Chapter 1

Introduction

1.1 Introduction

A healthy Environment is essential for the survival and growth of all living things. Sustainable development of any country depends on three pillars: economic growth, social progress and protection of the environment. The environmental pollution problems in developed and developing countries are growing rapidly. Air pollution is one of man-made environmental disaster which is a major problem all over the world. Exposure to air pollution is the main environmental threat to human health. There are two main sources of air pollution. They are vehicular emissions and industrial emissions. Increasing population not only needs the development of industrialization and urbanization but also leads environmental problems. Despite the impoverishment, pollution, health and environmental problems created, the government (people) believes that industrialization at any cost is the way for advancement and it is impossible to avoid industrialization. But the environmental assessment concerned with identifying, predicting and evaluating pollution both beneficial to people and development of a country is necessary. To make the world a better place to live, there is a need to wise in managing our resources, and take positive action towards preventing any forms of pollution to the environment. The first step is to do continuous monitoring around the clock and online reporting. Sensor networks for air pollution monitoring helps in determining the concentration of pollution and levels which will cause the deleterious effects on environment and living organism.

Environmental sensor networks are new way of monitoring the environment. They comprise sensor nodes in the environment that record real time data, which are retrieved, analyzed and integrated with other data sets to predict the future. The real success of the sensor network technology depends mainly on its application in eradicating a harmful
situation or in maintaining a good one. Designing an efficient application is one of the major challenges and sensor network challenges are application dependent.

Concern for the environment is a prospective application domain which is of particular value to our country. Predicting air quality from multiple sources by using modeling is very complicated [1]. So, air quality models are best used for isolated sources or situations. The main aim of this thesis is to propose the logical and physical topology design guidelines to an industry to do an intelligent data collecting system for continuous air pollution level monitoring specific to point source stack using Wireless Sensor Networks (WSN) in industrial areas.

This chapter contains a brief introduction about the importance of WSN and its applications. The present scenario of industrial air pollution monitoring adopted by Tamil Nadu Pollution Control board (TNPCB) and the outline of proposed intelligent data collecting system to measure pollutant levels that can be equipped with WSN, namely design of District Air Pollution NETwork (DAPNET) are described. The overview of the WSN design methodology and motivation for the choice of the present topic is also highlighted.

1.2 Importance of WSN

Technological innovations in modern communication have brought a deep change in our life style. The essential elements of modern communications are

- Information Gathering or Generation
- Information Transformation
- Information Storage

Information gathering involves the task of preparing information to be transmitted in a form easily understood by the receiver. This includes processing or converting information
by using computer. The function includes creation, processing, conversion, editing, analysis, computation, synthesis etc.

Information transfer occurs as information is delivered to remote destinations quickly without errors. The function includes broadcasting, transmission, switching, networking, reception, signal processing, collection, display etc.

Information storage is done for future use. This includes storage and retrieval.

In conventional communication the pattern of flow was Information generation …> Information transfer …> Information storage. Here the human being is the source and destination of information. However, there may be other sources and destinations of information in modern communications. One such example is the case of information being detected, sensed and taken from the natural environment by various devices (sensors) serving as information sources. Hence the network of such sensors came into use. Aggregating sensor nodes into sophisticated computational and communicational infrastructure is called sensor networks.

Sensor networks enable information gathering, information processing and reliable monitoring of a variety of environments. These networks promise to revolutionize sensing in a wide range of application domains. This is because of their reliability, speed, accuracy, flexibility, cost effectiveness and ease of deployment. [2]

Recent advancement in wireless communications and electronics has enabled the development of proposed WSN. WSN is a deployment of number of self powered devices that can sense, compute and communicate with other devices, for the purpose of gathering local information to make global decisions about a physical environment. A sensor is
equipped with radio transceiver, a small microcontroller and energy sources - usually a battery [3].

