Wireless Sensor Networks in Nature

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ABSTRACT

Wireless sensor networks are now a day's becoming an active research and application area. They have found applications in solving various engineering problems in past decade. This is further intensified by advancements in the technology such as decrease in size, cost, power usage of micro-controller and transceiver for communication. In this paper, basic concepts of wireless sensor networks are discussed along with their application in solving various problems especially related to nature. As a result wireless sensor networks are found to be helpful for mankind in its own way. Precise irrigation, agriculture, habitat monitoring, earthquake and fire monitoring in forests are few applications of wireless sensor networks in nature that have been discussed in this paper.

1. Introduction
What are Wireless Sensor Networks?

Wireless sensor network (WSN) consists of distributed, wireless enabled devices that have the ability to handle a variety of electronic sensors. Each node of the WSN called a mote and is accompanied with one or more sensors in addition to a microcontroller, wireless transceiver, and energy source. The microcontroller of the mote uses the electronic sensors along with the transceiver to build up a system with the ability to convey small amounts of important information with minimum amount of power consumption. The most important and attractive feature of a WSN is its self-sufficiency. The motes of a WSN automatically initialize communication with other motes which are in range and leads to creation of an ad hoc network with mesh topology. This ultimately leads to data forwarding to and from the gateway node. As a result, costly and cumbersome wiring is not required. It means, modes could be deployed in almost any location in a rapid manner. Large variety of sensors is available to be used in various kinds of WSN. It includes temperature, humidity and volatile compound detection sensor that help in monitoring of different environments and different applications.

2. Why Sensor Networks?
WSN are found to be advantageous over traditional wired systems as well as traditional sensing technology. The main reason behind this fame re

- Their embedded construction and distributed nature.
- Low Cost.
- Low-power consumption
- Inexpensive microcontrollers and transceiver.

Due to these reasons, WSN observes variety of commercial or military applications. Due to the low cost of motes, large number of nodes could be deployed and along with this, loss of nodes could also be bearded. In one of the applications of WSN, to detect forest fire, sensor nodes are dropped from a plane to detect fire in a forest. Due to the low cost of the sensors if some nodes get damaged or lost, the system can work without loss of its capability and application

Another advantage of WSN over traditional wireless sensing technology is due to the underlying topology they have. Due to mesh networking scheme and inherit nature of RF communication; transmission of data from one point to another among nodes in a mesh based topology network takes less energy (Zhao & Guibas, 2004).

Two main standard technologies used in WSN are ZigBee and Bluetooth. Both of these technologies operate within the Industrial Scientific and Medical (ISM) band of 2.4 GHz. This band leads to license-free operations and huge spectrum allocation for compatibility. Further, it is also possible to create a WSN using Wi-Fi (IEEE 802.11) which has high power consumption.

WSN has a better coverage than centralized traditional sensing technology. With increase in number of motes to be deployed in a particular application there is a decrease in the overall signal-to-noise ratio of the system and hence increased the amount of usable data.

Due to the advantages of WSN and technologies followed, they have observed wide variety of applications. In this paper, applications of WSN in nature have been discussed.

3. Applications of WSN in Nature
Precision irrigation
Researchers have (Damas, Prados, Gómez, & Olivares, 2001) developed and tested a distributed, remotely controlled, automatic irrigation system that controls an irrigated area of 1500 ha in Spain. They divided the area into seven sub-regions. Each sub-region was observed and controlled by a control sector. All the seven control sectors ultimately communicated to each other with a central control through a WLAN network. In this way, after using WSN, field tests showed saving of 30–60% in water usage. In an another work (Evans & Bergman, 2003), precise irrigation using combined on-site weather data, remotely sensed data and grower preferences has been studied.

Automated Fertilizer Application
For effective fertilization, researchers (Cugati, Miller, & Schueller, 2003) developed an automated fertilizer applicator for tree crops. In this WSN system, there is an input module for GPS and real-time sensor data acquisition, a decision module for calculating the optimal quantity for a fertilizer. There is an associated an output module which is used to regulate the fertilizer application rate. Required data communications among the modules were established using a Bluetooth network.

Supplying data to farmers
In order to convey information about pest and weather forecasts to the farmers, a web server has been developed by researchers (Jensen, Boll, Thysen, & Pathak, 2000).

Greenhouse control
Another powerful application of WSN is their use in controlling greenhouses (Alves-Serodio, Monteiro, & Couto, 1998). The distributed data acquisition and control system for managing a set of greenhouses has been developed.

In another work (Morais, et al., 1996), a wireless data acquisition network to collect outdoor and indoor climate data for greenhouses has been developed in Portugal. Several solar-powered

data acquisition stations (SPWAS) were installed indoor and outdoor to measure and monitor the climate data. SPWAS and a base station which controls the SPWASs has been connected using RF communication.

