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Implementation of Zigbee Hardware for Application of Air Pollution Monitoring

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Abstract: Air pollution is one of 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. This paper proposed an urban air quality monitoring system based on the wireless sensor network technology and integrated with the ZigBee wireless technology. The system consists of sensor node and a back-end platform controlled by the embedded data acquisition system through which sensing data can be displayed. This system is deployed to the main roads and automobiles to monitor the carbon monoxide (CO) concentration caused by vehicle emissions and oxygen (O_2) concentration of environment. The experimental results show that the proposed system can provide quality of air monitoring in real-time through the WSN technology.

Key words: WSN · ZigBee transceiver · Sensor arrays · Embedded data acquisition system

INTRODUCTION

Wireless Sensor Networks and intelligent wireless systems have successfully been applied in many situations including habitat monitoring, environmental monitoring, structural health monitoring, water and oil and gas pipelines, agriculture, active volcano monitoring, industrial control systems, process control systems such as the pulp and paper industries, mineral processing plants, road traffic control systems, food and chemical plants and many others. Monitoring and recognition of hazardous gases is important because human olfactory system has a very limited recognition of gases such as CO, O2 [1-5]. Humans are able to detect limited amount of mixture of gases yet it is very difficult to discern the different percentages of each gas individually. This is significant as there are number of toxic gases that humans cannot recognize, the carbon monoxide, (CO), has negative biological effects from the smallest organisms to some of the largest organisms depending on the dose levels [6-10]. CO is odorless, toxic, colorless and flammable gas and it is present in the atmosphere in small amounts. the wireless integrated gas sensors for hazardous gases, e.g. CH4 and CO, the wireless sensors detect O2and CO and generate frequency modulated (FM) signal in a set range of frequencies bands 2.5823 GHz to 2.5542 GHz. Environmental pollution caused by transport, industry particularly by automobiles In recent years, due to advances in new technologies, the remote and local monitoring of gases caused by automobiles have attracted a renewed attention. Also, a great deal of research has been conducted to reduce the pollution caused by automobiles.the Fiber optic sensors were used to monitor several exhaust gases and operate within controlled environments.the optical fiber based system which can detect NO, NO2, SO2 to a minimum detection threshold of 5ppm, CO and HCs to a minimum threshold of 200 ppm, CO2 in the range 300 ppm operating in a temperature range 0°C to 900°C. In this paper, the detection of two types of gasses O2 and CO emanated for automobile exhausts have been studied and reported. The paper consists of three parts: first part concentrates on the CO, O2 sensor are interfaced to at mega 32 Microcontroller. Then the parameters sensed by these sensors are transmitted using Zigbee Pro Module. In the receiving side the data received by receiver Zigbee Module goes to microcontroller and display on computer or Liquid crystal display. Microcontroller gives indication

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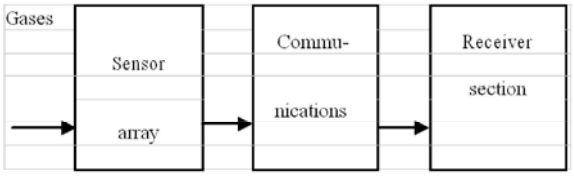


Fig. 1: System design and components

of danger condition if any of these sensor parameters goes above threshold level with the help of Buzzer. The second part is the transmission of the information from the sensor array to a central computer by using the ZigBee technology.the simulation results of Zigbee protocol using Network Simulation software such as OPNET 14.5 Modeler. Various scenarios such as Star topology, Mesh topology, Tree topology, Device Failure are implemented with the help of OPNET modeler. Report shows simulation results for only star topology. The final part is the embedded hardware tool for the analysis, display and control of the information [11-15].

System Setup and Communication Method: The overall system set up is shown in Figure 1. This section will concentrate on the communications between the sensor array and a host computer. The sensor array and software tools will be discussed in Sections III and IV respectively.

