DESIGN OF ENERGY AWARE AIR POLLUTION MONITORING SYSTEM USING WSN

Sonal. A. Mishra[1], Dhanashree S. Tijare[2] and Dr. G. M. Asutkar
[1, 2] G. H. Raisoni College of Engineering / Department of Electronics, Digdoh Hills, Nagpur, India
sonal.mishra007@yahoo.com, dhanashree.tijare@gmail.com, g_asutkar@yahoo.com

ABSTRACT

The paper presents Wireless sensor network system used to monitor and control the air quality in Nagpur city, India. Environmental air pollution monitoring system that measures, RSPM (Respirable Suspended Particulate Matter), NO_x, and SO_2 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. Wireless Sensor Networks are a new and very challenging research field for embedded system design automation, as their design must enforce stringent constraints in terms of power and cost. Wireless Sensor Network is a fast evolving technology having a number of potential applications in various domains of daily-life, such as structural and environmental monitoring, medicine, military surveillance, condition based maintenance etc. A 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. Several sensor nodes, which measures pollutants information, were uniformly deployed in the networks to create sensing phenomena. The simulation results consist of the scenario generated and x and y co-ordinates of the nodes from the gateway by using Network Simulator (NS-2.33). For better power management we used low power strategies and hierarchical routing protocol in wireless air pollution system and caused the motes to sleep during idle time.

KEYWORD

*Wireless Sensor Network, Power Consumption, Energy Saving Strategy***.**

1. INTRODUCTION

Air pollution has been aggravated by developments that typically occur as countries become industrialized: growing cities, increasing traffic, rapid economic development and industrialization, and higher levels of energy consumption. The high influx of population to urban areas, increase in consumption patterns and unplanned urban and industrial development has led to the problem of air pollution. The report, prepared by Global Scientific Inc., found that suspended particulate matter (SPM) including dust, fumes, mist, and smoke in the air in commercial, industrial and even residential areas of the city exceeds the National Ambient Air Quality Standards throughout the year. The concentration of SPM in and near the urban areas causes is worrisome for people's health. The areas in Nagpur, India, where pollutants exceeded the ambient air quality standards as stipulated by Central Pollution Control Board (CPCB) are Shankar Nagar, Ajni square, Manewada, Baidyanath square, Cotton Market, Itwari, Sadar, Kamal square, Gittikhadan, Mankapur, Sakkardara square etc.

1.1Wireless Sensor Network

A sensor network is a group of specialized transducers with a communications infrastructure intended to monitor and record conditions at diverse locations. A sensor network consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable. Every sensor node comprises of a transducer, microcomputer, battery, transceiver and power source. The transducer generates electrical signals based on sensed physical effects and phenomena. The microcomputer processes and stores the sensor output. The transceiver, which can be hard-wired or wireless, receives commands from a central computer and transmits data to that computer. When such thousands of nodes are brought together that communicate through wireless channels for information sharing and cooperative processing makes Wireless Sensor Network. Although each node in the WSN is very limited in energy, communications ability and computing and storage ability, the WSN has very obvious advantages:-

1) They can store a limited source of energy.
2) They have no hassle of cables and have mobility.
3) It can work efficiently under the harsh conditions, and it has deployment up to large.
4) It can be accessed through a centralized monitor.
5) Communications networks are self-organized with network topology adaptive to various environments.

The Wireless Sensor Networks are being used in many ways. Traditionally, it has been used in the high-end application such as radiation and nuclear-threat detection systems, weapons sensors for ships, biomedical applications, habitat sensing and seismic monitoring. Recently, Wireless Sensor Networks are focusing on national security applications and consumer applications such as:-

1. Military applications
   - Monitoring, tracking and surveillance of borders
   - Nuclear, biological and chemical attack detection
   - Battle damage assessment

2. Environmental applications
   - Flood and oceans detection
   - Forest fire detection
   - Precision agriculture

3. Health applications
   - Drug administration
   - Remote monitoring of physiological data
   - Tracking and monitoring doctors and patients inside a hospital

4. Home applications
   - Automated meter reading
   - Home automation
   - Instrumented environment

5. Commercial applications
   - Monitoring vibration that could damage the buildings structures
   - Monitoring traffic flow and road condition
   - Vehicle tracking and detection