1.3 Applications of WSN

Advances in instrumentation and pervasive networking technology give WSNs into wide range of uses. The main driving force behind research in sensor networks is the military application. The SOund SUrveillance System (SOSUS) is the first obvious sensor networks application used by US navy. Modern research on sensor networks started around 1980 at the Defense Advanced Research Project Agency (DARPA). Distributed sensor network program, smaller computing chips, more capable sensors, wireless networks and other new IT technologies are pushing the development of sensor networks. As sensor network research has moved out its infancy, its focus has started to shift away from short-lived hand-configured tests and demonstrations (small scale habitat monitoring sensors to measure the population of birds) to long-lived, larger-scale sensor systems that are situated in real environments and collect real data (FLOODNET project to provide a flood warning in UK). [4]

In monitoring application, sensor nodes are deployed either very close or directly inside the phenomenon to be observed. Therefore, they usually work unattended in remote geographic areas. They may be working in the interior of large machinery, at the bottom of an ocean, in a biologically or chemically contaminated field, in a battle field beyond the enemy lines and in a home or large buildings.

Environmental sensor networks facilitate the study of fundamental processes and the development of hazard response systems. They have evolved from passive logging systems that require manual downloading, into intelligent sensor networks that comprise a network of automatic sensor nodes and communication systems which actively communicate their data
to a sensor network server. Tsunamis monitoring, UV monitoring, water/air quality monitoring, habitat monitoring, flood warning are some examples. [5]

Although computer-based instrumentation has existed for a long time, the density of instrumentation made possible by a shift to mass-produced intelligent sensors and WSN gives a new kind of scope that can be applied to a wide range of uses. The industrial processes such as assembly, manufacturing, instrumentation, packaging and communications, data is continuously being monitored through sensors, digitized, analyzed, collected and stored. Some of the modern applications in industries are

Machine vision system – Installed at the end of production lines, to inspect for flawed products.

Automated assembly – Automated assembly of devices using robots - commands for aligning the parts were automatically calculated based on the sensor data and executed.

Intelligent system – Real-time process diagnostics and abnormal condition management.

Smart transmitters – In refineries, chemical plants, paper mills and power generating plants to measure and report fluid flows, temperatures, pressures, tank levels and valve positions at specific points in the process to the host computer.

Managing inventory control, Vibration analysis, Condition-based maintenance of machinery in complex environments, Intelligent control system, Intelligent integrated management system, suspicious individual detection, fire monitoring, leak detection and many more.
These are all for the growth and safety of an industry. In addition to that, for environmental safety, continuous air pollution monitoring sensor networks must be installed in all industries.

WSNs have found their way into wide variety of application domain characteristics. Each application domain introduces novel challenges and involves specific optimization to the application domain space and network domain space. List of application domain space characteristics and their choices, network domain space design requirements, logical and physical topology design considerations are analyzed in subsequent chapters.

1.4 Pollution Monitoring Scenario in TamilNadu – Today and in Future

With the increasing pace of industrialization in Tamilnadu, the need for continuous monitoring of pollution due to industrial sources has become significant. The TNPCB has established its organization structure with a two-tier system consisting of head-office at Chennai and district offices. To assist the board in monitoring the industries, 3 Advanced Environmental Laboratories in Chennai, Salem, and Madurai, 10 District Environmental Laboratories in Chennai, Coimbatore, Cuddalore, Dindigul, Hosur, Trichy, Tirunelveli, Tirupur, Vellore and Manali; and three mobile environmental laboratories in Manali, Thoothukudi, and Karur are functioning. These laboratories carry out analysis on samples of sewage, trade effluents, emissions and hazardous wastes. [6]

Industries are required to provide pollution control measures to meet the standards prescribed by the board. The field officers of the board inspect the industries under their jurisdiction periodically to assess the adequacy of pollution control measures provided by the industries to treat sewage, trade effluent and emissions and to monitor their performance. They also investigate complaints of pollution received from the public, organizations and the Government. For effective monitoring, industries are categorized as ultra Red, Red, Orange,
and Green according to their pollution potential. The industries have also been classified as Large, Medium and Small scale based on the gross fixed assets of the industry. Depending upon the category and size, industries are monitored periodically.

As per the Air (Prevention and Control of Pollution) Act, 1981, the entire State of Tamilnadu has been declared as air pollution control area. The board is monitoring the ambient air quality in Chennai (3 stations), Coimbatore (3 stations), Thoothukudi (3 stations), Madurai (3 stations) and Salem (1 station) under the National Air Quality Monitoring Programme (NAMP) carried out by Central Pollution Control Board (CPCB). In addition the board has established 5 Ambient Air Quality monitoring stations in Chennai City and 5 in Thiruchirapalli. The ambient air quality in residential, industrial, commercial and mixed zones is monitored by these stations.

