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Power Consumption and Maximizing Network Lifetime during Communication of Sensor Node in WSN

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Abstract

The recent advances and development of wireless sensor network is dependent on low-cost, low-power and multifunctional sensor nodes. Sensor Networks are very much data concentric and it is totally depends on the activities of the sensor node. The natural job of sensor node in a network are sensing the network, processing the data and broadcast the communication to other nodes. Generally sensor node performs four basic important activities in the sensor network such as a sensing unit, a processing unit, a transceiver unit and power unit. Since a sensor node may sense many nodes at a time and transmitting, receiving data from those node may forms a queue. A sensor node has to communicate to all other neighbour nodes for data communication i.e. distribution of energy consumption of sensor node is also simultaneously done. This distribution of energy consumption forms a queue. Here in this paper we have discussed and proposed a mathematical queuing model to find an optimal solution to optimize energy consumption of the sensor node and to maximize system life time. Through an extensive simulation results show that the proposed model has good performances in the aspects of energy consumption and efficiency of the system network to prolong the system life time.

Keywords- Sensor Nodes, System Life Time, Power Distribution, WSN.

1. Introduction

Energy is the precious resource of WSN nodes, and the lifetime of WSNs is totally depends on the energy of the sensor node. WSNs are generally deployed in large numbers in different environments such as remote and hostile regions, with ad-hoc communications as key. For this reason the mathematical model,different algorithm and protocols are needed to address the maximize the lifetime of sensor node in WSN. Here in this paper [1] Wireless sensor networks consist of battery-powered nodes that are endowed with a multitude of sensing modalities including multimedia (e.g., video and audio) and scalar data (e.g., temperature, pressure, light, magnetometer, and infrared). The sensor network with a single sink node as base station has been discussed in [2]. The demand for these networks is spurred by numerous

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applications that require *in situ*, unattended, high precision, and real-time observations over a vast area. Although processing design and data computing technology have been significantly improved but advances in battery technology still lag behind, making energy resource the fundamental constraint in wireless sensor networks. For a sensor network having multiple sink nodes, the data traffic generated by any sensor node may be split and sent to multiple different mobile node and BSs. As a result, in [3], [4] there has been active research on exploring optimal flow routing strategies to maximize the lifetime of the mobile node and network. Network lifetime refers to the maximum time that all nodes in the network remain alive until one or more nodes drain up their energy. Most prior efforts assume that the mapping between a sensor node and one (or more) sink node is given *a priori*. For example, for a sensor network having only a single sink node [e.g., a base station (BS)] [5],[6], all the data traffic generated by the sensor nodes will be delivered to this sink node.

1.1. Hardware Analysis of Sensor Node:

Here a simple architecture of a sensor node is given and the components are explained. Since Wireless sensor networks are comprised of a number of distributed sensor nodes which cooperate to monitor the environment. Commercial wireless sensor node are generally composed of a single microcontroller and a number of other components.

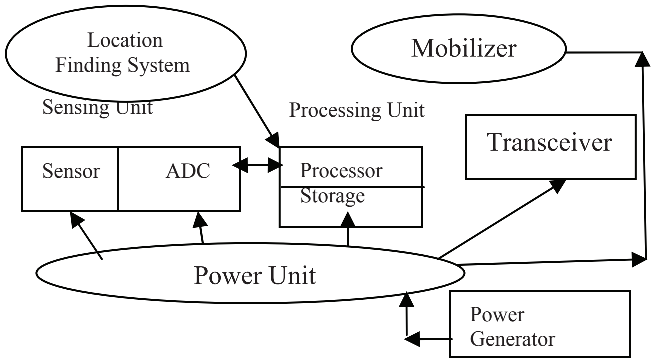

Figure: 1 The Components of a Sensor Node

The controller performs different task such as processes data and controls the functionality of other components in the sensor node. Now the microcontroller is the most common controller. A microcontroller is frequently used in several embedded systems such as sensor nodes because of it is flexibility and low cost to connect to other devices, for of programming, and minimum power consumption. Since the positions of the node are not always fixed in the network and different algorithms are also applied for the communication to the other sensor node in different situation because the topology of sensor network changes very frequently. A sensor node has major four basic components [9], as shown in Figure 1.These components are sensing unit, a processing unit, a transceiver unit, and power unit. Sensors and analog-to-digital converters (ADCs) are two main components of Sensing unit. The analog signals produced by the sensor node are converted to digital signals by ADC and then fed into the processing unit. The processing unit (microcontroller) is associated with a small storage unit which performs the procedures that make the sensor node collaborate with the other nodes. A transceiver unit connects the every node to the sensor network. The transmitter and receiver both are combined into a single device which is known as transceivers. Generally the sensor nodes are consumes power for sensing other node, communicating and data processing. Power is stored in batteries which is both rechargeable and non-rechargeable, are the main source of power supply for sensor nodes. To carry out the assigned tasks mobilizer may be needed to move sensor nodes when it is require.

