A REAL TIME MONITORING AND DETECTION OF VOC's AND FAULTY SENSOR NODES IN ZIGBEE SENSOR NETWORK FOR INDOOR APPLICATIONS

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***Abstract*— Monitoring the indoor air pollutants represent a considerable health risk, especially for the people who works in the paint manufacturing companies these people currently spend >80% of their time indoors. The primary aim of this project is to design a low power ZigBee wireless sensor network and inter node data repetition control framework to use real- time acquisition of data concerning air pollutant level of Volatile Organic Compound (VOC) and Carbon Monoxide (CO). The design is based on the Arduino Uno microcontroller and ZigBee module, which are used to effectively process communication data with low power. The measured data are displayed on a computer monitor. Also, monitor the faulty sensor nodes in the wireless sensor network by the Round Trip Time and Round Discrete Path method. Priority is given to power consumption and sensing efficiency. Both good indoor air quality and energy conservation can be achieved by integrating the pollutant monitoring system with the residential integrated ventilation control.**

***Index Terms*— Volatile Organic Compound(VOC), ZigBee Module, wireless sensor network, Sensors.**

I. INTRODUCTION

People are paying more attention to the air pollution as the issue of global warming becomes important. The solvents used in products such as coatings, inks, adhesives, and consumer products are generally classified as Volatile Organic Compounds(VOCs). Unless they are controlled (by an incinerator on a painting operation, for example), these solvents are emitted into the air after they perform their function. Thus, solvent emissions from products and industrial operations are one of several significant sources of VOC emissions. VOCs include a variety of chemicals, some of which can cause short-and long-term adverse health effects. Many VOCs are found at consistently higher (up to ten times higher) concentrations indoors compared to outdoors[1].

Long-term exposure to VOCs can cause damage to theliver, kidneys, and central nervous system. Short-term exposure to VOCs can cause eye and respiratory tract irritation, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reactions, nausea, and memory impairment.VOC concentration in an indoor environment during winter is three to four times higher than the VOC concentrations during the summer. High indoor VOC levels areattributed to the low rates of air exchange between the indoor and outdoor environment as a result of tight-shut windows and the increasing use of humidifiers.

According to World Health Organization statistics in 2014, there were approximately 115 million deaths resulting from indoor air pollution, an about 1.96 million from outdoor air pollution. The number of deaths due to indoor air pollution is much larger than that of outdoor air pollution. Furthermore people in metropolitan area spend 90% of the time every day to stay in different kinds of indoor spaces[2]. Nowadays, the gas monitor equipment sold in market is not only too expensive, difficult to operate, but also unsuitable for long time monitoring data on VOCs that are normally found in low concentrations in indoor air are highly dependent on how the VOCs are measured. All available measurement methods are selective in what they can accurately measure and quantify,and none are capable of measuring all of the VOCs presenting an area.

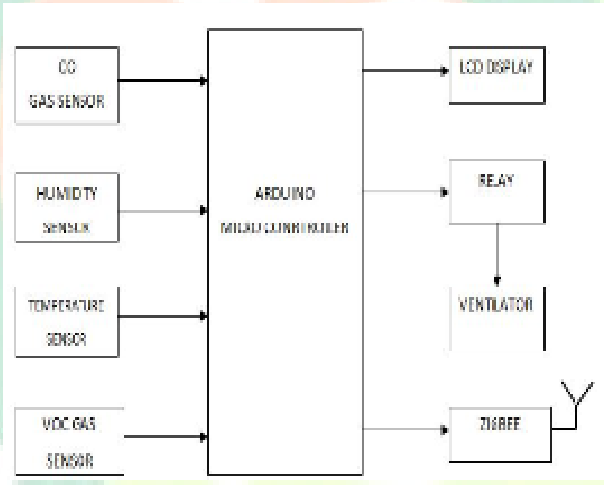
ZigBee-based WSNs are an emerging technology with awide range of potential applications, including environmentalmonitoring and measurements. ZigBee-based WSNs consist ofseveral nodes that are equipped with processing, communicationand sensing capabilities. These nodes are smaller and lessexpensive than regular sensor

devices. Such networks consist of a large number of distributed sensor nodes that organize themselves into a multi-hop wireless network.

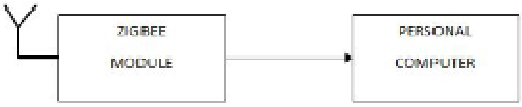
This paper proposes a ZigBee WSN-based monitoring system for measuring VOC and CO concentrations. The proposed system is to monitor the VOC and CO gas concentration in the indoor based on the ZigBee wireless sensor network and Arduino Uno microcontroller. To find the faulty sensor nodes in the sensor network can also be detected by the Round Trip Delay and Round Trip Path method. Also using the relay there a dynamic relay control for all the ventilation in the building.