Fig 1shows, a sensor consists of a transducer which is a device that converts energy from one domain to another. In our application, it converts the quantity to be sensed into a useful signal that can be directly measured and processed. Signal conditioning means manipulating an analog signal in such a way that it meets the requirements of the next stage. Digital signal processing is needed so as to observe only the required output specifically. After processing and getting the required result this signal is further converted into digital. Now, this signal by using a hardware interface is connected to the network area.
By, using proper data aggregation algorithm we need to minimize the amount of duplicates and invalid values. Local User Interface is a panel-mounted device that allows building and locally monitors and control system equipment. Further this data is been compared with data base and is accordingly reflected by using output device.

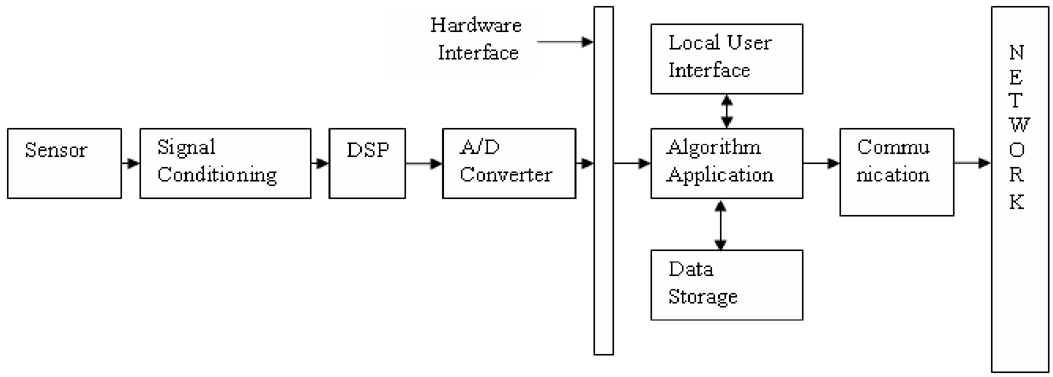

Fig 1: A Generalized Model of Smart Sensors

When health is a major concern of our daily life, the pollution monitoring and control system becomes a very useful tool that offers:

- Up-to-date information about the composition of air, based on user location.
- An easy to use interface, available to users everywhere.
- Pollution warnings via SMS and email for registered users.
- An organized way to view information about the evolution of pollution in certain locations.
- A cheap and robust system for air pollution monitoring.

The system's functionality can be extended furthermore by creating personalized alerts for users that have an increased sensibility to a certain substance. Conventional air quality monitoring approaches are limited with respect to time, expense, and installation sites. Therefore, limited data is available for the estimation of ambient air toxins. Further, air quality monitoring systems built into compact, handheld devices have spatial and temporal limitations, since the measurements are conducted manually. With the rapid development of micro-electro-mechanical systems and wireless sensor network (WSN) technology, it is possible to create cost effective & low power air quality monitoring system. The integration of an air pollutant monitoring system with WSN technology will reduce installation costs and enable the quick and easy reconfiguration of the data acquisition and control systems.

1.2 Power consuming factors in Wireless Sensor Network

The power issue in wireless sensor network is one of the biggest challenges, because the sensor has limited source of power which is also hard to replace or recharge. Wasteful power consumption is due to:

- Idle listening to channel "waiting for possible traffic".
- Retransmitting because of collision "e.g. two packets arrived at the same time at the same sensor"
- Overhearing "when a sensor received a packet doesn't belong to it".
- Generating and handling control packets.
- Over-emitting "when a sensor received a packet while it is not ready".

1.3 Energy-saving Strategies of Wireless Sensor Node [2]

1) Reducing power consumption starts from the selection of Microcontroller unit (MCU), low power consumption MCU should be considered at first.[12]
2) Choosing chip with low standby current and steady transreceiving current for Radio frequency module.
3) Power source with low output voltage and low consumption power itself.
4) Reducing system operating frequency can lower current consumption effectively.
5) Lowering system operating voltage influences system power consumption. So under the premise of system credibility, make sure that system is in lower operating voltage.
6) Use interrupts to make the processor into deep sleep. As we all know, sleep and power down mode will lower operating current greatly.

