A confined strategy to analyze the lifetime of sensor nodes for multihop WSN

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Abstract

Wireless Sensor Networks (WSN) is nowadays gaining a great popularity based on the increase in semiconductor technology. From daily life activities to military services this increase leads to greater uplift in the technology with efficiency and manufacturing cost. The success of the WSNs is determined mainly based on two factors they are network lifetime and sensing coverage. The network lifetime is characterized by the energy optimization of the sensor systems and the sensing coverage is qualified by the data collection process from the target that directly affects the network traffic. In this paper the network lifetime mathematical queuing model to find an optimal solution of energy Consumption is analyzed. 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. Finally it is shown that as the network lifetime improves, the percentage energy consumption reduces with increase in the total number of hops and attains a minimum value at critical hops. After the critical hops, the energy consumption gradually improves due to change in cumulative energy consumption of the midway nodes.

Keywords:

Wireless Sensor Networks, optimal energy balancing, queuing theory, critical hops.

1. Introduction

Wireless Sensor Networks (WSN) is acquiring a great importance with its up growing advantages in healthcare monitoring, area monitoring, earth/environmental sensing, fire detection and seismic monitoring etc [1]. This type of network consists of group set of nodes with signal processing, wireless communication capabilities, sensing and reduced battery energy. A military sensor network is one of the main applications of WSN.

Supervising the target is an important area of interest with sensor networks based on detachment of human [2]. Nevertheless sensors are not deployed regularly because area of interest should be guaranteed with full coverage which is a very important aspect of WSNs. Consequently, random scattering deployment using sources such as automotive vehicles and helicopters has developed as an approach based on sensor networks. Through wireless transmission, each sensor tends to collect information by sensing its surroundings and change the information to the sink data center. Recharging a sensors battery is impossible because it differs from other battery powered setup. Even though wind and solar energy are utilized they cannot always be reliable.

The sensing activities with active mode and sleep mode are scheduled with the WSNs. One methodology to separate the sensors into sensor covers or disjoint sensor covers should fulfill the coverage constraints. With its functionality, one sensor cover will be in active mode and the other sensors will be in sleep mode. Generally when the sensor covers are in lack of energy utilization it cannot carefully maintain coverage constraints, in this case the other sensor will enter into active mode and it will supply the operational functionality continuously. With this wireless sensor transmissions, energy efficiency and network lifetime is considered as important fundamental features on sensor covers [3]. The lifetime of the network is related to many important factors such as topology, protocol, architecture, QoS and routing. Based on multihop transmission, WSN mostly work on ad hoc topological functions. So there is a chance for the network to get disjoined if some nodes die prior to other nodes. Mobile devices have the tendency to quickly exhaust their batteries and become ineffective to the owners. Therefore in wireless networks, power optimization methodologies have been considered as important system design. The effect of transmission power and aggressive spectral reuse is an important factor in system performance assessment. In this paper the network lifetime mathematical queuing model to find an optimal solution of energy Consumption is analyzed. 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.

The contributions of paper are termed as follows: section 2 deals with various related studies based on WSN. Section 3 deals with the methodology of queuing theory mathematical model, Section 4 deals with comparative result analysis and section 5 deals with the conclusion of the study.

2. Related works

Hou et al [4] studied about various algorithms and protocols which prolong the lifetime of the wireless sensor

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networks. The energy provisioning problems based on two tier approach is studied with relay node placement and energy provisioning. The combined analysis of node placement and energy provisioning will lead to mixed integer nonlinear programming problem (MINLP). A heuristic algorithm called SPINDS can overcome this MINLP problem. Based on numerical analysis SPINDS shows very best solution with its important solutions. Al-Karaki et al [5] evaluated the major optimization goals in WSN through energy conservation. The algorithm based on HEED and LEACH with Bacterial foraging optimization algorithm (BFOA) protocols was studied in this paper. These algorithms enhances the lifetime of the network by improving the energy optimization techniques. Finally a comparison is made among all the algorithms and the BFOA produces best lifetime for nodes compared to LEACH and HEED.

