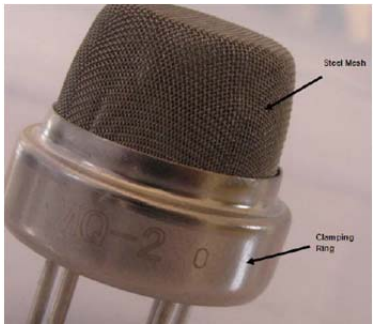

Fig. 4 MQ 2 Gas Sensor

C. MQ-3 Gas Sensor

This is highly sensitive to alcohol and small only sensitivity towards benzine .It has fast response and high sensitivity with a stable and long life. This also has a simple drive circuit. These are suitable for alcohol checker, breathalyser etc.

1) Sensitivity adjustment: Resistance value of MQ-3 is different for various kinds and various concentration of gases. So, when using these components, sensitivity adjustment is very necessary. So calibrate the detector for 0.4mg/L (~200ppm) of alcohol concentration in air and use value of load resistance (R_L) about 200 KΩ(100KΩ to 470 KΩ). When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence.

Fig. 5 MQ 3 Alcohol Sensor

Gas sensors are available in wide specifications depending on the sensitivity levels, type of gas to be sensed, physical dimensions and numerous other factors. When a gas interacts with a sensor, it is first ionized into its constituents and is then adsorbed by the sensing element. This adsorption creates a potential difference on the element which is conveyed to the processor unit through output pins in form of current. The gas sensor module consists of a steel exoskeleton under which a sensing element is housed. This sensing element is subjected to current through connecting leads. This current is known as heating current through it, the gases coming close to the sensing element get ionized and are absorbed by the sensing element. This changes the resistance of the sensing element which alters the value of the current going out of it.

D. The Front End Application

A front end application was developed in .Net to acquire the transmitted air pollution data from the transmitter block. Here wireless communication is done through zigbee protocol. A zigbee transceiver module transmits the data from the arm processor (transmitter end) which is acquired from interfaced mq-2 and mq-3 sensors. At the receiver end this .Net windows form application acquires the data from the receiver end zigbee transeiver module. This windows form application reads the data via selected com port (through which the zigbee module is connected) and finally the acquired data is made to store in the text file.

IV. CIRCUIT DIAGRAM

The hardware design constitutes of ARM7 developer board (LPC2148), two sensor, two Zigbee modules and RS 232.

The microcontroller is used to perform two functions. First one is, compare emission values with standard values. Second one is, activates the timer and alerts the buzzer. The microcontroller performs functions according to the software programmed in EEPROM of microcontroller.

A. Implemented Block Diagram

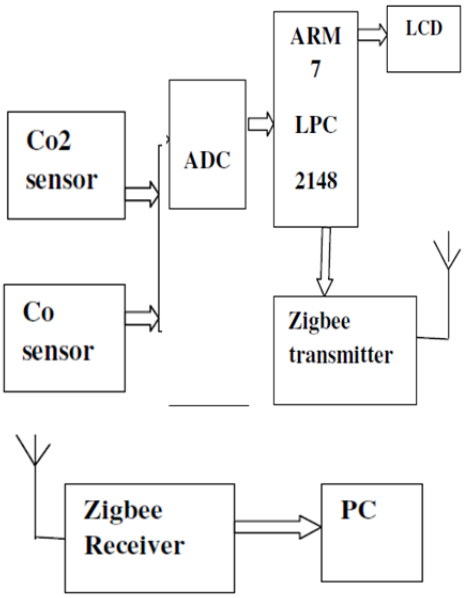

Fig. 6 Block Diagram

The ARM board is having two 10 bit successive approximation ADCs namely ADC0 and ADC1. Input is multiplexed among 8 pins. The measurement range is from 0 V to V_{ref} (3V). Basic clocking for A/D converters is provided by the APB clock. A programmable divider is included in each converter, to scale this clock to 4.5 MHz clock needed by the successive approximation process. A fully accurate conversion requires 11 of these clocks. The two sensors are then connected to the board and along with it the zigbee module is also being interfaced. Then the data acquisition takes place by the sensor.

