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Wireless Sensor Networks for Pollution Monitoring and Control

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ABSTRACT

Wireless Sensor networks make available the capability to gather precise and consistent data, to facilitate early cautions and fast synchronized actions to potential threats of natural disasters and environmental changes. The vast synchronization is essential requirement for the optimal information related to different types of pollution. The sensor nodes sense the data related to parameters of pollution and forward it to sink to draw an overview about the state of pollution. This paper provides an analysis of usage of wireless sensor networks for pollution control and monitoring.

Keywords: Wireless sensor networks, Pollution monitoring and control, Air pollution, Water pollution, Noise pollution

I. INTRODUCTION

The development of wireless sensor networks(WSN) was motivated by military applications such as battle field surveillance and are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, health care applications, home automation and traffic control [1,2,3]. So A WSN node consists of four subsystems [1]:

- ✓ A computing subsystem having an MCU,
- ✓ A communication subsystem having RF transceiver,
- ✓ A sensing subsystem having the sensor/actuator interfaces and,
- ✓ A power Supply subsystem.

The most straightforward application of wireless sensor network technology is to monitor remote environments for low frequency data trends.

Even a chemical leakage could be easily monitored with help of hundreds of sensors that form a wireless interconnection network and immediately report the detection of any chemical leaks. Due to precision and consistency of data, WSNs are vastly used for pollution monitoring and control.

A. Pollution

Pollution means introduction of chemical substances and unwanted energy into the environment that cause unfavorable variation in natural system [1]. There is many types of pollution like air pollution, water pollution, noise pollution, soul pollution etc. We are focusing on air pollution, water pollution and noise pollution in this paper and analyze use of the sensors to control various pollutions like air pollution, water pollution and noise pollution.

B. Need of WSN for Pollution Control

With the rapid growth of industries, the problem of pollution becomes a key concern for healthy life style. Raw readings of pollutant can be obtained by monitoring and these readings can be analyzed and interpreted to know the status of pollution. Wireless sensor networks are useful to understand the state of pollution in a particular area. In critical situation, there is a need to provide safety guidelines and a alarm which can be possible with application of Wireless sensor and actor networks [7].

C. WSN and Air Pollution

Wireless sensors can be deployed in huge numbers around the region of interest that will monitor the air

pollution [8]. Fast growing industry and vehicle traffic are major reasons behind air pollution [9]. So it is important to consider ways in which to monitor the industrial and vehicle exhaust. Due to real time information gathering, WSN is an extremely valuable tool monitoring levels of air pollution in a particular area because it gives alert in case of severe change in quality of air. The data provided by WSN can be used to take preventive actions to control air pollution. So WSN provides less complex and more instantaneous monitoring as compared to traditional data loggers [10, 11, 17].

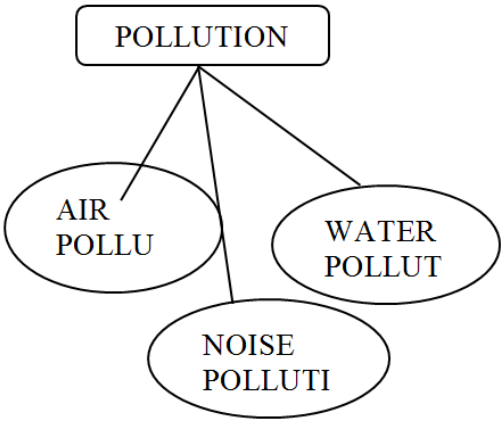

Figure 1. Types of Pollution

D. WSN and Water Pollution

As the country is making its progress through industrialization, our water resources are prone to a threat of pollution especially from the industrial activities. So the problem of water pollution has increased seriously [13]. For the effective protection to the water environment the automatic monitoring and real-time control for the treatment of waste or to determine the quality of water are some of the reasons to raise the efficiency in dealing with the waste water [14]. So to determine water quality, we should first measure and analyze characteristics of the water such as temperature, pH, turbidity etc. Selected characteristics are then compared to numeric standards to decide if the water is suitable for a particular use. For that, it is important to have a monitoring system such as WSN with characteristics of autonomous, lower cost, reliable and flexible, so that we can monitor the condition of the water resources [15].