Md Nafees Rahman, M A Matin [6] analyzed the major challenges of wireless sensor networks with energy efficient routing, optimal sink position and low power techniques. The main aim of this study is to find out the optimal sink position. The PSO algorithm is used to identify the correct position of optimal sink position based on rely nodes. The test shows that this methodology can save energy level upto 40% by prolonging the energy efficiency and network lifetime. Rani et al [7] investigated the energy consumption and total transmission time of WSN using multihop data collection by organizing coordination in hierarchical clustering method. The Chain Based Cluster Cooperative Protocol (CBCCP) executes well in terms of time and energy. Finally this protocol is compared with all other protocols and found to be efficient in terms energy optimization. Jun long [8] inquired about the major factors of WSNs by analyzing the target of packets. A Ring Based Routing (RBR) scheme is used to tackle the effects of sink location privacy in WSNs. This methodology can preserve the sink location privacy of sinks effectively.

Alkhdour [9] examines the optimal cross layer improvement of wireless sensor networks. The joint energy efficient routing algorithm with reduced delay scheduling is studied in this paper. The problem formulation was acquired as Integer Linear Program (ILP) model which reduces the delay and network lifetime. This model represents the function of Energy-Efficient Distributed Schedule-Based (EEDS) protocol.

3. Methodology

3.1. Operation of Sensor node in WSN

To calculate the energy efficiency and the network lifetime of the WSNs, initially the sensor node architecture should be carefully analyzed. Generally, the wireless sensor network consists of many numbers of distributed nodes. Profitable wireless sensor node consists of one microcontroller with other components.

The controller executes various tasks such as data processing and it controls the operational functionality of other components of sensor node. Microcontroller is used as one of the most common controller which is used in many embedded systems such as sensor nodes because of its low cost and flexibility for minimum power consumption and programming. As all the nodes are not always fixed in a particular position, based on different topological situations different algorithms are applied to the network. Generally a sensor network consists of four basic components. They are processing unit, power unit, transceiver unit and sensing unit. The processing unit consists of microcontroller linked with small storage unit which evaluates the procedures and performance of sensor nodes with other nodes.

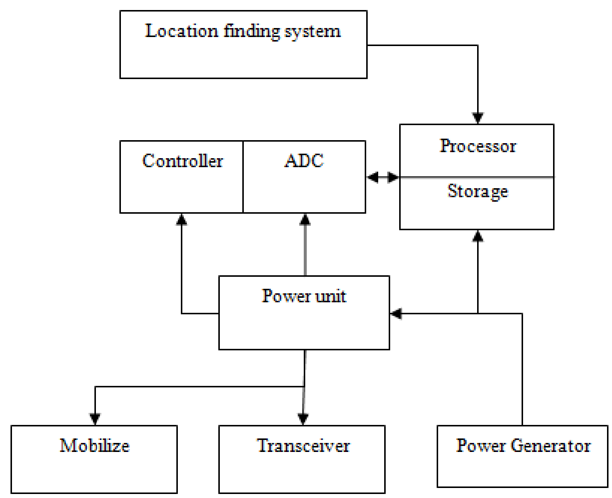

Fig 1 WSN node architecture

The sensor node engages large amount of power for sensing, data processing and communicating other nodes. The main sources of power supply are power accumulated in non-rechargeable and rechargeable batteries. Analog to Digital converters (ADC) and sensors are the two main elements of sensing unit. The analog signals are converted into digital signals through ADC and are fed into the processing unit. To perform the given tasks, Mobilizer should be moved within the sensor nodes whenever it is required.

3.2. WSN mathematical model and problem definition

The queuing problem is defined by the allocation of power supply within the sensor nodes [10]. For N diverse direction, let there be a sensor node which supplies power.