One of the routine actions done by the TNPCB is the field officers of the board periodically inspect every industry to assess the pollution measures manually or by using sensors. Table (1.1) shows the category of industries and number of samples tested by field officers.

To do continuous monitoring, small industries are not willing to bear the amount of sensors. But highly polluting industries have been directed to establish their own continuous air quality monitoring systems. These units have also been asked to set up continuous stack monitoring systems with computer recording arrangements so as to monitor emissions at the source itself. Some large scale industries have already installed these air quality monitoring systems. Moreover they display the pollution level through public display screen, to inform the public about the outdoor pollution level. The problem is several monitoring stations in industries are still not online. [7]

<table>
<thead>
<tr>
<th>Table 1.1 Industries category wise Samples tested by field officers</th>
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<tr>
<td>Category of Industry</td>
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<tr>
<td>---------------------------------------</td>
</tr>
<tr>
<td>Large Scale Ultra Red</td>
</tr>
<tr>
<td>Large Scale Red</td>
</tr>
<tr>
<td>Medium Scale Red</td>
</tr>
<tr>
<td>Small Scale Red</td>
</tr>
<tr>
<td>Large and Medium Scale Orange</td>
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<td>Small scale Orange</td>
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<tr>
<td>Green</td>
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In a factory operating in a remote place, the concentration of pollution level if it exceeds certain ambient level may be left unnoticed by the PCB. To gather real time data PCB has to give some guidelines to industries about monitoring and reporting mechanism. Hence the main aim of this thesis is to provide the possibilities of reporting mechanism and design guidance to industries to establish energy efficient air monitoring WSN.

From the analysis of the present pollution monitoring scenario it is proposed to form a new network namely, DAPNET – District Air Pollution NET for different districts of TamilNadu [8]. To make the system more effective, network of continuous monitoring plan by installing sensor nodes at different places, controlled by pollution control board is a solution. Monitoring is done by continuously collecting data from a distributed network of sensor devices deployed in various industries. There is no need for someone to go to each sensor and collect the information. It is easy to maintain proper inventory of polluting industries and find the location of critically polluted areas.
Figure 1.1 Generic Network Architecture of DAPNET

Figure (1.1) shows simple sensor network. For efficient implementation, the district is divided into several industrial zones. One industrial zone may be treated as one sensor field. A sensor field is an area which contains many sensor nodes doing the same work. [3] The number of sensor nodes deployed will be decided according to the capability of sensor nodes and size of sensor field. The typical job of a sensor node is to sense the environment, collect data and route the data. A network is used to pass the data to base stations, which forward the data to a sensor network server (sink) at industries and then to the head office (PCB).

Instruments with networked sensor nodes provide valuable scientific information enabling to predict the future. To obtain the real concentration of various pollutants a highly
reliable device for measurement is needed. The equipments already available to monitor pollution levels can vary from a complex array of continuous air monitors that operate 24 hours a day year round to a single sampler with a filter that captures particulates once a week.

After analyzing the capability of the available equipments the number of nodes and position of a node may be decided. Whatever may be the node, much of the data collected from the air monitoring network is submitted to the PCB data base for use in determining air pollution trend and standard.

Recently, in order to monitor both source emissions and ambient air quality on a real time basis, TNPCB has established a Centre for Accessing Real Time Air (Quality) Information Report (CARE AIR) at the Head office of the Board on June, 2010. This is a continuous real time emission monitoring system. [9] When the emission levels exceed the norms, an inbuilt alarm system has been established to inform the concerned industry and the District Environmental Engineer/Member Secretary through automated SMS for remedial action immediately. So far, 85 industries have been connected to the CARE AIR centre and the emissions are monitored continuously. Apart from the above, monitoring of effluent discharge has also been included and monitored at the centre. During the year 2011 – 2012, 28 major industrial units started uploading the details to the CARE AIR centre.

The data generated from various monitoring networks set up around industrial clusters will be fed into a centralized database system for the State. TNPCB is in the process of establishing a Technology Demonstration Centre in collaboration with leading institutions in the State. Every effort will be taken to provide a focal point of reference on all environment related issues in the TNPCB.

The system works on a double module. Data generated by the analyzers of the ambient air and the chimneys, generated every 10 seconds are transferred via a data
acquisition system to the centre at the TNPCB office. The gathered data is validated, and if there is a cause for concern, e-mail and SMS alerts are sent to the nodal officials. Top TNPCB officials will also be kept informed.