A fundamental part of the paper is the use of ZigBee for remote monitoring purposes. ZigBee has been finding some applications in process control industry. In this study, among other possible technologies such as the Wi-Fi or Bluetooth, the ZigBee has been selected for the communication of the sensor array with a host computer [16-18]. The ZigBee, also known as IEEE 802.15.4 standard, is a Low Rate (LR) - Local Area Network (LAN) suitable for instrumentation applications. It is a simple and low cost communication network that permits wireless connectivity in applications with limited power and relaxed throughput (or low rate data transfer) requirements. The advantages of ZigBee lies in its ease of installation, reliable data transfer, low implementation cost and it have a reasonable battery life span whilst operating on a simple and flexible protocol. In general the ZigBee allows three types of data transfer, these are:

Data Transfer To a Coordinator

- A device that transmit the data

Data Transfer From a Coordinator

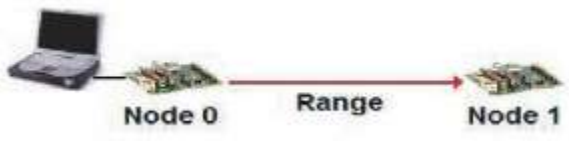


Fig. 2: Communication Setup.

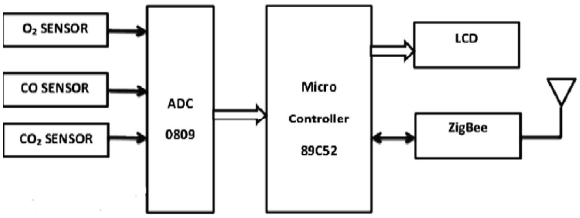


Fig. 3: Block Diagram of Transmitter section

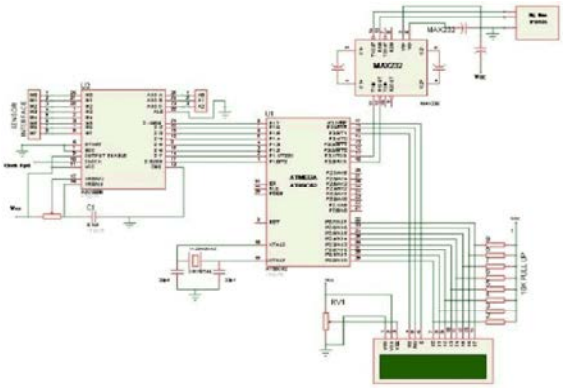


Fig. 4: Circuit of Transmitter node

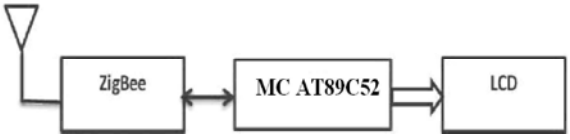


Fig. 5: Block diagram of Receiver section

- A device that receives the data

Data Transfer Between Two Peer Devices

In this paper, the ZigBee Wireless Sensor Network has been developed for remote monitoring using wireless microcontroller hardware as shown in Figure 2. The ZigBee has been programmed for data transfer to a coordinator. Since the sensor array device was already equipped with RS-232 it was necessary to use an RS232/USB converter before the wireless transmission took place. Also, with the permission of the developer, the source code was modified so that it would operate on a quiet channel.

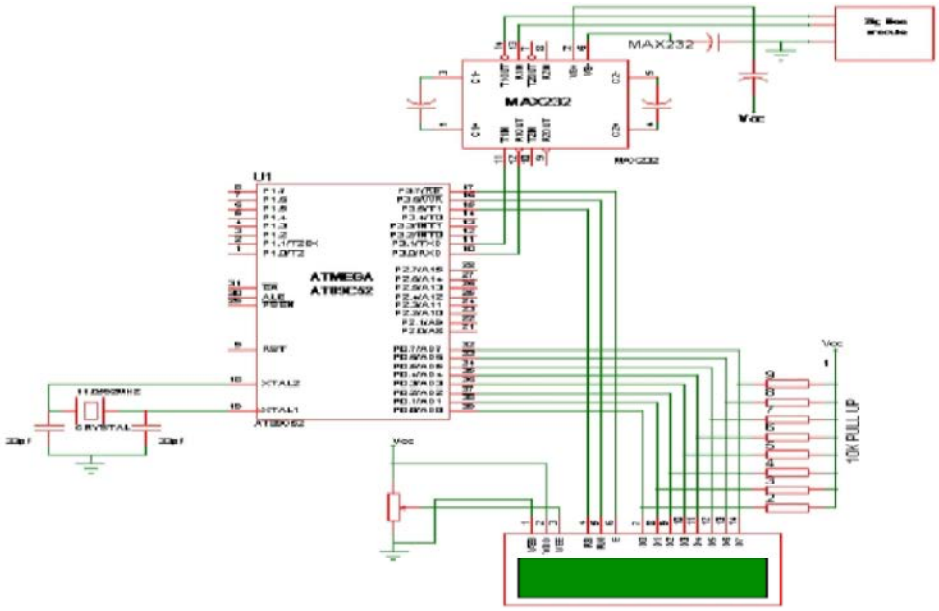


Fig. 6: Circuit of Receiver section

System Implementation: Gas sensor array together with wireless communication system has been applied for monitoring of exhaust gases. the sensor array could be applied to monitor the gas levels of automobile exhausts.

