WIRELESS SENSOR NETWORK FOR VOLCANO ENVIRONMENTS

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Abstract: Recent technological advances in the areas of microcontroller architectures, sensors and low power wireless transceivers have made it possible to deploy large wireless sensors. There have been numerous research results in the area of power efficiency in the adhoc and wireless sensor networks. In this paper, we propose a new algorithm, which is used to monitor the events about anomalous behaviors of the volcanic edifice. This model uses the sensor devices to monitor the volcano with the help of support node to detect early hazards. It has consumed fewer amounts of the resources while transmitting the data packets from the regular node to the base station. It is compared with the existing algorithms and has shown better results in terms of power consumption and control message packets over the network.

Keywords: Wireless sensor network, sensor, base station, support node, regular node.

1. INTRODUCTION

Wireless Sensor Network(WSN) is a mobile adhoc network. The WSN consists of the sensor devices to monitoring the physical quantities at different places such as vibration, pressure, motion, temperature and sound[1]. Usually, these sensor devices are very small and inexpensive. It can be easily installed and deployable in a large numbers over the network[2]. In addition to this, each node in the WSN is typically equipped with radio transceiver, microcontroller and battery. The size of the sensor varies from the application to application. The cost of sensors is very low, depends on the size and complexity[3].

In a large scale of networking environment, one of the most important networking factors is self-organizing capability and interoperating capability between the sensor nodes. Many studies have shown that there are varieties of sensors used to gather sensing information efficiently. The node transfers the data to the sink node. Thousands of sensor nodes are expected to auto configure and operate for extended periods of time without human intervention. In many systems, it can be expensive or impossible to replace the batteries. In the WSN, the power management models play a vital role in extending the lifetimes of node and network.

This paper describes how to reduce the consumption of power in the WSN for monitoring the volcano. The rest of paper is arranged as follow. Section 2 presents some of the existing models. Proposed work is discussed in section 3. Section 4 presents statistical analysis of the proposed model. The simulation results are discussed in section 5. Section 6 presents the conclusions and future research work.

2. EXISTING WORK

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There are number of groups looking forward to design an efficient routing algorithm for WSNs to reduce the power consumption. The power consumption of a system depends on collection of the information, communication and maintenance[3]. There are several types of sensors used to monitor the rainfall and to measure water levels and weather information. These sensors are used to send the sensing information to Base Station(BS). In general, the agriculture officers are used underground sensors to monitor the soil conditions, like mineral content and water level. The WSN is also used to monitor integrity of below ground infrastructures such as landslide, earthquake and plumbing[4-5].

Flood detection system is an intelligent model, which is used in the America to measure floodwater level[6]-[7]. Levelly approach[8] is used to monitor the urban areas for collecting data in the street and sidewalk. Low- Energy- Adaptive Clustering- Hierarchy(LEACH) algorithm is a cluster based protocol and is used to minimize the energy dissipation in the WSN[9]-[10]. It randomly selects a cluster-head to route the data packets. The energy dissipation in the communication with BS is spread to all the sensor nodes. The function of LEACH is separated into two-phases such as set-up and steady. The duration of the steady phase is longer than the set-up phase in order to minimize the communication overhead.

Hierarchical protocol is used a cluster approach to perform the data aggregation and fusion at cluster-head[11]. It reduced the communication overhead efficiently over the network. Local-greedy algorithm is presented in[12] to select the next most informative node based on the utility and entropy respectively. The problem, however, is that, if the optimal path is always chosen, then the nodes with the path will deplete the energy quickly than others, which greatly affects the network lifetime.

In Geoffrey model, it has attempted to understand how the WSN is used to monitor the volcano with low-frequency acoustic sensors[14]. Here, we use a flat based routing model to send the sensing data to the BS. Here, each node has played an important role. All the sensors have worked together to perform all tasks. However, this model is not good choice for a large number of sensors over the network.

3. PROPOSED MODEL

The focus of this work is reduced the consumption of power over the network. The proposed model has two types of nodes such as support and regular as shown in the figure 1. The regular node transmits the data packets with the help of support node. The regular nodes only communicate with the support nodes to transmit/receive data. The support node covers more graphical area(250 m) than that of regular node(100 m). The support nodes work as backbone nodes to relay packets to the base station. The support node has more battery power(4000 mAh) to transmit the data packets form the source to BS while regular node does not have sufficient power to transmit the data(it has powered with 800 mAh).

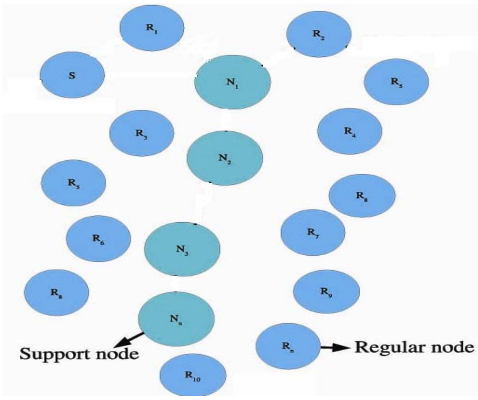

Figure 1. Type of mobile nodes.