The above method is the simplest way of data gathering that is by delivering each sensed data periodically to the sink, where the data can be assembled for subsequent analysis. Since the amount of data generated in large sensor network (from all industries) is usually enormous, this approach results in excessive communication. For this reason, the possibilities of data reporting methods proposed are carried out using Castalia Simulator. Based on the type of industry the PCB may insist the industries to follow different method of reporting mechanism.

1.5 WSN design methodology

The design methodology of WSN for a particular application may be viewed in three directions [10]. An overview of the WSN design methodology is shown in Figure (1.2).
The problem specifications procedure consists of the physical description of the area to be monitored by WSN, such as area size, list of any obstacles, buildings and list of items to be monitored. The determine coverage procedure is find the minimum number of sensors and their locations so that entire area is covered. The design communication network procedure is to find the minimum number of base stations and their locations so that all allocated sensors can communicate each other.

1.6 Motivations to this study

- Living green and clean is a global expectation. Due to the lack and delay in implementing certain regulations in both government and private sector industries, threat of global warming is increasing.
- Air monitoring equipment is not something new, but the integration of this technology with existing Information Technology (IT) operations is new and necessary to keep a pollution free environment.
The air quality monitoring is already undertaken to detect any deterioration in air quality arising from residential, industrial and vehicular sources of pollution. National Air Quality Monitoring Programme (NAMP), Global Environmental Monitoring System (GEMS), World Health Organization (WHO) and World Bank Programme are some of the monitoring programmes in India. The major thrust of the ministry is to control pollution and take stringent actions against the polluting industrial units [11,12].

The air quality data generation through air quality monitoring network available today, involves large number of monitoring agencies, personal and equipment sampling, chemical analysis and data reporting etc. The involvement of several agencies increases the probability of variations reflecting on the data. Therefore, air quality data statistics is being recognized to be more indicative rather than absolute and perfect [11].

Centre for Science and Environment, New Delhi (India), has Green Rating Programme (GRP), to rate industries based on their environmental performance. Information for the programme is collected directly from the industries as well as from other secondary sources such as State Pollution Control Board, local newspapers and NGO’s [13]. It is also reported that the Clean Development Mechanism (CDM) meant to tackle climate change is unclean and corrupt [14].

With the increasing pace of industrialization all over the world, the need for continuous monitoring of air pollution due to industrial source has become significant. World Bank report says “India has 4.5 million small and medium enterprises which contribute 40 percent of the industrial production but create 70 percent of the industrial pollution” [15]. It is seen that, the gain of the product is comparable to the
cost, to make up the effect of industrial pollution. Therefore, it is necessary to monitor and control air pollution around a clock using SN.

- From literature survey, it is understood that, most of the previous research deals with air pollution monitoring from vehicular source or collective sources. For example,
  - Develop low-cost and ubiquitous sensor network to collect real-time large scale and comprehensive environmental data from road traffic emissions for air pollution monitoring in urban environment [16].
  - Taxi drivers were provided with a dash mounted Global Positioning System (GPS) device and a tube to hang from their passenger window. The tube contained a carbon monoxide sensor. This study is used to collect actual air quality sensor data by citizens across an urban landscape [17].
  - Geo sensor network designed to measure data related to geo spatial information. It could be useful to detect the conditions of remote place as a new instrument for environmental monitoring in the physical world. It employs the context model for understanding the status of air pollution in the current and near future area [18].
  - Sensor technologies designed to collect and relay information about specific events [19].
  - In Washington, every day, on and above Earth, millions of sensors collect vast amounts of data representing interactions among the planet’s systems of land, air, water and life. This is the kind of data needed to address the complexities of climate change or a move to a low-carbon-dioxide world economy, but gathering it is just the first step [20].
To develop risk free residential and industrial areas in Europe and to cover large monitoring area, sensor is placed in the luggage compartment of a glider [21].

Health risk assessments are also analyzed in some papers. [22, 23].

In essence, the drawbacks of existing air pollution monitoring methods and limited study on industrial air pollution monitoring have motivated this study.

1.5 Conclusion

This chapter outlined that an intelligent data collecting system to measure pollutant levels that can be equipped with WSN. In future this application will help to make a raw data for useful information available globally.