Wireless Sensor Networks for Environmental Monitoring

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***Abstract* - The paper is concerned with the applications of Wireless Sensor Network (WSN) technology for large scale and long duration environmental monitoring. We illustrate here the technological difficulties and challenges that have been encountered in meeting end-users requirements for information gathering. The main aim is to provide greater reliability and productivity to influence the design choices of system hardware and software. WSN technology can be used for various large scale monitoring purposes, providing sensor measurements at high resolution. This technology, therefore, provides various information regarding different monitoring applications such as forests, waterways, buildings, security, agriculture, battlefield etc. Wireless Sensor Networks (WSNs) can also perform operations such as event detection, aggregation, sensing and actuation. We conclude with the discussion of long-term environmental monitoring using WSN technology. Considering future challenges and opportunities our objective is to provide the applications of WSN technology in the field of environmental and agricultural monitoring.**

***Index Terms* – Environmental Monitoring; Wireless Sensor Networks (WSNs)**

I. INTRODUCTION

Wireless Sensor Network (WSN) is an instrument for gathering information about the natural world. WSN technology introduced a low-cost, low-power featured hardware consisting of rich microcontrollers, storage memory, power supply, single-chip radio transceivers, one or more sensors and in some cases an actuator. Environmental monitoring needs some technical requirements such as high level of system integration, performance, reliability, productivity, accuracy, robustness, flexibility etc.

System integration means creating an end-to-end system that delivers data to an interested user. Performance and reliability of a node refers to its power source, radio links, overlying protocols, and reliability of the application and operating system software. Lack of performance leads to gaps in the data record, negating the claim about high temporal precision, and incorrect data lead to a lack of trust and confidence in the system [1]. The network has to perform simple and predictable operations, to prevent unexpected crashes. Accuracy and calibration of the system are also of the key concerns. Batteries must be able to power the weather stations during the whole deployment because the radio transceiver is a massive energy consumer. Robustness relates to the network that must account for a lot of issues such as poor radio connectivity or hardware failures. We must be able to quickly add, move, or remove stations at any time depending on the needs of the applications. Human maintenance should be avoided, first, because end users may not have networking knowledge, second, because areas of interest are most often remote. And also we need to lead an emphasis over the cost and productivity of the system [3].

II. WSN ENVIRONMENTAL MONITORING

Environmental monitoring applications can be broadly categorized into indoor and outdoor monitoring. Indoor monitoring applications typically include buildings and offices monitoring. These applications involve sensing temperature, light, humidity, and air quality. Other important indoor applications may include fire and civil structures deformations detection. Outdoor monitoring applications include chemical hazardous detection, habitat monitoring, traffic monitoring, earthquake detection, volcano eruption, flooding detection and weather forecasting. Sensor nodes also have found their applicability in agriculture. Soil moisture and temperature monitoring is one of the most important application of WSNs in agriculture. Only outdoor environmental monitoring will be considered in this work.

The WSN architecture consists of a Reduced Instruction Set Computer (RISC) microcontroller with a small program and data memory. An external flash memory can be used to provide secondary storage. Two approaches have been adopted for the design of sensing equipment. The first approach uses a sensing board that can be attached to the main microcontroller board through an expansion bus. Usually, more than one can be attached. Other boards only have I/O (input-output) connectors and can be used to connect custom sensor to the main board. In the second approach, the main board also includes the sensing devices. The sensing devices are soldered or can be mounted if needed [2].

Here, we have used the Atmega 128 processor, with 128 KB flash memory, 4 KB RAM, and a stream-based Nordic nRF903 radio transceiver of 433 MHz, providing 72 Kb/s channel and a range of 500m using quarter-wave antenna. The board includes power supply, solar charging circuit, and sensing for on-board temperature, battery voltage, and charging current [1]. Battery, solar cell, serial, and analog and digital transducers could be connected using just a screwdriver- no expansion board was required. The BMAC protocol is used here and TinyOS operating system is used which is the most used open source and freeware WSN operating systems. In addition the sensor nodes are provided with the cameras attached to, it to capture the images of the key locations. This deployment had raised new challenges to routing and network topology.

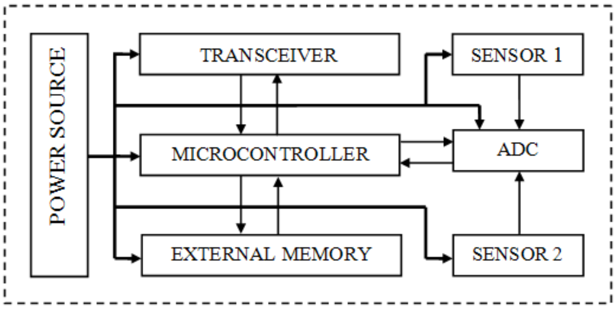

Fig.1 Wireless Sensor Network Architecture

III. APPLICATIONS

In this paper, we discuss the wireless sensor network applications that have been introduced over past six years, the technical challenges they faced and what we have learned from them. These applications follow a common theme: understanding the natural and agricultural environments. This includes monitoring of farms and rain forests, cattle monitoring, agricultural monitoring, water quality monitoring, volcanic eruptions and earth-quake monitoring etc. Our design choices and technologies were made in accordance to meet the different challenges presented by each application.