3.1. Sensor Node

The infrasonic sensor is able to detect the volcano before the eruption occurs. Figure 2 shows the wireless infrasonic sensor. It picks up the signals and forwards to the BS. The infrasonic sensor contains the amplifier, Omni-directional antenna and microphone.

Figure 2. Wireless infrasonic sensor.

The proposed model uses the Mica2 mote devices. The Mica2 mote device has atmega128 embedded processor running at 4M Hz, 128 KB flash memory, 8-channels of A-to-D convert, 48digital I/O, UART and SPI serial interface. The structure of sensor is shown in the figure 3. The estimated power consumption of each sensor is shown in Table 2.

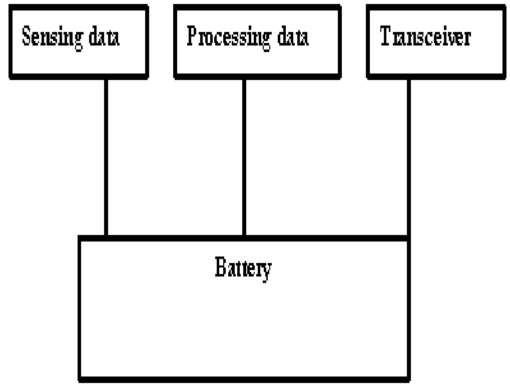

Figure 3. Structure of sensor node.

The proposed model uses both the seismic and infrasonic signals to monitor the volcano. The seismometer provides the data about seismic waves. The proposed model is used in two cases namely, continuous-data-collection and distributed event detections. The continuous-data-collection is used to transmit the sensing information from one node to another continuously. The distributed-event-detection is used to transmit the data in a distributed manner.

Table 2. Power consumption at sensor.

Operation	Power in mV
Sensing data	0.6
CPU	1.1
Transmitting data	16
Receiving data	13
Listening	13

3.2. Communication System

The proposed model uses IEEE 802.15.4 to transmit the data packets from one place to another. The IEEE 802.15.4 is a wireless multi-hop protocol and provides low-bit-rate, low-cost, less-energy-consumption. The model makes uses of MAC protocol, 900MHz frequency band and uses hierarchical routing. We have used support node to perform the data aggregation and fusion. The volcanic tomography is used to collect the signals and analyzes the signals at different places. It is produced the internal structure of volcanic edifice. In general, the precision and accuracy of mappings increase as the nodes are added into the network to monitor the events. The sensors are equipped with the regular nodes. The regular node senses the information and transits data to the support node. Then, it transmits to the BS periodically as show in the figure 4. In order to transmit *z*-bit packet for distance *d*, it is required power as:

$$P_T(z,d)= zEl+€_{am}zd^2 \qquad \text{——(1)}$$

and to receive *z*-bit packet, the radio consumes

$$P_R(z)=zEl \qquad \text{——(2)}$$

In equation(1), each regular node sends the sensing information to the BS every 60s. This model uses the shortest path routing algorithm to transmit the data packets. All the regular nodes are placed within the transmission range. The communication between the regular node and support node is followed by carrier sense multiple access protocol. It reduces the collisions and improves the network throughput.

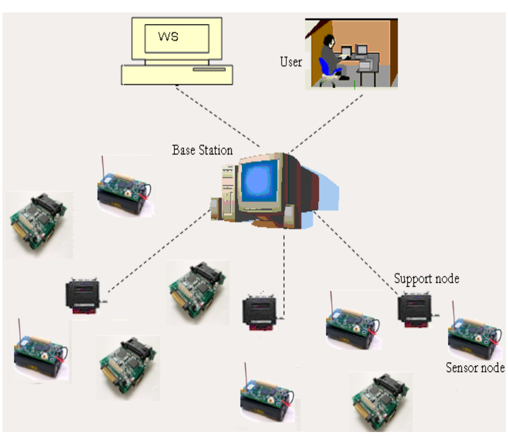

Figure 4. Proposed work.

In equation(2), *El* represents the energy dissipated by the electronics to transmit and receive a *z*-bit of packet. €$_{am}$ represents the energy expended by amplifier at the transmitter for achieving an acceptable bit energy to noise power spectral density ratio at the receiver.

4. STATISTICAL ANALYSIS

In this section, it is presented statistical information about the arrival rate of packets and power. The expected power is calculated as follows:

$$\mathrm{Exp}(P)=P_{current}-R-H_J+\mathrm{Exp}(P_A).F-\mathrm{Exp}(P_{type}\neq J)+\mathrm{Exp}(P_{type}=J).F \qquad \text{——(3)}$$

$P_{current}$ is the current energy, R is the reconfiguration cost, H_j is the cost of running task *j* on the node, $Exp(P_A)$ is the expected cost to run the next task *j* and *F* represents the number of tasks.

$$\mathrm{Exp}(P_{type}=J)=\sum_{I\neq J}^{TT} \frac{N_I}{\sum_{I\neq J}^{TT} N_k} S_I \qquad \text{——(4)}$$

$$\mathrm{Exp}(P_{type}=J)= \frac{N_I}{\sum_{I\neq J}^{TT} N_k} H_I \qquad \text{——(5)}$$

The equations(4) and (5) are used to calculate the power to run on a task. In equation(5), *TT* refers the number of tasks, N_i indicates the number of occurrences for a task *i*, S_i refers power to execute a task *i*. H_i defines the cost to execute a task *i*.