1.2. Related Work

A distributed position-based network protocol has been described in [7]. This paper explain about minimum energy consumption in mobile wireless networks that support peer-to-peer communications and optimizing the distribution the power consumption between source node and sink node. Given any number of randomly deployed nodes over an area, we illustrate that a simple local optimization scheme executed at each node guarantees strong connectivity of the entire network and attains the global minimum energy solution for stationary networks. Due to its localized nature, this protocol proves to be self-reconfiguring and stays close to the minimum energy solution when applied to mobile networks. This paper [8] explore the energy efficiency aspect of the system design, and discuss its impact on the scalability of the network. Here they made up of a multitude of relatively low mobility, short range, wireless devices, pervasively deployed throughout the environment Then details information about networking and applications of the Wireless Sensor Networks are outlined. Here [9] they include *i*) Top-*Kmax* algorithm, *ii*) maximizing the minimum residual energy algorithm, and *iii*) minimizing the residual energy difference algorithm and propose energy efficient low-complexity algorithms to determine the locations of the base stations. [10] They consider a real-time scenario for mission-critical applications, where the data gathering must be performed within a specified latency constraint. They first propose an offline numerical optimization algorithm. This paper [11] describe the pair-wise optimization of the hareware and MAC layer design is considered to present an optimal scheduling protocol to minimize the energy utilization for data fusion in wireless sensor network, which includes both the transmission energy and the circuit energy consumption. This paper [12] explains if deploying nodes by the density formula are distributed then the ratio of whole energy of sensor nodes to energy consumption speed of sensor nodes in every area can get consistent and hence system lifetime is prolonged. In this paper, we considered a mathematical distribution model for distribution of data communication between source node and sink node with algorithms to increase network lifetime. Several cases have been discussed with numerical simulation of data delivered by the sensor nodes during the deploying in the sensor network field.

1.3. System Mathematical model and Problem definition

The distribution of power supply of a sensor node is also a queuing problem. Let there be an Sensor node which supplies power to 'N' different direction. The different sink needs the signal from the sensor node which are assumed to follow Poisson distribution with parameter λ and the distribution of power supply schedule also follows Poisson distribution with parameter μ .The signal acceptance strategies may follow a queue. Then to find the convenient solution for the system here we have considered n numbers of nodes are there in the queue. If at any time there are 'n' different sink in the queue, then

$$\begin{cases} \lambda_n = (N - n)\lambda \\ \text{and} \\ \mu_n = n\mu \end{cases} \quad \text{for} \quad 0 \le n \le N$$

The probability that (a) there is no sink and (b) there are 'n' sink in the system which are getting signal from the node at time $(t+\Delta t)$ are given by

$$\frac{p_0(t+\Delta t) - p_0(t)}{\Delta t} = -N\lambda\, p_0(t) + \mu\, p_1(t) + \frac{o(\Delta t)}{\Delta t} \quad \text{for} \quad n = 0 \tag{i}$$

When $0 \langle n \langle N$ then

$$\frac{p_n(t+\Delta t) - p_n(t)}{\Delta t} = \lambda_{n-1}\, p_{n-1}(t) - (\lambda_n + \mu_n)\, p_n(t) + \mu_{n+1} p_{n+1}(t) + \frac{o(\Delta t)}{\Delta t} \tag{ii}$$

When $0 \langle n \langle N$ then

$$\lambda_{n-1} = \{N - (n+1)\}\lambda, \quad \lambda_n = (N-n)\lambda, \quad \mu_n = n\mu \quad \text{and} \quad \mu_{n+1} = (n+1)\mu$$

Then (ii) becomes,

$$\frac{p_n(t+\Delta t) - p_n(t)}{\Delta t} = (N-n+1)\lambda\, p_{n-1}(t) - \{(N-n)\lambda + n\mu\} p_n(t) + (n+1)\mu\, p_{n+1}(t) + \frac{o(\Delta t)}{\Delta t} \tag{iii}$$

when $n = N$ then

$\lambda_{n-1} = \{N-(n-1)\}\lambda = \{N-(N-1)\}\lambda$, $\lambda_n = (N-n)\lambda = (N-N)\lambda$, $\mu_n = n\mu = N\mu$ and $\mu_{n+1} = 0$

Then (ii) becomes

$$\frac{p_N(t+\Delta t) - p_N(t)}{\Delta t} = \lambda p_{N-1}(t) - N\mu p_N(t) + \frac{o(\Delta t)}{\Delta t} \quad \text{(iv)}$$

Taking $\Delta t \rightarrow 0$ from equation (i),(ii),(iii),(iv) and simplify we have three steady- state equations of the system .