A. Cattle Monitoring

We organized a network for research at a farm over 500 km from our lab. The first phase of our project covers the positions of cattle over time, and soil moisture at different points in the farm. Soil moisture measurement shows how quickly the pasture will grow and hence how many animals required per unit area. The information from static and mobile nodes are conveyed to the base station and then over the internet to a remote server. The cameras that attached to the sensor nodes periodically capture the images of key locations at the farm. The Fleck nodes were built into collars that were worn by the cattle and these nodes was specialized for animal tracking applications [1].

B. Ground Water Quality Monitoring

For this purpose, we developed a relatively small network, located 2000 km from our lab. Its purpose was to monitor the salinity, water level, and water extraction rate at a number of bores. This is a coastal region where over extraction of water leads to saltwater intrusion into the aquifer [1].

C. Lake Water Quality Monitoring

The purpose of our project was to measure vertical temperature profile at multiple points on a large water storage that provides most of the drinking water for the city. The data, from a string of temperature transducers at depths from 1 to 6 m at 1-m intervals, provide information about water mixing within the lake which can be used to predict the development of algal blooms. Low-power wireless communications over water proved to be a challenge due to multipath as radio waves reflected from the water surface destructively interfere with waves traveling directly. Interfacing a robotic boat to the static sensor nodes was another challenge. The network comprises floating sensor nodes and a custom expansion board for the one-wire temperature transducer string. The node is mounted on an anchored float, along with a solar cell and a high-gain whip antenna. The most novel element in this network is a solar-powered robotic boat. Navigation is by GPS and depth sounder, and a scanning laser range-finder mounted high and looking forward detects obstacles [1].

D. Rainforest Monitoring

The major initiative is to provide reliable, long term monitoring of rainforest ecosystems and also monitoring the restoration of biodiversity. The first phase of the project concerned with the long-term, low-power WSNs in rainforest environment. As the solar energy was very limited, we had to first quantify the performance of current WSN technology, in order to develop the network and energy management protocols required for robust and reliable performance of long-term rainforest networks. We implemented a low-power MAC protocol, to help meet the power budget. The nodes used the Fleck boards and environmental housing as shown in Fig. 2. A custom expansion board was built to interface to the many transducers: wind speed and direction, leaf wetness, soil moisture, temperature, and relative humidity [1].

Fig.2 Wireless sensor network at the Springbrook.

E. Volcano Monitoring

A different type of extreme environment is targeted in the volcano monitoring system. In this application WSNs are equipped with low-frequency acoustic sensors to monitor volcanic activity. While traditional systems involved local storage of data, which thus required a manual collection of the sampled data for further processing, the WSN-based system allows real-time monitoring of the activity over wireless links. In addition to the continuous monitoring of the volcanic activity, the researchers implemented an event-detection mechanism to reduce the amount of data which had to be communicated and processed.

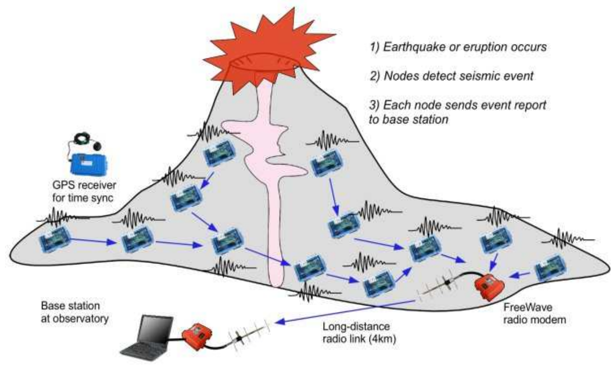

Fig.3 Wireless Sensor Networks for Volcano Monitoring

IV. CHALLENGES FOR ENVIRONMENTAL WIRELESS SENSOR NETWORKS

Although, extensive efforts have been done, there are still some challenges that need to be addressed. Power- management is essential for long-term operation, especially when it is needed to monitoring remote and hostile environments. In terms of scalability, a wireless sensor network can accommodate thousands of nodes. Systems installed on isolated locations cannot be visited regularly, so a remote access standard protocol is necessary to operate, to manage, to reprogramming and to configure the WSN, regardless of the manufacturer. The WSN need to become easier to install, maintain and understand. The storage capacity and redundancy can be increased by adding nodes to the system. Increasing the storage nodes and configuring them to capture overlapping areas of the sensor nodes ensures that there are multiple copies of the data, thus providing redundancy in case some of the storage nodes fail. Reducing the size is essential for many applications. Battery size and radio power requirements play an important role in size reduction. Producing cheaper, reliable, and disposable sensor platforms is also a big challenge [2].

V. CONCLUSIONS AND FUTURE WORK

In this research work, a survey on Environmental Monitoring using Wireless Sensor Networks and their technologies and standards was carried out. Some of the most relevant environmental monitoring projects with real deployments were analyzed and the conclusions used to identify the challenges that need to be addressed [2].

Wireless sensor networks continue to emerge as a technology that will transform the way we measure, understand and manage the natural environment. For the first time, data of different types and places can be merged together and accessed from anywhere. Some significant progress has been made over the last few years in order to bridge the gap between theoretical developments and real deployments, although available design methodologies and solutions are still relatively immature. As a consequence, widespread use of WSNs for environmental proposes is not yet a reality.

Future work in WSN energy management should include further investigation into node platforms, the balancing of unequal energy distributions and long-term behavioral studies of systems in real-world deployments. Additionally, the problem of unequally distributed energy availability should be addressed. Finally, long-term studies of systems at the deployment stage might provide data, relating environmental conditions to system behavior. Energy-efficient self-monitoring mechanisms are necessary in order to allow these studies without unnecessarily influencing the system lifetime.

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