5. SIMULATION RESULTS

The proposed model has considered an area of 1,000 m X1,000 m. This model uses 200 regular and 19 support nodes for simulation work. The support nodes are placed within the network randomly but each node has connectivity with others. The broadcast range of each support node is 250 m and regular node is 100 m. The simulation is carried over period for 48 hours. The infrasonic waves are generated by volcano resulted in explosive events. The model starts measuring the velocities of infrasonic waves and is recorded in a BS. The infrasonic waves are generated in the microphones. It is easy to determine the waves. For transition of a single data packet, it takes t_n*4*32 bytes/s and requires 7.5 Kbps. All the sensor nodes send the samples at 102.4 Hz for continuous-data-collection model. In the distributed-event-detection model, it takes 21ms for forwarding a single data packet and has a buffer size(100 packets). The power consumption of regular node in the continuous-data-collection case is shown in the figure 5.

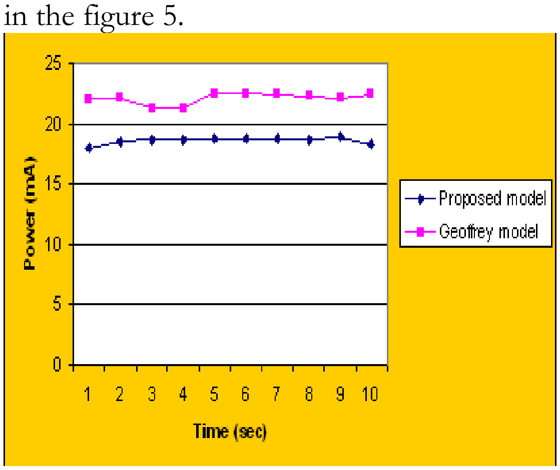

Figure 5. Continuous-data-collection.

The proposed model has shown better results in terms of power consumption as compared to Geoffrey model. The continuous-data-collection is not suitable for a large network due to bandwidth. The power consumption of the regular node in the distributed-event-detection model is shown in the figure 6. Initially, Geoffrey model takes 16mA for 4s whereas in the proposed model, it consumes 11mA. When the time increases, Geoffrey model has consumed more amount of power than the proposed model to send the sensing information to the support node.

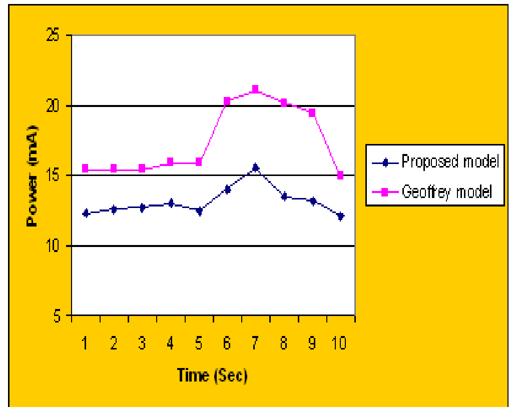

Figure 6. Distributed-event-detection.

Time versus packets is shown in figure 7. Here, the number of control message packets is transmitted by the sensor node during the detection of an event. From the results, it is clearly shown that Geoffrey model has taken more number of control message packets whereas the proposed model takes less control message packets due to support node. In fact, Geoffrey model will relieve the sensor node with heavy load. It is expressed by large buffer occupancy. In the proposed model, the support node does not transmit the data packets to all the nodes over the network.

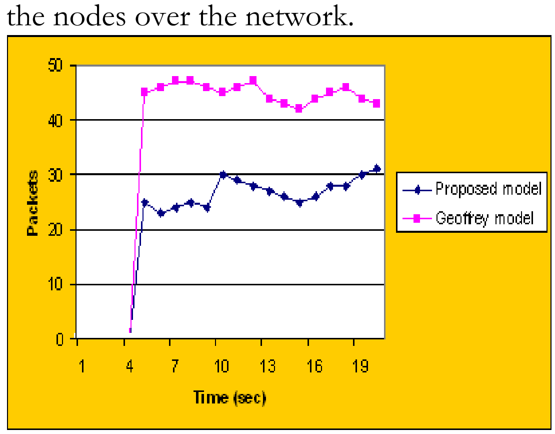

Figure 7. Time versus packets.

5. CONCLUSIONS AND FUTURE RESEARCH WORK

This paper makes use of the sensor devices to find the anomalous behaviors around volcanic edifice. All these sensor nodes give the electrical signal output either in digital or analog. This model has considered with a limited distance for detection of the event. The proposed model has not considered channel interferences and packet loss across the network. The WSN is eventually stabilized. The development of the WSN embedded senor protocol is just started. The scalable power consumption will achieve maximum system lifetime in the most challenging and diverse the environments.

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