7) Dynamic Power Management. When there is nothing interesting happened around, some modules are idle, switching to low energy consumption state (sleeping mode). This event-driven energy management is very important to enhancing life cycle of sensor node.
8) Dynamic Voltage Scaling. When calculated load is low, reduce working voltage and frequency of MCU and thereby reduce processing capacity, can reduce power consumption of MCU.
9) Reduce starting time of Sending and receiving module.

To design an energy-aware WSN node, it is mandatory to analyze its power dissipation characteristics. A WSN node consists of four subsystems: [5]

i) Computing subsystem having an MCU.
ii) Communication subsystem having RF transceiver
iii) Sensing subsystem having the sensor/actuator interfaces and
iv) Power Supply subsystem.

Among them, communication and computation subsystems consume bulk of the power-budget and it is generally accepted that efforts toward energy reduction should target both of them in particular. There are two states for each sensor mote, ACTIVE and SLEEP. In the ACTIVE state the whole part of the mote is ON, whereas in SLEEP state, all the parts including the radio transceiver are in OFF state. The sensor and the processor come ON periodically to collect data. Here, we have separated out the receiving part into two, one is data communication and another is channel monitoring. Data communication is totally handled by the radio transceiver and the channel monitoring is the duty of wake-up interrupt. The purpose of this wake-up interrupt is to monitor the channel when the mote is in SLEEP state and to switch the mote's state from SLEEP to ACTIVE when it receives a wake-up signal. The wake-up circuit does not consume any extra power from the battery rather by extracting energy from the radio signals; it generates an interrupt to wake-up the mote from SLEEP to ACTIVE state. The working principle of this wake-up hardware is provided in. All the motes will be in SLEEP state until it gets a wake-up signal. Data transfer will always be initialized by one of the base stations alternatively. Vehicular air pollution monitoring is not a delicate application; hence we make the system into sleep mode for fixed time, let's say for 15 minutes if pollution level is under control or 5 minutes if it is high and then use interrupt to wake-up system to take current data.

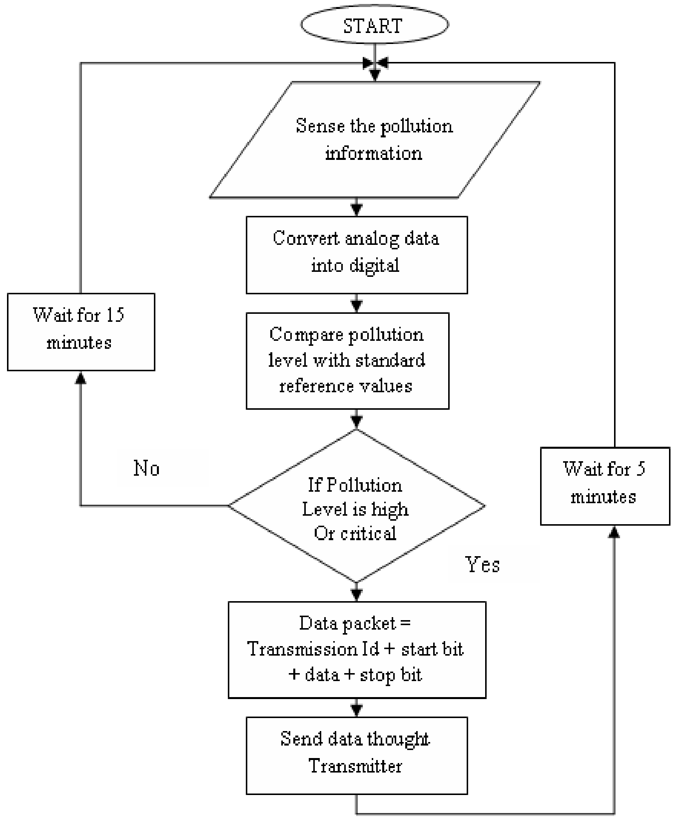

Fig 2: Flow chart for energy saving strategy

2. Distance Vector Algorithm

Wireless Sensor Network (WSN) [1] is the collection of power-efficient sensor nodes that work together to form a network for monitoring the target region. The no. of nodes in the wireless sensor network has a common tendency to send the data with itself to transmit it to the nearby nodes so as to send the data to the gateway. The nodes utilize their energy for data sensing, data processing, and data transmission/reception, amongst which, the energy consumed for communication is the most critical.