E. WSN and Noise Pollution

Noise pollution is a big challenge in today's scenario. The negativity of environmental pollution clearly affects the health of people & the quality of their life. Also the pollutants level is increasing day by day, due to which human's life becomes haphazard [28, 29]. Any noise which is greater than 80db is treated as noise pollution [5]. If the high level of noise is exposed, it is very harmful for human and animal health. It may cause a serious illness like hypertension, hearing loss and sleep disorder [30]. As sensors can monitor noise level in particular area, WSN are used control the noise pollution in the surrounding. The sensor nodes operate unattended to gather readings of noise pollution in an area of interest. Wireless Sensor Networks can also provide a traffic management system based on road traffic noise.

II. WORK DONE TO MONITOR AND CONTROL POLLUTION USING WSN

A lot of researchers have done a tremendous job to monitor and control pollution using wireless sensor networks. We are providing analysis of three kinds of pollution:

A. Air Pollution Control using WSN

WSN can be deployed over a region where some phenomenon is to be monitored. Wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars. Wireless sensor networks can be deployed in several cities to monitor the concentration of dangerous gases for citizens that effects air badly. These can take advantage of the ad-hoc wireless links rather than wired installations, which also make them more mobile for testing readings in different areas. There are various architectures that can be used for such applications as well as different kinds of data analysis and data mining that can be conducted. The wireless sensor network for air pollution monitoring comprises of an array of sensor nodes and a communications system which allows the data to reach a server. The sensor nodes gather data autonomously and the data network is used to pass data to one or more base stations, which forward it to a sensor network server. The system send commands to the nodes in order to fetch the data, and also allows the nodes to send data out autonomously.

Young Jin Jung et al. [6] explained a monitoring system to provide forecasting about environmental pollution. A flexible data acquisition based air

pollution detection system is designed by them. This context model can provide state of air pollution and gives alarm at appropriate time. The flexible sampling interval is changed depending on the pollution conditions derived from the context model. It can save the limited batteries of geo sensors, because it reduces the number of data transmissions.

Alan Mainwaring et al. [7] examines the requirements of environmental monitoring in the context of two wildlife habitats: Great Duck Island and James Reserve. Based on the requirements from the researchers studying these habitats and proposed sensor network architecture for this class of applications. Available energy emerges as the resource to dictate performance characteristics of various services: data collection, communication, sensor network Re tasking. They evaluated the tradeoffs between different approaches to implementing several sensor network services. The ultimate goal of our work is to provide life scientists with a reliable and predictable sensor network kit.

Kavi K. Khedo et al. [8] explained the reasons behind the air pollution and the use of wireless sensor networks for pollution detection. They explained the main requirements identified for sensor based system, which is to use appropriate data aggregation to reduce the power consumption during transmission of large amount of data between the thousands of nodes. This is where monitoring can be used to fill the gap in understanding i.e. it provides raw measurements of air pollutant concentrations. They also gave the strategy to deploy the WSN for the system.

Tajne K.M et al. [12] gives a brief description about the block diagram for air pollution monitoring and control system. They explained environment Monitoring requirement for the better measurement of the pollutant concentrations and their variations, Rapid alert of the critical situation, Continuous functioning, Autonomous power supply, Severe environment functioning. As power efficiency is one of the most important design parameter for WSN nodes, and energy efficient implementations is needed. The proposed air pollution monitoring & control system comprises of sensor nodes and a communications system which allows the data to reach a server. The sensor nodes gather data autonomously and the data network is used to pass data to one or more base stations, which forward it to a sensor network server. They give the brief description of each component of air pollution monitoring & control system.

Sukwon Choi et al. [16] focus on the design and implementation of a sensor board for air pollutant monitoring applications. Several hardware and software issues are discussed to explore the possibilities of a practical WSN-based air pollution monitoring system. In this paper, through extensive experiments and evaluation, They have determined the various characteristics of the gas sensors and their practical implications for air pollutant monitoring systems.

L E Cordova-Lopezet al. [18] explained that a Geographical Information System (GIS) is a computer system designed to integrate, store, edit, analyze, share and display geographically referenced data. This paper presents the integration of these two technologies to create a system able to detect measure and transmit information regarding the presence and quantities of internal combustion derived pollution and the geographical location in real time with the aim of creating pollution maps in urban environments.