In another work (Liu & Ying, 2003), a greenhouse monitoring and control system has been developed using the Bluetooth technology. This system collects environment data from a sensor network in a greenhouse and transmitted the data to a central control system.

Further, some other researchers (Mizunuma, Katoh, & Hata, 2003) deployed a network of sensors in farm field and greenhouse to monitor growth of plants.

Animal-feeding facilities
In order to maintain good animal health, monitoring of climate-related variables within an animal house is helpful. One of the application of WSN is (Pessel & Denzer, 2003) development of a portable, mobile instrument which is used to measure temperature, humidity, noise and ammonia content in the air within the animal shelter and transferred the data wirelessly to a computer through an infrared data link. It is found to be particularly useful in case of horse monitoring. This is because, the quality of indoor environment of a horse-riding stadium is very important to the horses as well as the riders. So, in order to observe temperature and humidity, many motes were used (Wheeler, Zajaczkowski, & Diehl, 2003).

Animal identification and health monitoring
In order to monitor health of cattle, a remote health-monitoring system (Nagl, et al., 2003) has been developed by using various sensors, a GPS unit, a pulse oximeter, a core body temperature sensor, an electronic belt, a respiration transducer and a temperature transducer. This system communicates with a base station via Bluetooth telemetry.

In another work, an intelligent animal management system has been developed (Mayer, Taylor, & Campus, 2003). Each animal is fed with a mote, which is used to provide accurate measurements of the location and health-related information of the animal wirelessly.

In another experiment (Brown-Brandt, et al., 2003), in order to measure core body temperature in poultry, beef and dairy cattle a short-range telemetry system has been used. Temperature transmitters were implanted into the body of animals.

Some researchers (Kononoff, Lehman, & Heinrichs, 2002) used a WSN to record the chewing and ruminating behaviours. This study helps to analyse milk giving capability of cows.

In another work ((Butler, Corke, Peterson, & Rus, 2004), a moving virtual fence has been developed for herding cows. Each animal in the herd is allocated a smart collar consisting of a GPS, a PDA, a radio unit (WLAN) and a sound amplifier. The animal's location could be evaluated using the GPS and is verified through a measurement of closeness of the cow relative to the fence boundary. In animal becomes very near to fence, a sound occurs which guides the animal away from the fence.

Assessment of animal welfare can also be determined by using WSN which enables to make the right decision based on real-time scenario. Some researchers enlightened the problem of online monitoring of cows' presence and pasture time in an extended area covered by a strip of new grass using wireless sensor networks (Nadimi, Søgaard, & Bak, 2008)

Precision Livestock
Modern animal welfare has been changed in recent years due to

the use of precision tools. Recent research has opened doors to use preventive diagnostics as inputs to develop decision-making software in several areas to predict events.

Quality of indoor environment is very important for animal health and welfare which ultimately impacts productivity and quality. Over-critical exposure of the animals to ammonia must be avoided using ventilation. It causes stress, pour health and reduced productivity of animal. Cai *et al*. presented a wireless, remote query ammonia sensor that can track both low and high concentrations of ammonia (Cai, Jain, & Grimes, 2001)

As in order to save energy, ventilation and heating must be minimize keeping temperatures at an adequate level. Cugnasca *et al*. Proposed WSN to monitor environmental variables in an animal housing facility. The motes could be moved to determine different profiles of temperature, humidity and luminosity

A wireless data acquisition system has been proposed to monitor temperature variations in swine barns (Darr & Zhao, 2008).

It is observed that there is an increasing demand of traceability in the food chain. We need to have information from the raw material to the sale of goods. With decrease in cost of WSN, opportunity to track and trace not only large and expensive products, but small and cheap ones has increased. It created a new generation of intelligence products (Meyer, Främling, & Holmström, 2009). Furthermore, the information gathered by the WSN can be linked with a other system in each step (Meyer, et al., 2009)

Earthquake and Fire prediction
Other indoor applications can be mitigation of fire and earthquake damage. Fire and smoke detection could be seen easily these days and nowadays in most countries it is compulsory by relevant laws. The existence, also, of light-signals indicating exits is, most of the time, mandatory in big buildings. Nevertheless, these two approaches do not cooperate in case of a fire. The usage of sensor networks in buildings can lead to the combination of these two systems. WSN could be used to guide the rapt residents through the safest route to save their lives.

WSN could be helpful before and after an earthquake. It has been observed by the civil engineering research that the inspection of structures based on vibrations is possible (Rytter & Kirkegaard, 1994). So, it is possible to incorporate wireless motes inside cement blocks during construction, or their attachment to structural units makes sense. The footage of vibrations of the building or bridge during its life can function as the identity of the building, (Arampatzis, Lygeros, & Manesis, 2005). The inspection of a building after an earthquake, by the use of this system makes it to be done faster and the determination for any repairs can be more precise. A team of researchers (U.C. Berkeley's Richmond Field Station seismic research laboratory) has conducted experiments with 15 motes which were further installed in a three-story model apartment of wood framing. This model has been placed over a "shake table" that simulates earthquakes (Arampatzis, et al., 2005).