II.SYSTEM DESCRIPTION

The system has been designed based on a low-power ZigBee WSN and to controlthe inter-node data reception for use in real-time acquisition andcommunication of levels of air pollutants from VOCs and CO. The networkconsists of end devices with VOC sensors, CO sensors routers that propagatethe network over long distances, and a coordinator that communicates with acomputer. The design is based on the ATmega 328 (Arduino Uno)microcontroller and the ZigBee module, which effectively process andcommunicate data with a low power consumption.Fig. 1 shows the functional description of the developed system to monitoring of VOC.



a) Transmitting Section



a) Receiving Section

Fig 1. Functional block diagram of the system

VOC and CO gas sensors are use for to sense the gas concentration in the building. Humidity sensor and temperature sensors are used for to monitor the room conditions[3]. Relay switch is used for to control the ventilation of the building. Buzzer is used to alert indication. The Arduino Uno microcontroller is based on the ATmega 328. For the real time monitoring of the environment monitoring humidity sensor and temperature sensor are used along with the CO gas sensor.

It receives the information liketemperature, humidity, concentration of VOC and CO gases..etc. The ZigBee is connected to the personal computer through USB connector. Also detect thefaulty nodes in the wireless sensor network and shown in the personalcomputer.

III. WORKING METHODOLOGY

A. Monitoring of Volatile Organic Compound

1) *VOC monitoring*:TGS-2602, Metal Oxide Semiconductor Gas Sensor, is produced by FIGARO, a Japanese company. Under the circumstance of oxygen, the resistance of sensor in clean air should be measured as the reference value in advance, and the reference value will be compared with the resistance value when measuring gas.[4] The resistance values of different gases and different concentrations of gases are not the same. Then the sensor resistance ratio (SRR) can be obtained according to the specification. When the concentration of gas is higher, the resistance value will be lower. Then the value of Rs/Ro will be decreased. However, such curve is shown in the conditions of 20 degrees Celsius and 65% relative humidity.

2) MQ6 CO gas Monitoring: The MQ 6 sensor for CO compound sensor used in the system detectsthe concentrations of gas in the air and readings are obtained as an analog voltages. The sensor operates within the temperatures range -20 to 50°C and consumes less than 150 mA at 5 V[5]. The sensitivity characteristic of the MQ6 sensor depends on the ratio (Rs/Ro) of the Sensor Resistance (Rs), sensor value during exposure to CO/smoke and the original or initial Sensor Resistance (Ro) of 10 kOhm.

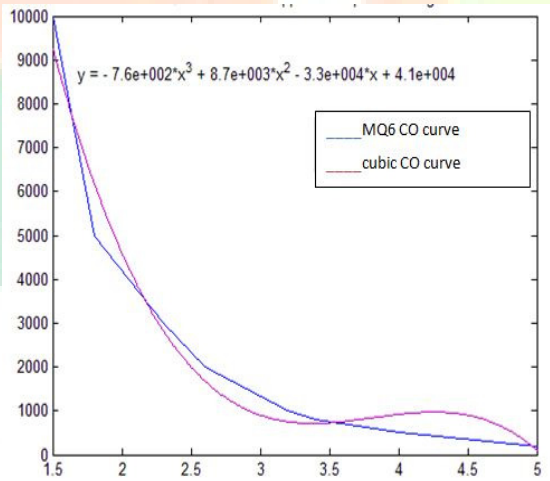


Fig 2 MQ6 CO curve fitting

3)Temperature and Humidity monitoring: Temperature and humidity can influence the sensing data, and the result is shown in Fig 3 In ventilation condition, the temperature is approximately 30°C, and relative humidity is about 60%[6]. At 4000 seconds, it begins to rain, and the indoor temperature is about 25°C and relative humidity is90%. The curve begins to decrease obviously.The air-conditioner outlet will affect sensing value too. Although the variation of values is large in short time, the average data is not large.

4) ZigBee Module: The ZigBee module is composed of remote processor/radio platforms (XM2110) and usesthe Atmel RF230, IEEE 802.15.4 compliant, ZigBee-ready radio frequency transceiver integrated with an Arduino Uno

microcontroller[7]. These enhancements provide up to three times the radio range and twice the programmable memory of previous generation MICA motes.ZigBee is a wireless network protocol that is owned by the ZigBee Alliance and is adapted from the IEEE 802.15.4 standard, which defines the media layer and objective layer[8]. ZigBee provides a low transmission speed at low cost, low power consumption, and high security and supports a large number of web node operations.