After this the data is transferred to the ARM for further processing and we could get the digital values of the pollution contents either by using the LCD screen or by a uart to the computer screen or via zigbee. Here LCD is used for direct viewing and a zigbee for transferring the data to the computer application. The flow diagram could be used for showing the flow of control of the pollution detection system.

After the power on the start condition executes by collecting the pollution data. Then the analog data is converted to the corresponding digital value. This is compared with the value fed at the database and checks for the value at which current value of gas is present. If the present pollution is critical then a data packet is sent indicating a high level of pollution.

At the same time an alarm is being activated by the system showing an alert. The level could be seen at the LCD screen and also by an application at any system having a zigbee module.

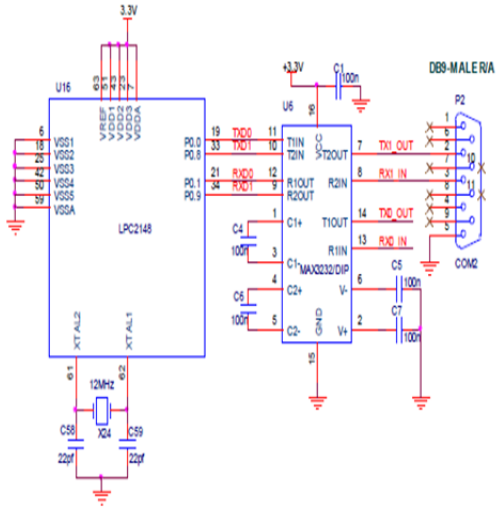

Fig. 7 Connection of UART to LPC2148

V. HARDWARE ARCHITECTURE

A. Sensor Node Functionality

The proposed pollution node is designed by integrating the sensor associate circuitry, LPC2148 low power microcontroller and zigbee communication module. Design of Sensor node consist of 4 basic functionalities

1) *Signal Conditioning:* The time gap between amount of gas concentration deposited on the sensing plates in heater and time requires to clear the gas concentration on the sensing plates.

2) *Sense The Changes In Air:* Three sensor are used to detect the changes in gas concentration of various pollutions such as Carbon monoxide, carbon dioxide & sulphur concentration in air. As the output of the sensors are analog signals, strength and correctness of signals need to assured.

3) *Signal Amplification:* As the signal detected by the sensors are need to be amplified and regenerated to increase the accuracy of the systems.

4) *Signal Calibration:* ADC in LPC2148 provide the 10 bit resolution, provides the mapping between the analog input signal to digital signals for processing. Sequence of steps in design of sensor node is shown in figure 8.

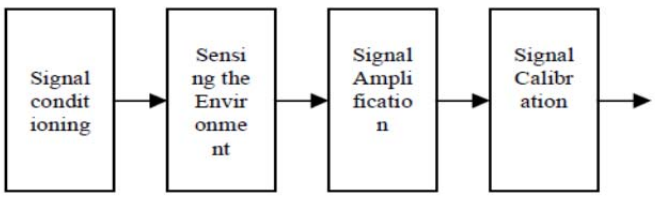

Fig. 8 Signal Flow

B. Design Of Pollution Sensor Node

The group of various sensor are connected to analog ports of the microcontroller. The build-in Analog to Digital Converter(ADC) in micro-controller unit is used to convert the analog signal to digital values. IDE of ARM board was used for writing coding in microcontroller.

1) Processing Unit: LPC2148 is the widely used IC from ARM7 family. It is manufactured by Philips and it is preloaded with many inbuilt peripherals making it more efficient and a reliable option for the beginners as well as high end application developer. Let us go through the features of LPC214x series controllers has 8 to 40 kB of on chip static RAM and 32 to 512 kB of on chip flash program memory. Its 128 bit wide interface/accelerator enables high speed 60 MHz operation. It has single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1ms. Embedded ICE RT and Embedded Trace interfaces offer real time debugging. It has USB 2.0 Full Speed compliant device controller with 2kB of endpoint RAM.