In Wireless Air Pollution Monitoring System a packet consists of two parts: the data, which is the reading collected by the source node, and an id, which identifies the node uniquely in the network such as a network address. The cluster head collects readings from every node and stores them in a list. The processes carried out in produce a performance output before the WSN model can analyze. Three major process involved in analyzing the performance of WSN are, creating a scenario model, simulating and analysis. All these processes were done by the Network Simulator (NS). While simulation is running, we can see packets being animated at various layers, flow through the network. We can also speed up or slow down the speed of the simulation to clearly observe and analyze the network scenario. Once the simulation has been done, the graphical metrics results collected during simulation of a network scenario.

The performance of WSN models, which are created and simulated. Several sensor nodes can be uniformly deployed in the networks to create sensing phenomena. The simulation results recorded are the amount of data packets sent and received by each node. The throughput and the delay can be noticed. All these graphical simulation results from several WSN models can be compared and analyzed separately. The coordinate of each node and the distance between each sensor node to the sink node for both WSN model created.

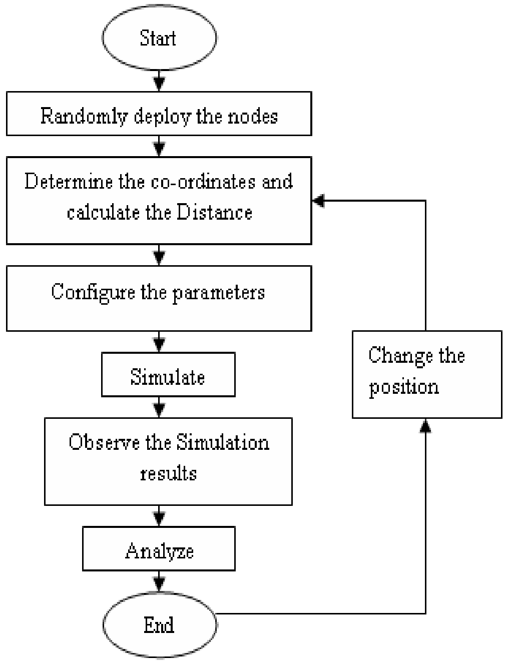

Fig 3: Flowchart of the algorithm to analyze the performance of WSN

The location of each sensor node are determined and defined in terms of coordinate (Xn, Yn). The distance (D) between each sensor node from sink node had been determined:-

$$D=\sqrt{Xn^2+Yn^2} \qquad \text{---- (1)}$$

Where, Xn – difference between coordinate X of the sensor nodes and the sink node

Yn – difference between coordinate Y of the sensor nodes and the sink node

2.1 The strategy to deploy the WSN for our system is as follows:-

1) First partition the region of interest into several smaller areas for better management of huge amount of data that will be collected from the system and for better coordination of the various components involved

2) Deploy one cluster head in each area; these will form cluster with the nodes in their respective areas, collect data from them, perform aggregation and send these back to the sink.

3) Then, randomly deploy the sensor nodes in the different areas. These will sense the data; send them to the cluster head in their respective area.

4) We will use multiple sinks that will collect aggregated data [10] from the cluster heads and transmit them to the gateway. Each sink will be allocated a set of cluster heads.

5) The gateway will collect results from the sinks and relay them to the database.