These three equations give the recurrence formula

$$(N-n)\lambda p_n = (n+1)\mu p_{n+1} \quad \text{for} \quad n = 0,1,2,\ldots N$$

Then we get

$$p_n = \frac{\{N-(n-1)\}}{n}\frac{\lambda}{\mu} p_{n-1} \text{ and } p_N = \left(\frac{\lambda}{\mu}\right)^N p_0$$

On simplifying we get, $p_n = \binom{N}{n}\left(\frac{\lambda}{\lambda+\mu}\right)^n\left(\frac{\mu}{\mu+\lambda}\right)^{N-n}$ which is a Binomial Distribution.

This model indicates that the distribution of energy from a sensor node to 'N' different sink can be communicated 'n' times to the sensor node.

1.4. Mode Calculations of Power Model

Different Strategies are discussed here to find the maximum Probability of the Power Distribution Model. Mode is the value of 'n' for which p_n is maximum.

Now Consider, $\frac{p_n}{p_{n-1}} = 1 + \frac{\{(N+1)p-n\}}{nq}$ where $p = \frac{\lambda}{\lambda+\mu}$ and $q = \frac{\mu}{\lambda+\mu}$

Case 1: When $(N+1)p$ is not an integer. Let $(N+1)p = m + f$ where m is an integer and f is a fractional such that $0 < f < 1$ Therefore

$$\frac{p_n}{p_{n-1}} = 1 + \frac{\{m+f-n\}}{nq} > 1 \quad \text{for} \quad n = 1,2,\ldots m$$

$$\text{and} \quad \frac{p_n}{p_{n-1}} < 1 \quad \text{for} \quad n = m+1, m+2, \ldots\ldots \ldots N$$

Thus the unique modal value for Binomial Distribution is'm', the integral part of $(N+1)p$.

Case 2: When $(N+1)p$ is an integer then

$$\frac{p_n}{p_{n-1}} > 1 \quad \text{for} \quad n = 1,2,\ldots m-1$$

$$\frac{p_n}{p_{n-1}} = 1 \quad \text{for} \quad n = m$$

$$\text{and} \quad \frac{p_n}{p_{n-1}} < 1 \quad \text{for} \quad n = m+1, m+2, \ldots\ldots \ldots N$$

Here it is verified that in this case the Binomial Distribution is bimodal and the modal values are 'm' and '(m-1)'.

1.5. Simulation and Result

Here simulation of the model analyzed and corresponding graph of system life time has been shown.

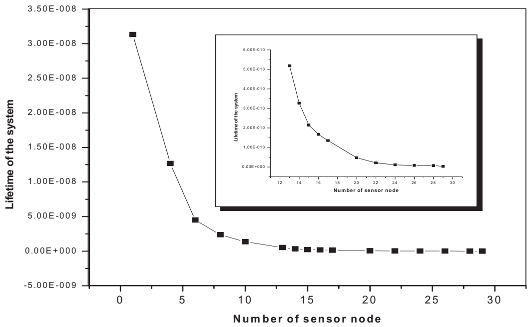

Figure 2: The ratio of the energy increases with respect to the Radio Range of Sensor Node

Conclusion

In this paper the lifetime of sensor network during communication is discussed. We propose a mathematical power distribution model and applied a heuristic analysis for all possible cases and propose a scheme for finding near-optimal solution of deploying nodes in the sensor network. Here we considered active mobile base stations together with the routing patterns to deliver data. The novelty of our approach is that a base station can be located anywhere without any defectiveness. To maximize the system life time several cases are analyzed and verified both mathematically and graphically. Here the mode of the distribution model implies maximum power consumption of the system depends on the number of source node and sink node and the number of times they communicated with each other. Generally the power consumption is increasing if a sensor node communicate data with several nodes. So the figure-2 shows that the life time of the system is gradually decreasing which is very much perfect with the reality.

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