Guillermo Barrenetxea et al. [19] explained that wireless sensor networks have been extensively studied in the past few years, most results are of theoretical nature and were obtained outside of a practical context. This can be problematic for real applications, especially in the area of environmental monitoring where many factors, such as harsh weather conditions, can greatly influence the performance of such a network, while reliable delivery and high-quality measurements are required. SensorScope is an interdisciplinary project, elaborated by environmental and networking researchers, that aims at narrowing the gap between theory and practice. Several successful real-world deployments have already been undertaken in rugged environments. In this paper, They analyzed the particular requirements of environmental monitoring and how these requirements have been met in the SensorScope project. They also present an application example of a deployment, undertaken in a harsh mountain environment.

B. Water Pollution Control using WSN

WSN can make use of multiple sensors as a device to check the level of water quality as an alternative method of monitoring the condition of the water resources. Several sensors that are able to continuously

read some parameters that indicate the water quality level such as chemical substances, conductivity, dissolved oxygen, pH, turbidity etc will be used to monitor the overall quality level. As the monitoring is intended to be carried out in a remote area with limited access, signal or data from the sensor unit will then be transmitted wirelessly to the base monitoring station. A currently becoming popular and widely used technology based on wireless sensor network is extensively used to determine water quality which is able to provide flexibility, low cost implementation and reliability.

Zang Huaigang et al. [13] described various reasons behind the water pollution. So the problem of water pollution has increased seriously. So for the effective protection to the water environment, not only to monitor the pollutants, but also to control the total discharge, the automatic monitoring and real-time control for the treatment of waste water or to determine the quality of water are some of the reasons to raise the efficiency in dealing with the waste water and to protect it. Selected characteristics are then compared to numeric standards to decide if the water is suitable for a particular use. So it is important to have a monitoring system such as WSN with characteristics of autonomous, lower cost, reliable and flexible that will reduce the reliance on man power at the monitoring site thus reducing the cost also.

Zulhani Rasin et al. [15] explained the application of wireless sensor network (WSN) for a water quality monitoring. The parameters involved in the water quality determination such as the pH level, turbidity and temperature is measured in the real time by the sensors that send the data to the base station or control/monitoring room. This paper proposes how such monitoring system can be setup emphasizing on the aspects of low cost, easy ad hoc installation and easy handling and maintenance. They explained the use of wireless system for monitoring purpose that will not only reduce the overall monitoring system cost, but will also provide flexibility in term of distance or location. In this paper, the fundamental design and implementation of WSN featuring a high power transmission Zig bee based technology together with the IEEE 802.15.4 compatible transceiver is proposed. The developed platform is cost-effective and allows easy customization.

Y.H. Zhou et al. [20] provides the characteristics of time consuming, complicated steps and lack of automatic of the traditional water quality monitoring, an automated real-time online water quality monitoring program based on wireless sensor network (WSN). This system combined micro-UV-Vis Fiber Optic Spectrometer with Zig Bee Wireless Communication Technique to constitute wireless Sensor Network Node which is placed at the monitoring water, and then used the Zig Bee protocol's real-time transmission and monitor data to raise the automation and monitoring level. This paper discussed the network architecture based on Zig Bee protocol, make design of Optical System of sensor node, hardware and software. The experiment results show that the industrial monitoring system of water quality has few transmission errors, better anti-jamming ability, small size of sensor node and fast inspection speed.

Ivan Stoianov et al. [21] explained that the recent developments in wireless sensor networks (WSN) promise to have significant impact on a broad range of applications relating to environmental monitoring, structural health monitoring, security and water safety. The paper describes the development of a monitoring system which bridges advances in wireless sensor networks with advances in hydraulic and water quality modeling. The prototype monitoring system was deployed at Boston Water and Sewer Commission (BWSC) in December 2004, and it has been successfully collecting water quality data as well as water levels in combined sewer outflows (CSO). The remote monitoring system has unique functionalities in terms of sampling rates, time synchronization and in-network processing. These features create novel opportunities for wirelessly collecting data for application such as remote acoustic leak detection together with monitoring water quality parameters and water levels in CSOs. The trial with BWSC has been tremendously useful to prototype hardware and software tools, and to identify deployment and operational challenges in using sensor networks for monitoring and management of large scale water supply systems.