Hardware Implementation

A Tmega 52 Microcontroller: The Atmega 52 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. ATmega 52 is used for this project because of its unique features such as 32 Kbytes of In-System Programmable Flash memory with Read-While-Write capabilities. It has the availability of 10-bit Analog to Digital Converter which can be used to connect to sensors without using additional ADC devices. ATmega 32 have 8 ADC inputs which make it possible to upgrade to 8 different sensors. For this project, we have used the port A as Analog to Digital input port to obtain the reading from temperature, humidity and smoke sensor. Xbee Pro module series 2 was connected to the Universal Synchronous and Asynchronous Receiver and transmitter port 0(USART 0) at port PD0 (RX0) and port PD1 (TX0).

XBee PRO RF Module: The XBee PRO RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and flexible wireless device which ideal for a wide range of remote monitoring and control application Through its serial port, the module can communicate with any logic and voltage compatible UART or through a level translator to any serial device RS-232 or USB interface board.

Smoke Sensor: This flammable gas and smoke sensor detects the concentrations of combustible gas in the air and outputs its reading as an analog voltage. The sensor can measure concentrations of flammable gas of 300 to 10,000 ppm.The sensor can operate at temperatures from -20 to 50°C and consumes less than 150 mA at 5 V.

Transmitter Section: The output pins of Temperature sensor, humidity sensor, smoke sensor are connected to ADC channel 0,1,2 of ATMEGA 52 Microcontroller respectively. The parallel data received is converted to serial data by the inbuilt USART. The Zigbee with whip antenna transmits this data. Power supply of 2.8V to 3.3V is required for the operation of Zigbee.

Receiver Section: The Zigbee at the receiving side receives the transmitted data. The similar power supply is required for receiving Zigbee as in the transmitter. The serial data received is converted into parallel data by the inbuilt USART and is displayed on LCD or Personal

computer using X-CTU terminal software or Hyper Terminal. LCD displays current temperature reading in degree Celsius, Relative Humidity in percentage and smoke sensor gives percentage of gas concentration in ppm. The buzzer is connected to ATMEGA 52 microcontroller. If the sensed parameters exceed threshold limits, the buzzer is on.

RESULT

Due to sophisticated graphical user interface and availability of Zigbee model family it is easy to simulate Zigbee using OPNET 14 modeler. Figure.7. Shows star topology in which central node called coordinator is surrounded by four end devices.

Then using edit attributes menu, setting of parameters is done such as transmission band of 2.4 GHz, network parameters, transmission power of 1mw, uniform packet interarrival time, constant packet size of 1024 bytes, destination selected at random, data rate, Enable or Disable ACK mechanism, setting CSMA-CA parameters of coordinator and end devices. Quality of service includes different statistics such as Delay, Throughput, Packets dropped, Simulation time, Traffic sent (packets/sec), Traffic received (packets/sec), simulation time. By setting such statistics for IEEE 802.15.4 MAC Layer, Zigbee Network Layer, Application layer simulation can be done. Global statistics provide information that relates to the overall system. Many separate objects may contribute to one global statistic during a simulation. Node statistics provide information about individual node such as coordinator or end device. It will gives idea about individual delay of each node, packets dropped by separate nodes, amount of time required by each node to reach to destination, traffic sent and received by each node. Throughput Represents the total number of bits (in bits/sec) forwarded from 802.15.4 MAC to higher layers in all WPAN nodes of the network. Data Traffic sent is the Traffic transmitted by all the 802.15.4 MACs in the network in bits/sec. while Data Traffic Received Represents the total traffic successfully received by the MAC from the physical layer in bits/sec. Delay Represents the end to end delay of all the packets received by the 802.15.4 MACs of all WPAN nodes in the network and forwarded to the higher layer. It can be seen that steady stream of traffic is sent without disruption shown in Figure 4. Small spikes in at the beginning of the simulation are indications of management and control traffic sent and received to determine the presence of devices as well as the optimal route.