The diverse sink nodes require the signal from the sensor node which is acquired to follow Poisson distribution with parameter λ and the allocation of power supply schedule also follows Poisson sharing with parameter μ. A queue is flowed with the signal reception strategies. To find out correct solution for the network queuing problem, consider a set of nodes in the queue. For n different sink nodes, consider:

$$\lambda_n = (N-n)\lambda$$
$$and \qquad o \le n \le N$$
$$\mu_n = n\mu$$

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

$$P_o(t+\Delta t) - P_o(t)/\Delta t = -N\lambda P_o(t) + \mu P_1(t) + o(\Delta t)/\Delta t$$

for n=0 (i)

When 0<n<N

$$P_n(t+\Delta t) - P_n(t)/\Delta t = \lambda_{n-1}P_{n-1}(t) - (\lambda_n + \mu_n)P_n(t) + \mu_{n+1}P_{n+1(t)} + o(\Delta t)/\Delta t \qquad \text{(ii)}$$

When 0<n<N

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

Then (ii) becomes

$$P_n(t+\Delta t) - P_n(t)/\Delta t = (N-n+1)\lambda P_{n-1}(t) - ((N-n)\lambda + n\mu)P_n(t) + (n+1)\mu P(n+1) + o(\Delta t)/\Delta t \qquad \text{(iii)}$$

When n=N

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

By applying the above values (ii) becomes

$$P_N(t+\Delta t) - P_N(t)/\Delta t = \lambda P_{N-1}(t) - N\mu p_N(t) + o(\Delta t)/\Delta t \qquad \text{(iv)}$$

Considering $\Delta t = 0$, (ii), (iii) and (iv) becomes as three steady state equations of the system.

$$(N-n)\lambda p_n = (n+1)\mu p(n+1) \qquad \text{(v)}$$

We get,

$$P_n = (N-(n-1))\lambda / n\mu(p_{n-1})$$
$$P_N = (\lambda/\mu)^N P_o$$

On further simplifying we get a binomial distribution as,

$$P_n = (\frac{N}{n})(\lambda/(\lambda+\mu))^n(\mu/(\mu+\lambda))^{N-n}$$

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

3.3. Power model mode calculations

To calculate the maximum probability of power distribution, different strategies of analysis should be taken into account. Mode is the value of n where P_n is considered as maximum.

$$P_n / P_{n-1} = 1 + ((N+1)p - n)/nq)$$
$$p = \lambda / \lambda + \mu$$
$$q = \mu / \lambda + \mu$$

By considering two equations:

Case: 1

Where (N+1) p is not an integer. Let (N+1) p=m+f. where m is the integer and f is the fractional value for 0<f<1. Therefore,

$$P_n / P_{n-1} = 1 + (m + f - n/nq) > 1 \qquad \text{(vi)}$$

for n=1,2…m

and

$$P_n / P_{n-1} < 1$$

For n=m+1,m+2,…………..N

Thus the unique model of binomial distribution is m and the integral part (N+1) p.

Case: 2

Where (N+1) p is an integer then,

$$P_n / P_{n-1} > 1$$
$$P_n / P_{n-1} = 1$$
$$P_n / P_{n-1} < 1$$

For n=1,2…..m-1 with n=m with n=m+1,m+2…N respectively.

From this it is identified that the binomial distribution is the bimodal and modal values of m and m+1.

4. Simulation Results

The simulation will be carried out in NS2 simulator for 30 sensor nodes. Based on the assumptions, figure 2 shows the lifetime of the system is reduced gradually with the reality [11].

4.1. Assumptions

i. There is one sink and one source. Distance between sink and source is constant with 100 meters. Hops are formulated between sink and source.

ii. All hops are equal with distance, homogeneous and independent to each other.

iii. Every node is immobile.

iv. Isotropic Rayleigh fading is encountered by all hops.

v. Sensing and processing energy consumption is not measured here.

