Air Pollution Monitoring System in Solapur City using Wireless Sensor Network

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ABSTRACT
Due to advances in technology there is trend in miniaturization of devices which demands to develop low cost sensor, low power and rugged devices .In view of this Wireless Sensor Networks (WSN) have gained importance in various applications: Business, Agricultural, Domestic, Industries, Traffic control, and environmental monitoring. The paper presents Wireless sensor network system used to monitor and control the air quality in Solapur city. Environmental air pollution monitoring system that measures, SPM (Suspended Particulate Matter), NOx, and SO2 are proposed. The traditional air quality monitoring system, controlled by the Pollution Control Department, is extremely expensive. Analytical measuring equipment is costly, time and power consuming, and can seldom be used for air quality reporting in real time. Attempt has been made to develop monitoring system using commercially available standard pollutant gas sensors and CC2530ZDK board that uses 2.4 GHz IEEE 802.15.4 standard, high performance low power 8051 core, which will serve as a node in a Wireless Sensor Network. A specific program made with LabVIEW is created to configure and supervise the operation and the sensing measurements on the network used.

General Terms
Methodology for Air Pollution monitoring system

Keywords
WSN, CC2530ZDK, Sensors, Zigbee, LabVIEW.

1. INTRODUCTION
Monitoring of air pollution is an important requisite in today's day to day life. Traditionally data loggers were used to collect data periodically and this was time consuming and quite expensive. However in order to eliminate these drawbacks WSN is best alternative which will suffice these requirements. By employing WSN system monitoring of air pollution can be made effectively simple and instantaneous readings can be recorded. Till today air pollution monitoring using WSN system has been rarely reported [1]. WSN is composed of a large number of sensor nodes that are usually deployed either inside a region of interest or very close to it. WSN nodes are low-power embedded devices consisting of processing and storage components (a processor connected to a RAM and/or flash memory) combined with wireless RF transceiver and some sensors/actuators. The proposed system makes use of an Air Quality Index (AQI) which is presently in use. The sensor nodes, which measures pollutants information, were uniformly deployed in the networks to create sensing phenomena.

The present paper reports on the air pollution monitoring system using CC2530ZDK and LabVIEW. As CC2530ZDK board utilises Zigbee and microcontroller in the same SOC, so hardware is reduced. Low Power consumption is one of the important criterions of WSN which fulfils as board can operate even with 2AA batteries. The self –healing property of Zigbee cause motes to sleep during ideal time hence power consumption of node is minimized. Generally, in air pollution control board display systems used are more bulky. However, GUI created using LabVIEW is more interactive, simple rather than other display systems.GUI created can run on any system with minimum system configuration. As data logger and hardware components are not utilized the present system is more facile and user friendly. It was decided to carry out air pollution monitoring in heavy traffic area in Solapur city where pollutants exceeded the ambient air quality standards as stipulated by Central Pollution Control Board (CPCB). In order to detect percentage of pollution, the array of sensors were used to measure gas species in the physical environment. Solapur has led to measure increase in number of vehicles on the roads, creating additional pollution problem with smoke emission and other pollutants. Apart from the concentration of vehicles in urban areas, other reasons for increasing vehicular pollution are the types of engines used, age of vehicles, congested traffic, poor road conditions, and traffic management systems. Solapur Municipal Corporation in collaboration with Central Pollution Control Board and State Pollution Control Board has installed air quality monitoring system as a part of India pollution map project. Air quality at different areas in Solapur city [2] for the year 2012-13 is summarized in Table 1 and Table 2:

Table1. Ambient Air Quality Monitored At Solapur (conc.ppm/m^3) year 2012

Months 2012		SO_2	NOx	RSPM
JAN	min	9.3	37.5	111.4
	max	14.3	58.6	193.0
FEB	min	9.5	37.0	117.7
	max	13.7	55.5	179.7
MAR	min	9.2	40.2	113.6
	max	16.8	68.5	253.8
APR	min	9.2	34.9	89.5
	max	13.4	51.0	184.5
MAY	min	9.9	34.7	70.6
	max	14.3	51.8	161.4
JUN	min	10.8	32.9	39.5
	max	14.9	47.7	136.5
JULY	min	9.9	33.3	34.0
	max	13.6	46.2	148.2
AUG	min	9.5	32.8	45.6
	max	14.8	43.9	74.7
SEPT	min	9.5	33.4	30.2
	max	14.6	46.5	125.6