B O'Flynn et al. [22] described the "Smart Coast" Multi Sensor System for water quality monitoring. This system is aimed at providing a platform capable of meeting the monitoring requirements of the Water Framework Directive. The key parameters under

investigation include temperature, phosphate, dissolved oxygen, conductivity, pH, turbidity and water level. The "Plug and Play" capabilities enabled by the Wireless Sensor Network (WSN) platform developed at Tyndall allow for integration of sensors as required are described, as well as the custom sensors under development within the project.

Raja Jurdak et al. [23] proposed a network architecture that builds on the success of terrestrial sensor motes and that relies on the coupling of software modems and widely available speakers and microphones in sensor motes to establish acoustic communication links. They analytically and empirically explore the potential of acoustic communication system for the underwater environment. Their experimental approach first profiles the hardware in water after waterproofing the components with elastic membranes. The medium profiling results expose the favorable frequencies of operation for the hardware, enabling us to design a software FSK modem. Subsequently, our experiments evaluate the data transfer capability of the underwater channel with 8-frequency FSK software modems.

Marco Zennaro et al. [24] presented the design of a water quality measuring system and proposes a prototype implementation of a water quality wireless sensor network (WQWSN) as a solution to this challenging problem. When applied to developing countries, the design and implementation of such a system must take into consideration the difficult environment in which it will operate. An application to water quality measurement in Malawi reveals the relevance of using our novel solution to mitigate two challenging issues: energy consumption of the system and the inter-networking problem. In WQWSN, sensors become an integrated component of their aqueous environment throughout data collection, and data are communicated between nodes and back to researchers remotely using wireless connections. In addition to describing the development of the system, we describe ongoing and future research related to the challenging environment in which the network is going to be installed.

E.P. Stuntebeck et al. [25] introduced concept of a Wireless Underground Sensor Network (WUSN) and discussed their applications. The feasibility of utilizing commonly available terrestrial Wireless Sensor Network (WSN) hardware solutions in the underground environment is examined. Experiments are performed to examine the packet error rate and the received signal strength of correctly received packets for a communication link between two underground sensors and between an underground sensor and an above ground sensor.

Kay Smarsly et al. [26] explained that water shortage is a global problem that has severe implications on economic growth and societal well-being, even in the most developed countries. As more than two-thirds of freshwater consumed worldwide are used for irrigation, large quantities of freshwater can be saved by improving the efficiency of irrigation systems. Automatically scheduling irrigation events based on soil moisture measurements is an effective means to reduce freshwater consumption and irrigation costs. This paper presents the design, the implementation, and the validation of an integrated soil moisture monitoring system, which is part of an ongoing research on intelligent irrigation control. The monitoring system consists of a number of wireless sensor nodes that are connected to an Internet-enabled computer system. Autonomous software in the form of self-contained interacting software entities is embedded into the wireless sensor nodes. The autonomous software is designed to precisely trigger irrigation events based on decentralized real-time diagnoses of actual site conditions and external weather information.

Peter Corke [27] is concerned with the application of wireless sensor network (WSN) technology to long-duration and large-scale environmental monitoring. The holy Grail is a system that can be deployed and operated by domain specialists not engineers, but this remains some distance into the future. We present our views as to why this field has progressed less quickly than many envisaged it would over a decade ago. We use real examples taken from our own work in this field to illustrate the technological difficulties and challenges that are entailed in meeting end-user requirements for information gathering systems. Reliability and productivity are key concerns and influence the design choices for system hardware and software. We conclude with a discussion of long-term challenges for WSN technology in environmental monitoring and outline our vision of the future.

C. Noise Pollution using WSN

Noise pollution is a big challenge in today's scenario. As the negativity of environmental pollution, affects the health of people & the quality of their life. The pollutants level is increasing day by day, due to which human's life becomes haphazard. Wireless sensor networks provide a promising technology to collect noise pollution readings.