In the woods
Another application is monitoring of the micro-climate in the woods. On order to monitor the forest ecosystems, in-depth knowledge about the physical, chemical and biological status of soil around the root of tree makes major contribution. WSN helps in effective monitoring of the forests for their welfare.

Fire detection
Another application of WSN is forest fire detection and prevention. Temperature sensors are used to collect data especially for fire incidents. Large Scale WSN-based Forest Fire Sensing and Management System use one or two such sensors on every sensor board to enhance trustworthiness. More sensors could be added

in the sensing area but it increases its cost. As an example, it would be better to deploy 400-800 sensors to cover one square kilometre and a sensor every 30-50 meters. The possible topologies include star and grid network topologies. The star topology can be related to a cellular WSN. In this way, the deployment of sensors in forest leads to its real time monitoring. The network status can be illustratable on Google maps and the alarms may be visual, audio, mobile call, message, or any other event that can be activated by an alarm. (Swayne, Yang, Rizzoli, & Filatova) .

Habitat monitoring applications
Habitat monitoring is an area which has large scope of work if WSN is used to monitor it. It could be used for habitat sensing for bio-complexity mapping.

UCB Mica mote
In an application of WSN, UC Berkeley Mica mote are deployed which are made of Atmel Atmega 103 microcontroller running at 4MHz, 916MHz radio which is omni-directional and thus perform bidirectional communication at 40kbps.The Mica Weather Board, attached to the processor board by using the 51 pin extension connector is coupled with temperature, photo-resistor, pressure measuring device, humidity and thermopile sensors. In order to preserve energy, some new designs are coupled with an analog to digital convertor and an I2C 8x8 power switch etc.

Great Duck Island
Great Duck Island (GDI) is located at (44.09N, 68.15W) and is a 237 acre island located 15 km south of Mount Desert Island, Maine. The Nature Conservancy department, the State of Maine, and the College of the Atlantic (COA) jointly work for the conservation of this island. This island contains approximately 5000 pairs of Leach's Storm Petrels who have made nests in three major habitat types spruce forest, meadow, and mixed forest edge. COA is conducting various field research programs on several remote islands. They are providing well established on-site infrastructure and logistical support. Researchers at COA are conducting seabird research on the Leach's Storm Petrel on Great Duck Island . They are working on following aspects:

- To study the usage pattern of nesting holes over the 24-72 hour cycle when one or both members of a breeding pair have been exchanging keep warm duties with feeding at sea.
- To study the environmental changes that occurs inside and on the surface of the nest in the course of the seven month breeding season (April-October).

- To study the distinction across petrel's breeding locations.
- To study the optimal conditions that could be beneficial for breeding, incubation, and hatching.
- To study the differences in the micro-environments among the areas that contain large numbers of nesting petrels and those areas that do not.

One sensor node is inserted per burrow and is used for data sampling. Further, the sensors should be small enough in size so that the sensor and petrel can stay without interfering with the petrel's activities and does not obstruct its passage. Burrows are distributed around the island that may be hundreds of meters from locations that can support network and power infrastructure. In a forest, the environmental conditions vary widely. It is different depending on vegetation type, density, exposure, and location. Further, the humidity at a given location in the forest varies with vegetation type; an area forested. As an example, area around trees has higher humidity due to moisture retained by trees whereas an open field have lower humidity due to direct sunlight and evaporation. Using sensors in WSN, monitoring the environment in and above the burrow can help biologists to examine differences.

The petrel cycle lasts approximately 5 months. So, the deployed WSN must efficiently manage its power consumption in all five months. In order to sufficiently monitor the habitat, it must be observed on the spatial scale of the organism at a pace that match environmental changes and behaviour of the organism. Using WSN helps to investigate large size of the area and large number of sampling locations. It increases the data at resolutions and densities not possible using traditional methods. Actually, sensors should collect data that has a rate in equation with or larger than changing environmental conditions which the organism experiences (5-10 times per hour). If traditional data collection systems has been used to calculate the average, minimum, and maximum over 24 hour periods the traditional methodology is not able to depict the working efficiently (Polastre, Szewczyk, Mainwaring, Culler, & Anderson, 2004).

4. Conclusion
Wireless Sensor Networks have been found to be very famous these days in solving various engineering problems. WSN are becoming popular due to their embedded construction and distributed nature, low cost, low-power consumption, inexpensive microcontrollers and transceiver. They are found to be advantageous over traditional wired networks. In this paper, applications of WSN have been discussed especially related to nature.

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