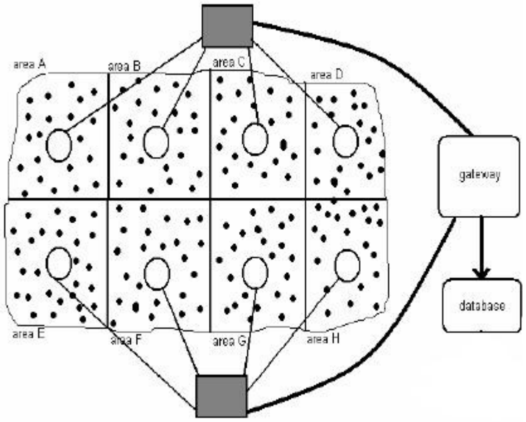

Fig 4: Node Deployment Strategy [3]

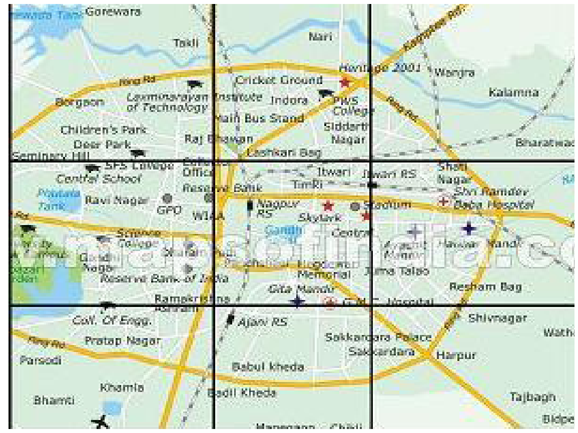

Fig 5: Area is divided into smaller parts

Fig 5 shows the area in Nagpur, which can be divided into smaller areas. Every small area will have number of nodes which will collect the data and send it to the cluster head. Practically, this analysis can be used to plot the nodes in any particular area. Then it is further send to the gateway and from gateway to the base station.

Pollution Level	Industrial (I)			Residential (R)	
	SO_2 & NO_2	RSPM	SPM	SO_2 , NO_2 & RSPM	SPM
LOW (L)	0-40	0-60	0-180	0-30	0-70
MEDIUM(M)	40-80	60-120	180-360	30-60	70-140
HIGH(H)	80-120	120-180	360-540	60-90	140-210
CRITICAL(C)	>120	>180	>540	>90	>210

Table 1: AQI prearranged by the Government of India

$$AQI = \frac{\text{Pollutant concentration}}{\text{Pollutant nominal concentration}} \times 100 \qquad \text{--- (2)}$$

3. Network Simulator [11] [13]

A methodology is a collection of methods, techniques, tools and documentation aids which help the system developers analyze, design and implement a software system. This section, describes the methods used to conduct the research and the fact finding techniques. Various research techniques can be used to gather data and analyze WSN routing protocols. NS-2 has emerged from the VINT project. It is written and developed in C++ and TCL. It is widely used network simulator. It provides extensive support for simulating TCP/IP, routing and multicast protocols over wired and wireless networks. Its object oriented design, mix of C++ and TCL increases the complexity of the software. NS-2 is a discrete event simulator targeted at networking research. NS-2 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. NS-2 can run either in Fedora version of Linux Operating Systems or in the surface used Windows XP with Cygwin. Ns are licensed for use under version 2 of the GNU General Public License.