Shikha aggarwal et al. [29] gives the definition of noise i.e. the unwanted or unbearable or harmful outdoor sound which is created by human activities through either by loud-speaking, by vehicles (road traffic) or from industry activities. It gives the various reasons behind the environmental pollution that clearly affects the health of people & the quality of their life. They also gave the reasons due to which animals are affected by the noise pollution. In this paper, they make use of the mobile phones with WSN within the network for noise pollution control because Wireless sensor networks with mobile phones monitor system has high energy efficiency, high tolerance, more security & ease of implementation because multiple sensor nodes collect high volume of data. They also gave the architecture to monitor the noise pollution. The mobiles phones which run their applications either by CPU connectivity or directly attach with internet, stores the output & that data which used to predict the noise level at particular position. This architecture may help in many research problems & may develop a new strategy to gain knowledge.

D. A. Bies et al. [31] gave the applications of wireless sensors to monitor the various environmental activities like air pollution, noise level, water level, greenhouse monitoring, agriculture monitor etc. They discuss how Wireless sensor networks can be used to control the noise pollution in the surrounding environment i.e. with the help of various sensor nodes we can measure noise pollution levels in urban areas i.e. Then they give some of the advantages of using WSN to control the noise pollution i.e.

Silvia Santini et al. [32] provided qualitative considerations and experimental outcome for the estimation of noise pollution in urban areas to demonstrate the viability of WSN to be used in this situation. They presented a prototype for the compilation and arrangement of noise pollution statistics based on the Tmote prototyping platform and gave tiny LAB which facilitates real-time acquisition, processing and visualization of facts gathered in WSN. They also measured the noise pollution level by different methods.

Rajib Kumar Rana et al. [33] explained that noise map can provide useful information to control noise pollution. They proposed a people-centric noise collection system called the Ear-Phone. Due to the voluntary participation of people, the number and location of samples cannot be guaranteed. They proposed and studied two methods, based on compressive sensing, to reconstruct the missing samples.

Luca Filipponi et al. [34] evaluated the energy utilization performance of the CTP and DMAC protocols to choose the most appropriate data gathering protocol for the species noise observing scenario. Their outcome proved that CTP gives the improved performances trade-off for noise observing scenario.

III. CONCLUSIONS AND FINDINGS

Wireless sensor networks have a variety of applications as they are used in many environment and habitat monitoring and health care applications.

These wireless sensor network have the ability to withstand the harsh environmental conditions as they are easy to use and handle. They also require unattended operation. They can also cope with the node failures. The 802.15.4 based Zig Bee protocol was specially designed for short range and low data rate wireless sensor networks (WSN). The first operating system specifically designed for wireless sensor networks was TinyOS. TinyOS is based on an event driven programming model instead of multithreading.
Due to the power consumption constraint in WSN, data aggregation can be used in order to tackle this challenge.

Using WSN for environmental monitoring and pollution control is advantageous as it's a more effective way of collecting data as the sensor nodes are light in weight, easy to install, low power and low cost. They can store a limited source of energy and have no hassle of cables and has mobility. Hence the flexibility, fault tolerance, high sensing fidelity, low power, low

cost and rapid deployment characteristics of wireless sensor networks create many new and exciting application areas for remote sensing.

Due to resource constraints, WSN has some disadvantages also. They have very insufficient speed of communication. Wireless network is less secure because hacker's laptop can act as Access Point. It is more complex to configure than wired network. It is also affected by surrounding like microwave oven. It gets distracted by various elements like Blue-tooth. It does not make sensing quantities in buildings easier. It does not allow us to do more than can be done with a wired system.

But in future, we can gather information more easily, with less improper data, save power consumption & also try to reduce the pollution at effected places. Due to their wide range of applications, Sensor networks will become an integral part of our lives in the near future.

One of the most important constraints on sensor nodes is the low battery power. Sensor nodes carry limited, generally irreplaceable power sources. However, realization of sensor networks needs to satisfy the other constraints introduced by factors such as fault tolerance or reliability, scalability, cost, hardware and topology change. But wireless sensor networking has a bright future in the field of computer networking because we can solve the monitoring problems at an advanced level in the future with the help of such technology of networking.

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