OCT	min	9.7	29.2	41.1
	max	14.6	44.5	145.0
NOV	min	10.4	31.3	59.0
	max	15.7	53.1	195.0
DEC	min	8.4	34.0	129.0
	max	60.0	85.9	288.0

Table 2. Ambient Air Quality Monitored At Solapur (conc.ppm/m^3) year 2013

Months 2013		**SO_2**	**NOx**	**RSPM**
JAN	min	15.4	37.6	103.6
	max	45.0	56.5	129.0
FEB	min	16.7	41.3	91.4
	max	22.8	53.2	128.0
MAR	min	16.3	31.1	87.1
	max	22.9	56.1	137.3
APR	min	13.7	38.7	72.4
	max	21.2	55.0	114.9
MAY	min	14.4	42.7	46.5
	max	18.2	52.9	113.4

2. HARDWARE ARCHITECTURE

CC2530ZDK is integrated Platform which includes hardware and software that allows quick testing of the CC2530ZDK RF performance. It also offers advanced prototype RF systems and Zigbee applications [3]. This platform includes three parts:

i) SmartRF05EB (Evaluation Board)
ii) CC2530EM (Evaluation Module)
iii) SmartRF05BB (Battery Board)

The permutation of SmartRF05EB (Evaluation Board) and CC2530EM (Evaluation Module) is the Gateway node which is connected to the server using DAQ card.

The permutation of SmartRF05BB (Battery Board) and CC2530EM (Evaluation Module) is the sensor node allowing easy interconnection to peripherals or other external sensor and devices powered with two 1.5v AA batteries.

2.1. Wireless Sensor Node

The following module shows the node prototype for air pollution monitoring system, the node hardware can be divided in three different sections such as sensors, centralized embedded system and RF unit. The CC2530ZDK will serve as a sensor node which includes 8051 core and Zigbee transceiver.

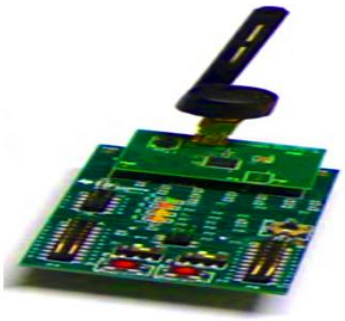


Fig 1: Wireless sensor node

2.2. Gateway node and Server

The task of Gateway node is to receive the data sensed and processed by sensor node. The architecture of this node is similar to Sensor node except it does not have sensor interfacing part. The sensed data can be sent or received through personal computer which is interfaced using DAQ card.

Fig 2: Gateway node

3. PROGRAMMING TOOLS

To develop software and debug an application on the CC2530ZDK using 8051 it is recommended to use IAR Embedded Workbench. It supports debugging of CC2530ZDK through the SmartRF05EB, without any additional hardware requirement [4].

3.1 Main Program

The flowchart of air pollution monitoring system is shown in Figure 3:

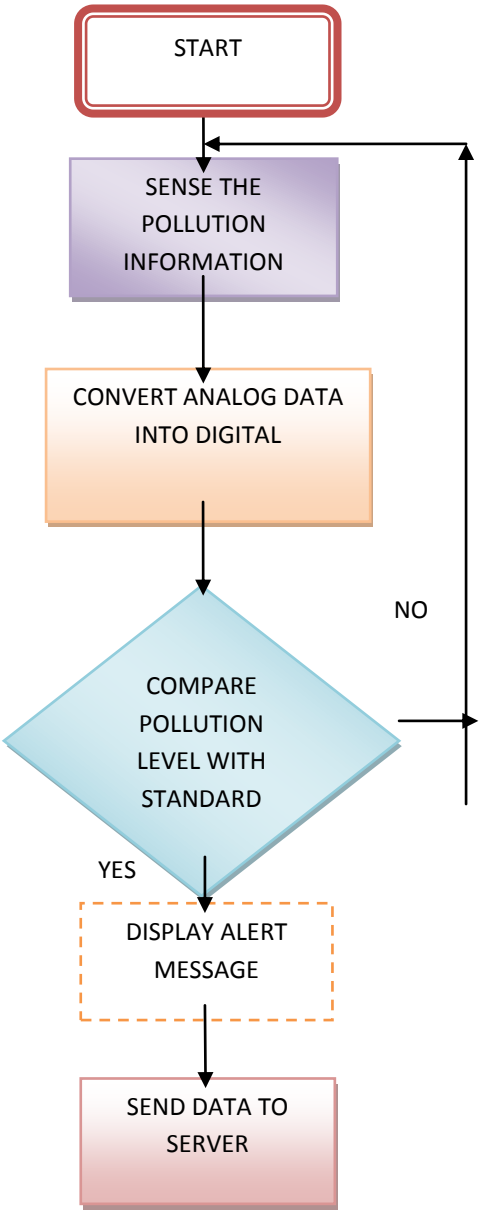


Fig 3: Flowchart of air pollution monitoring system

The control program is realized using LabVIEW from National Instruments and is executed in the personal computer [5-6].

3.2 Energy saving Strategies of Wireless Sensor Networks

1. Reducing power consumption initiates from the selection of Microcontroller unit (MCU),

2. Choosing chip with low standby current and steady transceiving current for radio frequency module.

3. Power source with low output voltage and low power consumption,

4. Reducing system operating frequency can lower current consumption effectively.

For better power management low power strategies to air pollution system is used and caused the motes sleep during idle time [7].

4. SYSTEM ARCHITECTURE AND FUNCTION

A block diagram for air pollution monitoring and control system is shown in figure 4.

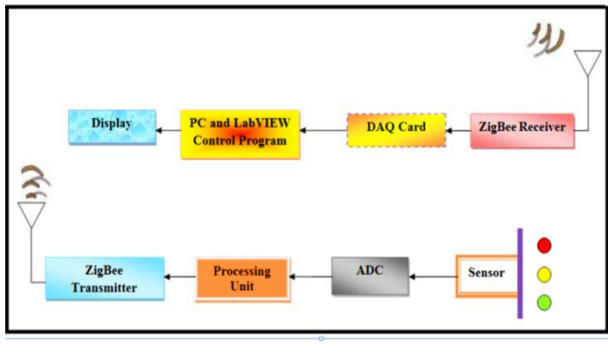


Fig.4: Block diagram of air pollution monitoring system

Fig.4: Block diagram of air pollution monitoring system

The proposed air pollution monitoring & control system comprises of sensor nodes and a communications system which allows the data to reach a personal computer. The sensor nodes collect data autonomously and the data network is used to pass data to a Gateway node, which forwards it to a sensor network computer. The air quality information from other node is also received by the node to control pollution level.
A brief description of each component of air pollution monitoring & control system is described below:

4.1 Sensor

There are many types of pollutant gas sensors, which can be used for gas detection. Sensors mainly operate on the principle of surface reactions. However, these sensors in comparison with analytical sensors have an excellent sensitivity, very short response time, low cost, and very good suitability for design of portable instruments.

4.2 ADC

An ADC is an analog to digital converter that converts a continuous signal into a digital number employing 24-bit delta-sigma ADC.

4.3 Microcontroller unit

In order to manipulate the air quality information, the data is stored in memory and transmitted to Gateway node, and received data is stored in the memory. It performs important manipulation eventually reduces power and time.

4.4 Display unit

Various display methods can be used to indicate pollution level. The pollution level can be displayed using SMS, GPRS in the vehicle, or LED/LCD display.