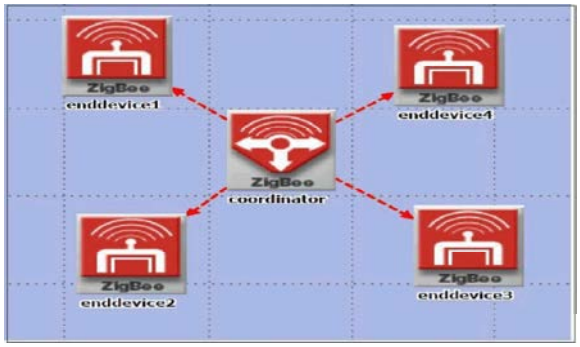


Fig. 7: Star Topology Scenario

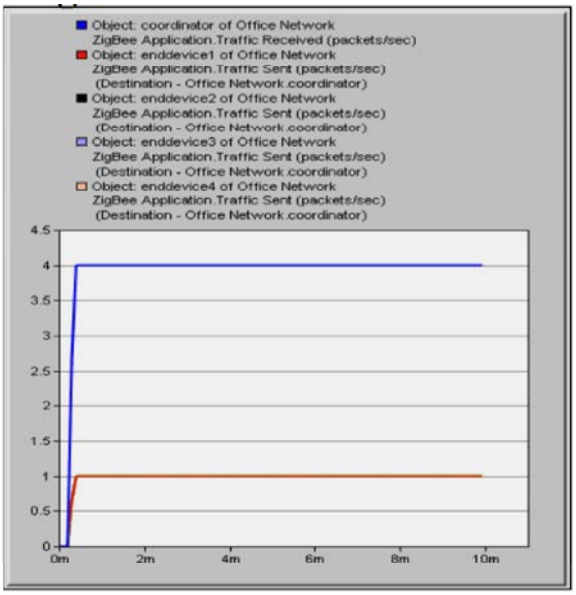


Fig. 8: Simulation Result

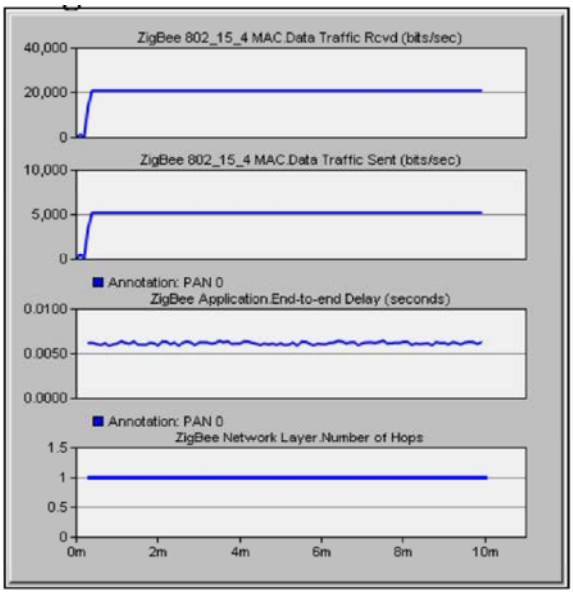
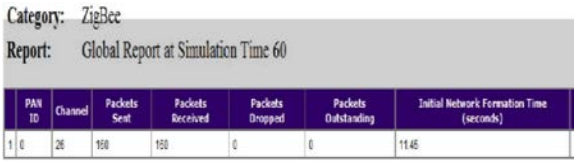


Fig. 9: Simulation result of individual Devices


Category: ZigBee
Report: Global Report at Simulation Time 60

	PAN ID	Channel	Packets Sent	Packets Received	Packets Dropped	Packets Outstanding	Initial Network Formation Time (seconds)
1	0	26	160	160	0	0	11.45

Fig. 10: Simulation Results

Figure shows that all end devices sends packet of 1024 bytes to coordinator and coordinator receives packets from all end devices.Graph shows coordinator receives packets from four end devices while bottom graph shows each end device sends a packet of 1024 bytes Total delay between creation and reception of an application packet is very small about 50 milliseconds.

CONCLUSION

This project focuses on the development of Wireless Sensor Network for application of Air Pollution monitoring. The network has successfully met the goal of providing real-time Presence of CO2,O2 and CO. The primary advantage is that the XBee modules are bi-directional. The second advantage is the unique addressing of Bee. Each Bee unit has a unique serial number. This means two (or more) units can be set up to exclusively talk to each other, ignoring all signals from other modules. The third advantage is that the XBee module has built in data-packet and error-checking to ensure reliable data transmission. Finally the XBee protocol allows for a number of channels. By setting different channels, additional interference can be avoided.

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