4. RESULTS & DISCUSSION

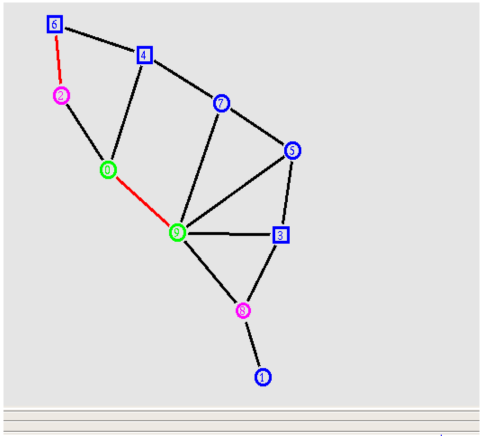

Fig 6: Node Deployment

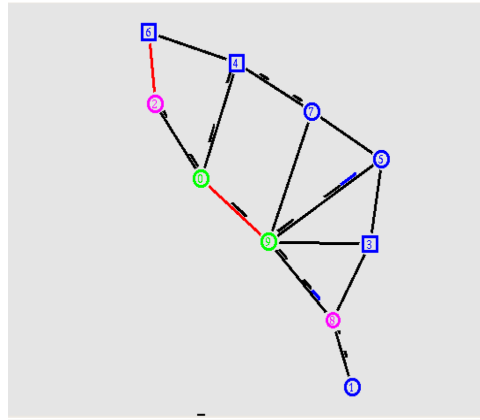

Fig 7: Data Transfer within the nodes

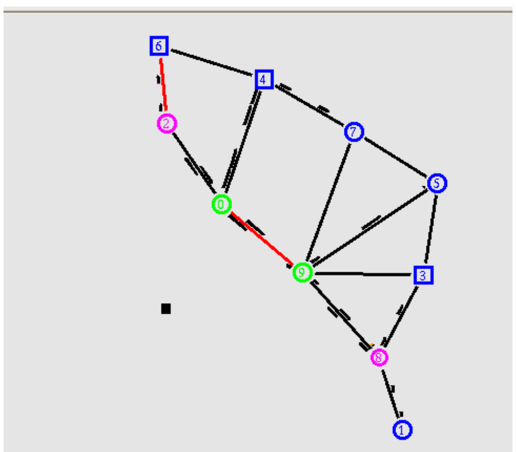

Fig 8: Data Transfer with Loss

```
.33/otcl-1.13:/root/Desktop/ns/ns-allinone-2.33/lib
[root@localhost project]# export TCL_LIBRARY=/root/Desktop/ns/ns-allinone-2.33/t
cl8.4.18/library
[root@localhost project]# export PATH=/root/Desktop/ns/ns-allinone-2.33/bin:/roo
t/Desktop/ns/ns-allinone-2.33/tcl8.4.18/unix:/root/Desktop/ns/ns-allinone-2.33/t
k8.4.18/unix
[root@localhost project]# ns wsnperformanceevalutionb4.tcl
num_nodes is set 10
creating nodes...
Creating links 0...10...14...starting
Node: 0, X: 175177776, Y: 1784827648, Z: 7627621, time: 0.000000
Node: 1, X: 1, Y: 0, Z: 173835968, time: 0.000000
Node: 2, X: 175272616, Y: 4, Z: 2, time: 0.000000
Node: 3, X: 175292440, Y: 4, Z: 2, time: 0.000000
Node: 4, X: 175312312, Y: 4, Z: 2, time: 0.000000
Node: 5, X: 138669824, Y: 0, Z: 175336984, time: 0.000000
Node: 6, X: 0, Y: 175337936, Z: 0, time: 0.000000
Node: 7, X: 0, Y: 175355392, Z: 0, time: 0.000000
Node: 8, X: 0, Y: 175375256, Z: 0, time: 0.000000
Node: 9, X: 175411016, Y: 4, Z: 2, time: 0.000000
Group1 addr: -2147483648
Group2 addr: -2147483647
```

Fig 9: X and Y co-ordinate of the distance from the gateway

```
src1:
pgmSender-0
        Last ODATA seqno: 106
        Last SPM seqno: 10
        Number of NAKs received: 3
        Number of RDATA transmitted: 3
        Max retransmission count for a single RDATA: 0
agent9:
pgmAgent-9:
        NAKs Transmitted:       5
        NAKs Suppressed:        3
        Unsolicited NCFs:       0
        Unsolicited RDATA:      0
rcv1:
pgmRecv-0:
        Last packet:            106
        Max packet:             106
        Packets recovered:      3
        Latency (min, max, avg):        0.074138, 0.099012, 0.083146
        Total NAKs sent:        3
        Retransmitted NAKs:     0
rcv5:
pgmRecv-1:
        Last packet:            106
        Max packet:             106
        Packets recovered:      3
        Latency (min, max, avg):        0.074138, 0.098915, 0.083113
        Total NAKs sent:        3
        Retransmitted NAKs:     0
rcv7:
pgmRecv-2:
        Last packet:            106
        Max packet:             106
        Total NAKs sent:        0
        Retransmitted NAKs:     0
```