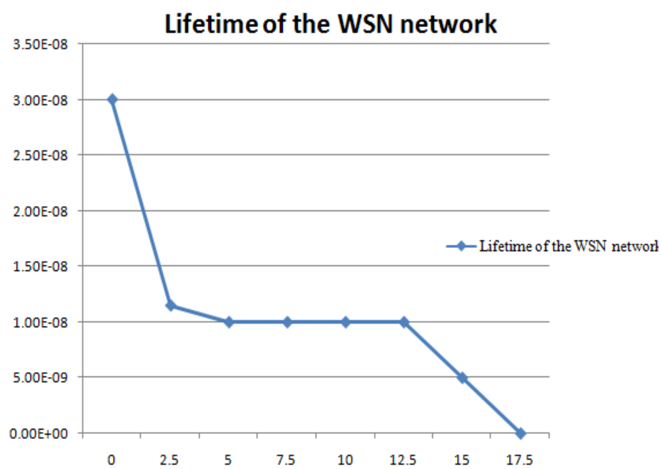

Fig 2 Energy ratio increases with the radio range of the sensor node

In the below figure, the x axis shows the total number of sensor nodes and y axis shows the lifetime of the system. To find out the energy consumption percentage of WSN with sleep mode, the simulation settings should be specified. During sleep mode, when the nodes are in reception and transmission of data the nodes will work and at other times the nodes will go to sleep condition [12].

Table 1: Energy consumption level of WSN

Simulation area	100.5 x 100.5 meters^2
Simulation Time	2000 seconds
Frequency	914MHz
Threshold	5e-07
Power	0.3W
Sleep power	0.01W
Transport layer	TCP
Initial energy	1000J
Traffic type	CBR
Adhoc routing protocol	AODV
Source to sink distance	100 meters
Deployment	Linear
MAC	SMAC

The effect of the variations in received power based on the percentage of energy consumed and the network lifetime is observed with the source to sink distance of 100 meters. Received power links with the transmission distance between two neighboring nodes and the values are observed significantly.

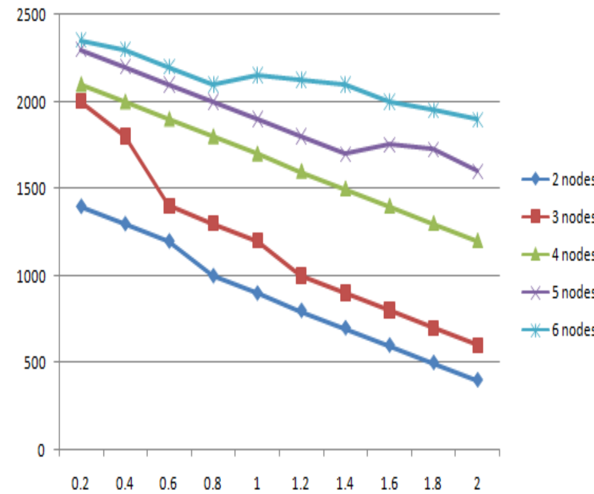

Fig 3 Network lifetime Vs received power

The x-axis denotes the obtained power in microwatts and y-axis denotes the network lifetime in seconds. The lifetime of the node is identified by the battery level of the node. Fig 3 shows the representations of received power versus network lifetime of the network for varying number of nodes from 2 to 6 [13]. The obtained power threshold is the least amount power of the sensor node below which it will fail to receive the signal properly. During simulation model, when the transmission power for particular number of hops becomes equal to the obtained power threshold, the route becomes abrupt. Now the node with the least power determines the lifetime of the network [14]. For equal values of received power the network lifetime is increased with the number of hops. Now when there is an increase in the received power the network lifetime will be decreased. This happens due to increase in power consumption during every transmission which gradually increases the energy consumption. For established power of 0.7 µW, the network lifetime reduces from 2300 seconds to 750 seconds.

5. Conclusion

The lifetime of the sensor network during transmission of data packets with WSN is discussed in this paper. For all possible cases of mathematical power distribution model, a heuristic analysis is proposed with the scheme for finding the near optimal solution of distributing nodes in sensor network. To deliver the data, an active mobile station combined with routing patterns is considered. The originality of this approach is that a base station can be positioned anywhere without any fault. Various cases are analyzed both graphically and mathematically to maximize the system lifetime. Here the normalized manner of the distribution model implies supreme power consumption of the system which depends on number of sink node and source node with the total number of times they are communicated with each other. With the increase in number of hops the energy consumption decreases.

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