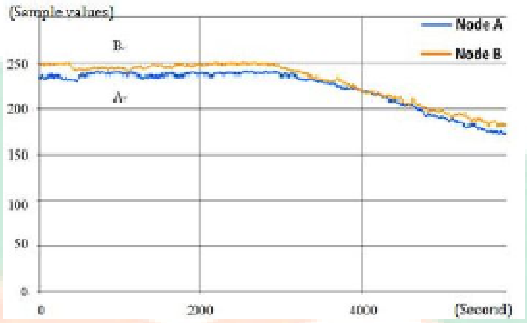


Fig 3 Influence of Temperature and Humidity

The radio module is usually the main component that causes the depletion of a sensor node's battery. To reduce energy dissipation due to wireless communications, we attempt to optimize radio parameters such as coding and modulation schemes, power transmission and antenna direction. Modulation optimization attempts to find the optimalmodulation parameters that result in the minimum energy consumption by the radio. For example, energy depletion is caused by the power consumption of the circuit and of the transmitted signal. The consumption by the circuit is greater than the transmission power at short distances, but the signalpower becomes dominant at longer ranges. Transmission Power Control (TPC) has been investigated for enhancing energy efficiency at the physical layer by adjusting the radio transmission power[9]. In Cooperative Topology Control with Adaptation (CTCA), regular adjustments of the transmission power of every node are proposed to consider the uneven energy consumption profile of the sensors.

Directional antennas allow signals to be sent and received inone direction at a time, which improves the transmission rangeand throughput. Directional antennas may require localizationtechniques for orientation, but multiple communications canoccur in close proximity, which results in the spatial reuseof bandwidth. In contrast to omni-directional motes, whichtransmit in unwanted directions, directional antennas limitoverhearing and require less power for a given range. Thus,these devices can improve network capacity and lifetime whilepositively influencing delay and connectivity.

B. Arduino UNO Controller

The Arduino Uno is a microcontroller board based on the ATmega328 it is Open source and extensible hardware.The output signals from the sensors are integrated to the control unit Arduino UNO controller. Arduino is a single-board microcontroller to make using electronics in multidisciplinary projects more accessible. The hardware consists of an open-source hardware board designed around an 8-bit AtmelAVR microcontroller, or a 32-bit Atmel ARM. The software consists of a standard programminglanguage compiler and a boot loader that executes on the microcontroller.

It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less.Arduino boards are

relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less.

An Arduino board consists of an Atmel 8-bit AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits. An important aspect of the Arduino is the standard way that connectors are exposed, allowing the CPU board to be connected to a variety of interchangeable add-on modules known as shields. Some shields communicate with the Arduino board directly over various pins, but many shields are individually addressable via an I²Cserial bus, allowing many shields to be stacked and used in parallel.

Arduino programs may be written in any programming language with a compiler that produces binary machine code. Atmel provides a development environment for their microcontrollers, AVR Studio and the newer Atmel Studio The Arduino IDE supports the C and C++ programming languages using special rules of code organization. The Arduino IDE supplies a software library called "Wiring" from the Wiring project, which provides many common input and output procedures. A typical Arduino C/C++ sketch consist of two functions that are compiled and linked with a program stub main() into an executable cyclic executive program.

C. Faulty Sensor Node Detection

The status of sensor nodes in wireless sensor network can be categorized into two types one is normal; in this status nodes are said to be working and sensing dataaccurately. And the second is faulty; in this status sensor node is said to be sensing and transmitting erroneous data to data collecting center or base station. Faulty in turn can be divided into permanent and static. The faulty status called permanent here means failed nodes will stay faulty until they are replaced, and status called static means new faults will not be produced during fault detection process. In node faults of WSNs can be categoriesinto two categories, soft and hard. The “soft faults” means the failed sensor nodes can continue to work and communicate with other nodes (software and hardware of communication modules are correct), but the data transmitted is not correct. The “hard fault” is one where sensor node cannot communicate with other nodes because of the failure of a certain module (e.g, communication failure due to failure of the communication module, sensor node energy depletion and so on). Generally, wireless sensor nodes can experience two types of faults that will guide to the deprivation of performance. Function fault is one of the type, which frequently results in colliding of individual nodes, loss of data packets, routing failure and network partitioning. The other type of error is data fault, in which a node behaves normal in all aspects expect the sensing results, leading to either significant biased or random errors.

Using Round Trip Delay (RTD) & Round Trip Path (RTP) The process of detection of faulty nodes using RTD & RTP can be viewed as two parts[14]. The first part involves assumption that all the sensor nodes are working correctly and there is no faulty node present in the network and the threshold value is set by measuring RTD time of all the RTPs. In second part actual detection of faulty node is done by selecting discrete RTPs and comparing their RTD times with predefined threshold which is set in first part.