Fig 10: Output of Source 1

```
src2:
pgmSender-1
        Last ODATA seqno: 106
        Last SPM seqno: 10
        Number of NAKs received: 2
        Number of RDATA transmitted: 2
        Max retransmission count for a single RDATA: 0
rcv3:
pgmRecv-3:
        Last packet:            106
        Max packet:             106
        Total NAKs sent:        0
        Retransmitted NAKs:     0
rcv4:
pgmRecv-4:
        Last packet:            106
        Max packet:             106
        Total NAKs sent:        0
        Retransmitted NAKs:     0
rcv6:
pgmRecv-5:
        Last packet:            106
        Max packet:             106
        Packets recovered:      2
        Latency (min, max, avg):        0.106205, 0.113998, 0.110102
        Total NAKs sent:        2
        Retransmitted NAKs:     0
```

Fig 11: Output of source 2

The above simulation result shows the scenario of the network designed by using NS-2. Fig 6 shows a diagram of two networks, each consisting of three nodes named (6,4,3) and (7,5,1) for collecting data, two sink node (2,6), two gateways named (0,9) for the transmission of data from the area to the base station. Fig 7shows the scenario of data packets transfers within the nodes. These data packets consist of frames of 512 bytes. Fig 8 shows the scenario of packets loss during the transfer of data. Fig 9 shows the x and y co-ordinate of every node from the gateway demonstrating the position of node in the network. Fig 10shows the loss of packets, NAK's (Negative Acknowledgment) suppressed of Network 1, Fig11shows the loss of packets, NAK's suppressed of Network 2 and the latency of both the network in terms of minimum, average and maximum.

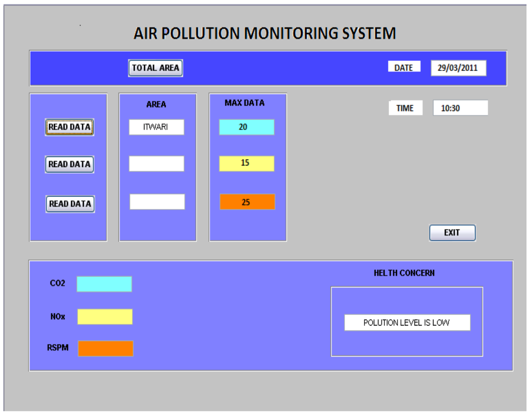

Fig 12: Pollution information at selected area

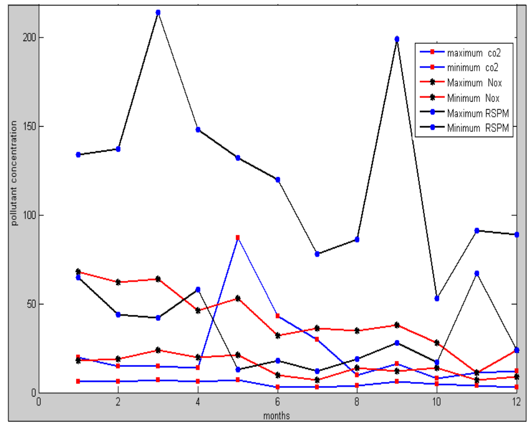

Fig 13: Pollutant concentration throughout the year

Pollution level at each sensor node can be provided to people by either using GPRS system [4] [9] or through SMS or we can display the pollution level information on large display close to square. People generally have more than one alternate path to reach at same destination; if person know the pollution information in advance they can follow the safe path. And simultaneously pollution can also control.

5. CONCLUSION

As discussed in this paper, recent technological developments in the miniaturization of electronics and wireless communication technology have led to the emergence of Environmental Pollution Sensor Network. 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. Node is designed for minimum power consumption with various strategies like sleep mode scheduling and time delay based design. Selection of low power modules also helps in improving power dissipation characteristics.

It uses an Air Quality Index to categorize the various levels of air pollution. It also associates meaningful and very intuitive colours to the different categories, thus the state of air pollution can be communicated to the user very easily. The system also uses the AQI to evaluate the level of health concern for a specific area.

Wireless Air Pollution Monitoring System uses a novel technique to do data aggregation in order to tackle the challenge of power consumption minimization in WSN. It also uses quartiles to summarize a list of readings of any length to just three values. This highly reduces the amount of data to be transmitted to the sink, thus reducing the transmission energy required and at the same time representing the original values accurately. The System uses Distance Vector Algorithm to calculate maximum allowable distance between sensor nodes with minimum power consumption, which helps to deploy sensor node in given area. The line graph allows the user to view the trend of air pollution for several areas at a time. Wireless Air Pollution Monitoring System also displays a map of the town of Nagpur, India, showing the locations of the deployed sensors nodes and the readings collected by each one. Using wireless sensor networks is a more effective way of collecting data. These sensor nodes are light weight, easy to install, low power and low cost. Unlike the conventional methods of data collection, this project provides a way to collect live and accurate data efficiently.