2) Pollution Detection Unit: The array of sensors consists of three sensors, used to detect the content of alcohol and harmful gas's concentration in air for example MQ-3 sensor measure the CO percentage from 10 to 1023 ppm in air. Each of the above sensors has a linear current output in the range of 4 mA–20 mA(minimum and maximum values). The 4 mA output corresponds to zero-level gas and the 20 Ma corresponds to the maximum gas level (+ 5 V). A simple signal conditioning circuit is designed to convert the 4 mA–20 mA range into 0–5 V to be compatible with the voltage range of the built-in analog-to-digital converter in the microcontroller.

3) Zigbee Transceiver Module: Two types zigbee modules are used in the simulation to establish the small wireless sensor network for pollution monitoring system. One module used as transmitter and second as receiver. X-CTU software was used to configure the zigbee modules as co-ordinator and router. The network is controlled by devices called the ZigBee coordinator modem(ZCM). The ZCMs are responsible for collecting data and maintaining the other devices on the network, and all other devices, known as Zigbee end devices(ZED) can directly transfer the data to the ZCM. The ZigBee module is hardware platform of wireless device. The modules realize the basic function of Z-MACl and Physical layer, such as transmit and receive, modulation and demodulation, channel and power control. They operate at 2.4GHz frequency ISM band wireless communication. The modules include a digital direct sequence spread spectrum base band modem and an effective data rate of 250 kbps.

4) Transmitter Section: The output pins of sensor are connected to input port to obtain the readings, on ADC channel 1and channel 2 of LPC2148. The parallel data received is converted and to connected to the Universal Synchronous and serial data by the inbuilt USART. The Zigbee with whip Asynchronous Receiver and transmitter port 0(USART 0) antenna transmits this data. Power supply of 2.8V to 3.3V at port PD0 (RX0) and port PD1 (TX0) is required for the operation of Zigbee.

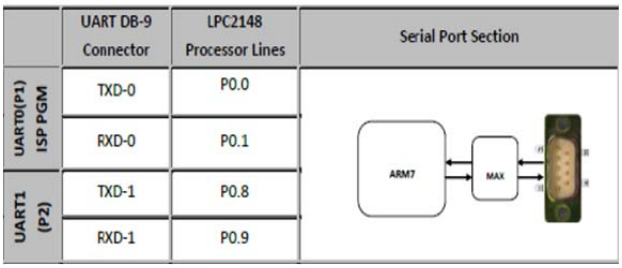

Fig. 9 UART Connection Diagram

5) Receiver Section: The Zigbee at the receiving side engineered to meet IEEE 802.15.4 standards and support receives the transmitted data. The similar power supply is the unique needs of low-cost, low-power wireless sensor required for receiving Zigbee as in the transmitter. The modules require minimal power and provide serial data received is converted into parallel data by the reliable delivery of data between devices. The modules have inbuilt USART and is displayed on LCD or Personal computer using X-CTU terminal software or Hyper Terminal. LCD displays value of gases found during detection.

6)Simulation of Pollution Detection Systems: The Gas Detection System is an off-the-shelf standard personal computer with accessibility by User Interface. LPC2148 ARM board was used in the simulation. The output of the LPC2148 ARM board was connected to zigbee module to extend the project to store the results in a computer application. Data collected in the application can be used by various clients like industry safety units, state insurance companies, government bodies, disaster management bodies etc.

VI. SYSTEM IMPLEMENTATION AND RESULTS

Below figures shows the hardware implementation of the proposed model. We must reduce the possibility of unplanned power off of system and thus reducing the downtime cost. Presented study, describe the way of continuously automatically monitoring system. In this project the system is developed with an ARM and ZigBee protocol to monitor and diagnose the gases. The zigbee network has zigbee cocoordinator is responsible for initiating and maintain the device on the network and network may be external through the use of zigbee routers which move data and control message through the network using hierarchical routing strategy.