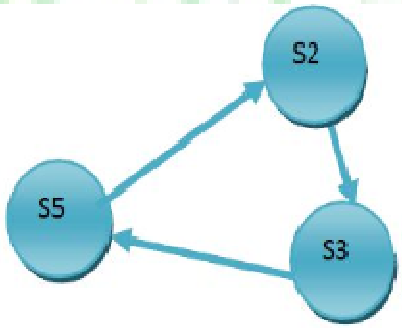


Fig 4 Example of discrete RTP

Round trip delay time of the RTP will change due to faulty sensor node. It will be either infinity or more than the predefined threshold value. The sensor node which is faulty can be detected by comparing the RTD time of RTPs with predefined threshold value. The sensor node common to precise RTPs with infinity RTD time is detected as failed. If this time is higher than the predefined threshold value then this sensor node is detected as malfunctioning.Fig 4 shows the example of RTP formed by taking sensor nodes S2,S 3 and S5. The time of detection of faulty sensor node depends upon the numbers of RTPs and RTD time. So, RTD time measurement and estimation of RTPs is ought to minimize the detection time.

D. Controlling and Monitoring of parameters

In the present system the monitored values are transmitted wirelessly through Zigbee to the system. The collected data's are controlled by various methods and the following parameters will be stored in a database andanalyzed[10].

Relays are electrically controlled switches. In the usual type, a coil pulls in an armature when sufficient coil current flows. Many varieties are available including "latching" and "stepping" relays; the later provided the cornerstone for telephone switching stations, and they're still popular in pinball machines[11].Relays are available for dc or ac excitation, and coil voltages from 5 volts up to 110 volts are common.

A dynamic controller would ideally be able to manageany mechanical ventilation system that is installed to meetthe whole-house mechanical ventilation requirements at aminimum energy cost[12]. The controller can do this by shiftingthe ventilation load of the whole-house off peakand by considering the exogenous mechanical ventilation ofother systems (such as bathroom and kitchen fans).

IV.RESULTS

The Fig 5 shows the monitoring system for gas concentration, humidity and temperature of the indoor room condition. Monitoring data's are collected by a controller, which saves all data in the system for processing as well as for future use. The parameters will be stored in the LabVIEW software include gas concentration, temperature and humidity. These parameters will be stored in a database and analyzed [15]. Collected data will be displayed on the computer through LabVIEW window sothat appropriate action can be taken from the visual programming language.

The monitoring system in the sensor node measures the parameters they processed concentration of gas, temperature and humidity values are displayed on the LabVIEW running on a computer for remote monitoring and for automatic control all the sensors are processed and controlled by a single Arduino board, with the help of relay it automatically control the ventilation. The faulty sensors in the wireless sensor network are identified by the Round Trip Delay (RTD) & Round Trip Path (RTP) method. The processed data are accurate and user friendly.

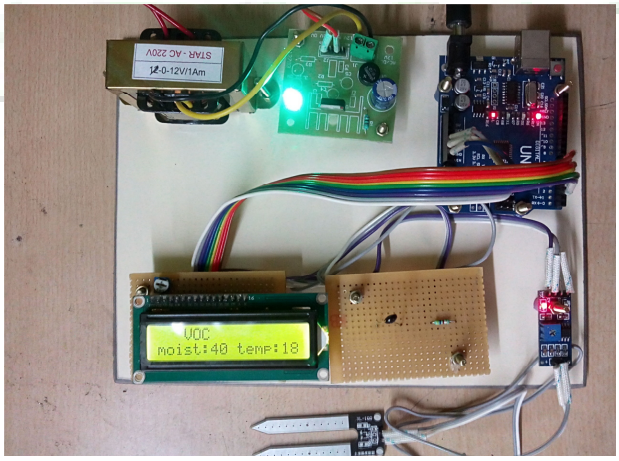


Fig 5. Gas, humidity and temperature monitoring system

V.CONCLUSION

The primary aim of this paper is to design a low-power ZigBee WSN and to control the inter-node data reception for use in real-time acquisition and communication of levels of air pollutants from VOCs. The network consists of end devices with TGS 2602 sensor, CO sensor, humidity sensor and temperature sensor. The routers that propagate the network over long distances, and a coordinator that communicates with a computer. The design is based on the Arduino Uno microcontroller and the ZigBee module, which effectively process and communicate data with a low power consumption. The faulty sensors in the wireless sensor network are identified by the Round Trip Delay (RTD) & Round Trip Path (RTP) method. Using the relay ventilation of the particular building is to be controlled.

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