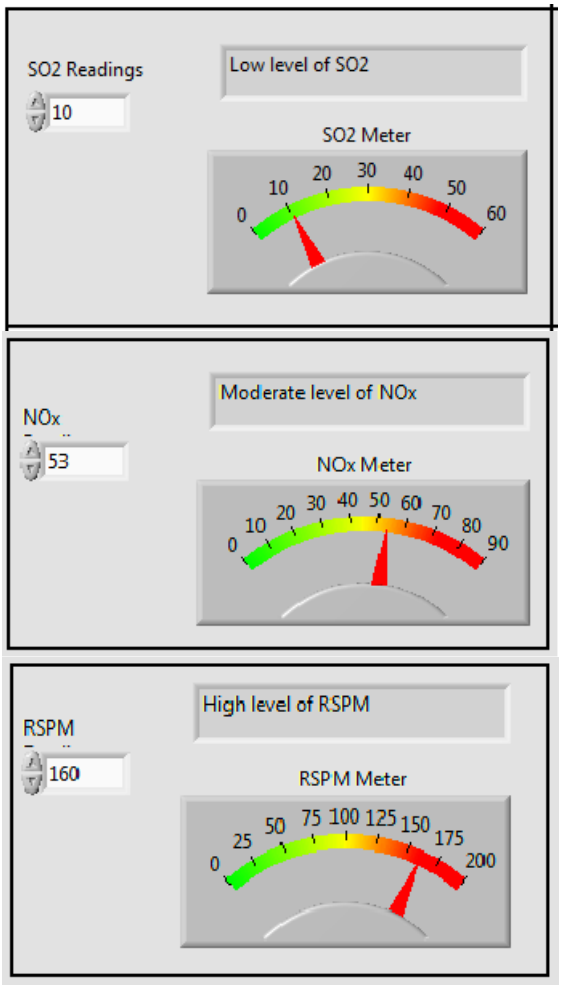
4.5 Transmitter

Transmits the pollution information from the current node to gateway node.

4.6 Receiver

Receives the pollution information from other sensor node.

5. SIMULATION RESULTS



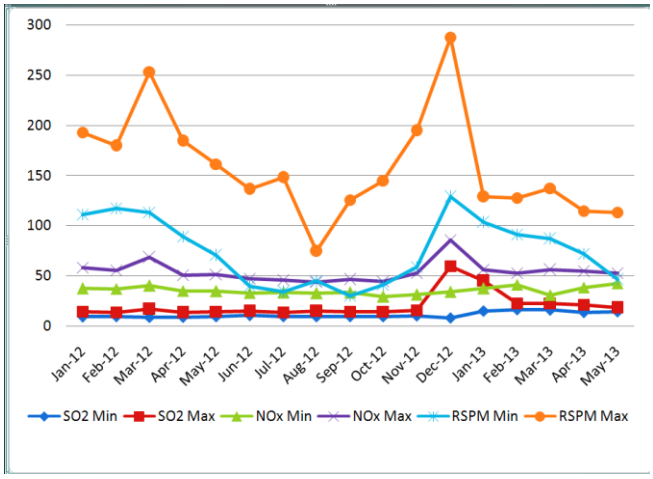


Fig.5: Time vs. Pollution concentration graph

5.1 Topology Monitoring

The Zigbee network model supports star and tree topologies and self healing property. The topology shown in the figure 6 illustrates that Zigbee can be used to extend the range of a network by using hops between communicating nodes.