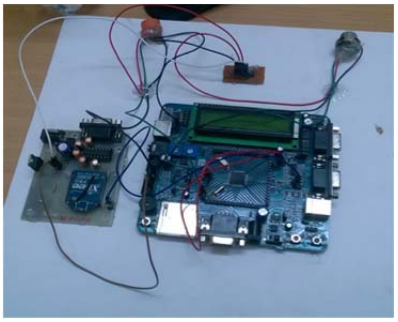

Fig. 10 Hardware implementation

The ZigBee protocol is used for serial communication which provides high data transmission rate and reliability. The behavior of the two sensors are observed in various conditions and heating plates in MQ-3 sensor produces the more heat even for small change of the gas concentration and two sensor get effected during simulation. The material used in construction of sensor, place a vital role in accuracy and performance of the pollution system The Zigbee modem connected to the central server receives the transmitted frame via RS-232 interface and the pollutant data was displayed on the LCD as well as stored to a computer application.

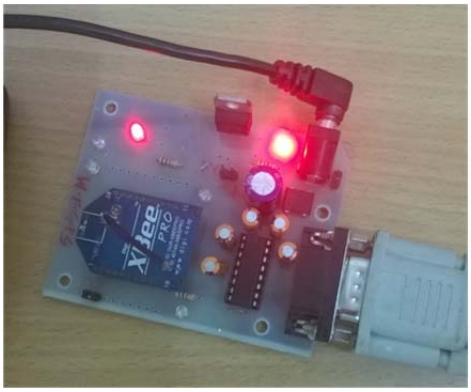

Fig. 11 Zigbee Module

If the amount of pollutants exceed a certain limit then an alarm is raised at the detection module for alcohol sensor. Also a led is made to glow if the amount of exceeds a certain level than the prescribed.

Fig. 12 Results at the LCD screen

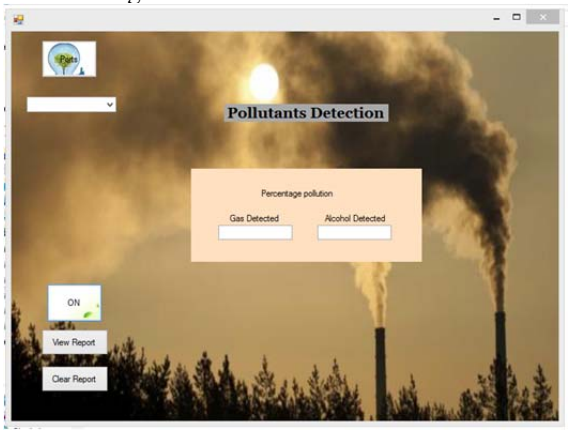

Fig. 13 Application window

The figure 13 shows the percentage of gases found as well as the gas detection on the application at the host side. The application is created using .Net format. The data sent from the transmitter zigbee module has the values of the gas and alcohol. A decimal digit is assigned to the amount of gas present depending on the percentage of gas. Also an alphabet is sent along with this to show the amount of alcohol. This alphabet depends on the amount of alcohol present. So for each range of values a particular decimal digit and an alphabet is sent via the zigbee module. This is received and decoded at the computer application. Also when the level exceeds a particular limit (here,set as 80%) an alarm is triggered and also an indication is made at the application window showing the presence of pollutants.

VII. CONCLUSION

As the increase of carbon dioxide concentration (especially in urban area) and deforestation is a major reason to cause a global warning in addition to other pollutants. This project describes the implementation constraints and attributes or measure of the various pollution monitoring system using ZigBee technologies and embedded system in an efficient way. This system has an advantage such as low power consumption, in order to monitor pollutant quantity in different sites. The zigbee network layers supports star, tree and mesh topology with each node having capability of transmitting and receiving data over communication links. The zigbee network has zigbee coordinator which is responsible for initiating and maintain the device on the network and network may be external through the use of zigbee routers which move data and control message through the network using hierarchical routing strategy.

Dependence & power consumption of sensor nodes need to be minimized and functionality of the each step should be optimized (maximize the cohesion and minimize the coupling). The selection of sensor and material used in construction of the sensor should select such that the there should be minimum changes in the accuracy of the system. 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.

VIII. FUTURE WORKS

Future work can be focused on establishing a system with more sensor node and more base station connection between node and base station are via WSN, while connection among different base station are via Ethernet (LAN), Ethernet can also be connected to internet so that users can login to the system and get real time data far away from the proposed site. Using more reliable methods like Bluetooth could also be used to access the converted values at the application end.

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