6. REFERENCES

[1] Faieza Hanum Yahaya, Yusnani Mohd Yussoff, Ruhani Ab. Rahman and Nur Hafizah Abidin "Performance Analysis of Wireless Sensor Network".

[2] Xiaoyan Cui, Xiaodong Zhang, Yongkai Shang, "Energy-saving strategies of Wireless Sensor Networks", IEEE 2007 International Symposium on Microwave, Antenna, Propagation, and EMC Technologies for Wireless Communication.

[3]Kavi K. Khedo1, Rajiv Perseedoss2 and Avinash Mungur3, 'wireless sensor Network Air pollution Monitoring system', International journal of wireless and mobile networks Ijwmn, vol2, no2, may2010

[4] Suciu Constantin, Florin Moldoveanu, Radu Campeanu Ioana Baciu, Sorin Mihai Grigorescu, Bogdan Carstea, Vlad Voinea, "GPRS Based System for Atmospheric Pollution Monitoring and Warning" 1-4244-0361-8/06/$20.00 ©2006 IEEE

[5] Muhammad Adeel Pasha, Steven Derrien, Olivier Sentieys," A Complete Design-Flow for the Generation of Ultra Low-Power WSN Node Architectures Based on Micro-Tasking

[6] R. Rajagopalan and P.K. Varshney, "Data-Aggregation Techniques in Sensor Networks: A Survey," IEEE Communication Surveys and Tutorials, Vol. 8 (4), pp. 48-63, December 2006.

[7] H. Albert, R. Kravets and I. Gupta, "Building Trees Based On Aggregation Efficiency in Sensor Networks," Ad Hoc Networks, Vol. 5 (8), pp. 1317-1328, November 2007.

[8]Zhong Hui, Qian Zhi-hong, Liu Ying, Wang Xue, Wang Yi-jun, "Modeling on Prediction of WSN Sleep Scheduling: Preliminary Study".

[9] A. R. Al-Ali, Imran Zualkernan, and Fadi Aloul," A Mobile GPRS-Sensors Array for Air Pollution Monitoring", IEEE SENSORS JOURNAL, VOL. 10, NO. 10, OCTOBER 2010

[*10] R. Rajagopalan and P.K. Varshney, "Data-Aggregation Techniques in Sensor Networks: A Survey," IEEE Communication Surveys and Tutorials, Vol. 8 (4), pp. 48-63, December 2006.*

[11]http://www.isi.edu/nsman/ns/

[12] Atmel Corporation. AT mega 103L 8-bit AVR Low-Power Microcontroller. Tech. Report, 2007.

[13]http://nsnam.isi.edu/nsnam

Authors

Ms. Sonal A. Mishra is a research scholar at G. H. Raisoni College of Engineering, Nagpur, India; she is currently appearing for M-Tech (VLSI).She got BE degree in Electronics and Telecommunication Engineering, from North Maharashtra University, Jalgaon, India (2007). Her area of interest is Lifetime optimization of wireless sensor node.

Ms. Dhanashree .S. Tijare is a research scholar at G. H. Raisoni College Of Engineering, Nagpur, India. She is currently appearing for M-Tech (ELECRONICS). She got BE degree in Electronics Engineering, from Rastrasant Tukdogi Maharaj University, Nagpur, India (2009).Her area of interest is Energy Aware Node deployment Strategies of Wireless Sensor Network.

Mr. G. M. Asutkar got Ph.D. from VNIT Nagpur, India. He has completed his M.Tech from VTU, Belgaum (Karnataka), India. He is working on Wireless Sensor Networks, and Block error diffusion for digital half toning for medical Images: Area Image Processing. He is actively participated in Organization of "KRITI 2004".He is member of the centralized cultural committee for 2005-06, Actively participated in Organization of "KRITI 2008",worked for TECH INDIA by times Group.