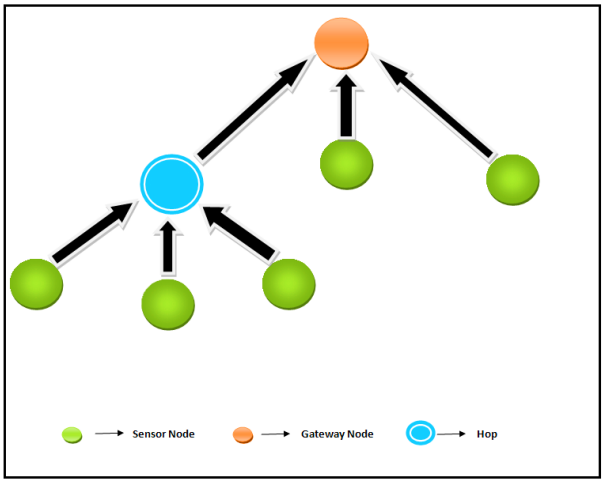
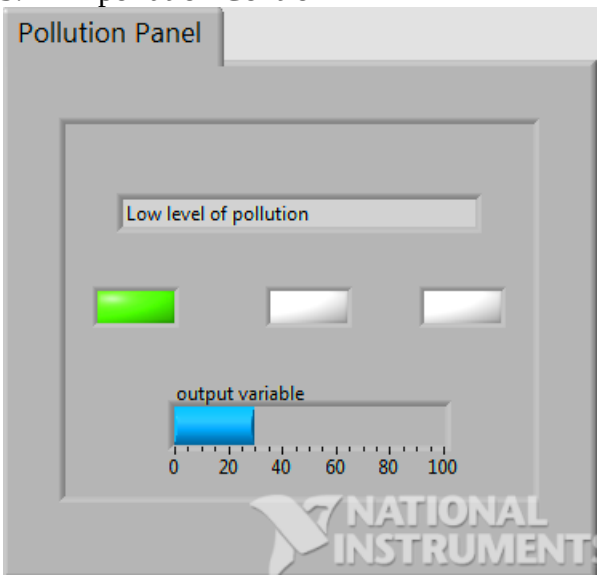
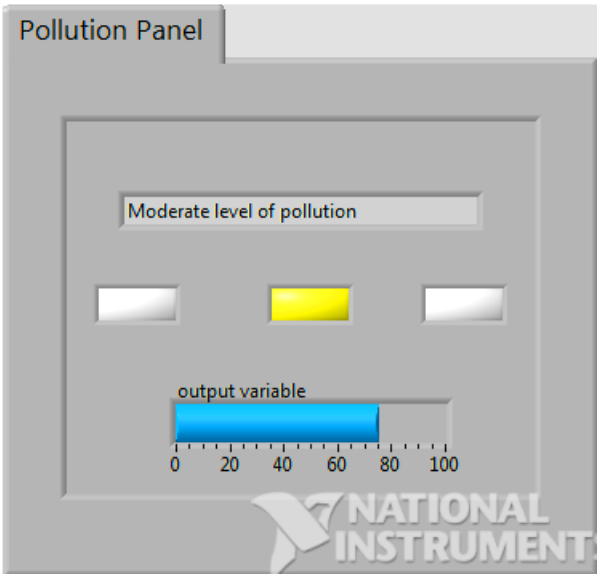
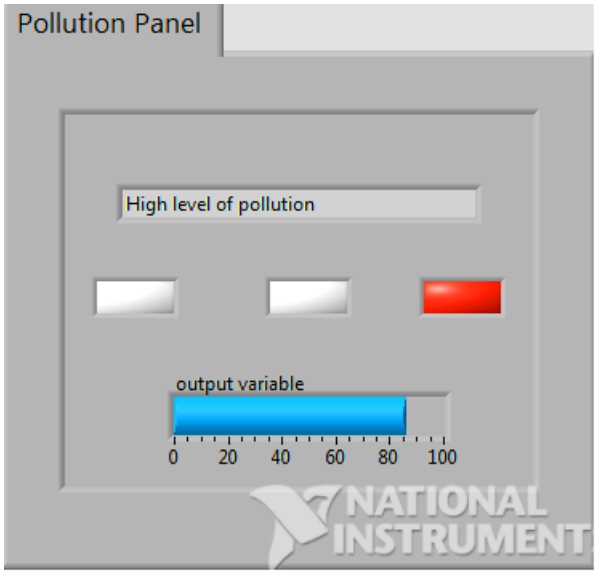


Fig. 6: Topology Monitoring

5.2 Air pollution Control







Pollution level information at each sensor node can be communicated to people through SMS or it be can be displayed on the display board in the vicinity of square [8]. As shown above red colour indicates high pollution concentration, where as green colour indicates normal pollution concentration while yellow colour indicates moderate level. When a person perceives the pollution information in advance they can follow the safe path, accordingly preventive measurement can be deployed.

6. CONCLUSION

WSN for air pollution and monitoring will be quite favourable for monitoring different high risk regions in the country. It will provide real-time information about the level of air pollution in particular regions, as well as provide safety alerts in cases of radical change in air quality. This information can then be used by the authorities to take prompt actions such as evacuating people or deploying emergency rescue team. Thus WSN networks can be effectively used for monitoring air pollution in the areas where regular monitoring is vital. The self-healing feature of Zigbee can simply turn off the hop that is not connected to the PC; then the sensors will join the gateway device (if it is in radio range).The gateway node does not allow new devices to join, but it allows to re-join nodes that are already in the network, hence it minimises the power consumption of nodes.

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Due to Wireless connectivity, low power consumption of sensor nodes and CC2530ZDK system, the designed WSN for air pollution monitoring system can be deployed in a short time without entailing considerable maintenance cost and overcomes the Shortcomings on current systems. It is used to improve the rescue quality and eventually reducing rescue time.

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