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Practical approach for node exploitation in wireless sensor network

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ABSTRACT : In resent years the low power wireless communication technology has enabled the development of low cost wireless sensor network. One very important performance index in wireless sensor network is limited battery backup of sensor node, direly affects the lifetime and cost of the network. Heterogeneous wireless sensor networks provide endless opportunities due to their extendable capabilities such as different computing power and sensing range, but at the same time pose formidable challenges, because of the fact that energy is a scarce and usually non-renewable resources. Exploitation of sensor nodes in a sensor network is a critical task as exploitation should be optimum to increase network lifetime. In this study we have deployed sensor nodes which are heterogeneous on the basis of energy they dissipate while transmitting data. For estimating energy dissipation by nodes we use a communication model where transmitter dissipates energy to run radio electronics. On the basis of energy dissipation by nodes we can predict optimum and worst case scenario of exploitation of sensor nodes. Our simulation results have provided valuable insight into the benefits of heterogeneity.

Keywords : Wireless sensor network, heterogeneous sensors nodes, network lifetime.

I. INTRODUCTION

Research in the field of wireless communication, micro-electromechanical systems and low power design is progressively leading to the development of cost effective, energy efficient, multifunctional heterogeneous sensor nodes. A large number of tiny sensor nodes can be organized to form a distributed network where nodes collaborate to perform functions as in [1] which are specific to a particular application. Some of the most popular applications of sensor networks include environmental monitoring, smart spaces, surveillance, security, military, medical systems and disaster management.

A Wireless Sensor Network can be classified in two broad types, *homogeneous* and *heterogeneous* sensor networks. In homogeneous sensor networks all sensor nodes are identical in terms of battery energy and hardware complexity. In a heterogeneous sensor network two or more different types of nodes with different battery energy and functionality are used as in [4]. The homogeneous architecture is attractive because it is resilient to individual failures. However heterogeneous sensor networks have become popular in real exploitations because of their potential to increase network lifetime and reliability without significantly increasing the cost.

Communications in a wireless sensor network occurs in different ways depending on the applications of the network. In all these cases the lifetime of the network, which directly determines the duration of sensing task, is limited by amount of energy each sensor has. Therefore when we examine these networks, efficient use of energy is of immense importance as in [2]. There are various factors which decide the heterogeneity in wireless sensor network. In some cases sensors have different energy, while sensor node may be heterogeneous on the basis of cost, size, hardware and software used. In this paper we have examined one of the heterogeneous scenarios in which sensors are equipped with same battery power but they are heterogeneous on the basis of energy they dissipate while sending sensory information to the base station.

II. EXPLOITATION OF HETEROGENEOUS WIRELESS SENSOR NETWORK

Among many challenge issues, a fundamental and practical problem is that how we should deploy these nodes within the given energy constraints. Once a wireless sensor network has been deployed, it is expected to operate for extended period of time, and, typically without human intervention as in [5]. Most of the researchers to date tend to consider homogeneous sensors exploitation, where all the sensors have same specifications, including their sensing range. But the varying range of applications of wireless sensor networks has made it clear that sensor nodes should be of variety of size, processing power and radio interface capability. Heterogeneous node exploitation is shown in Fig. 1.

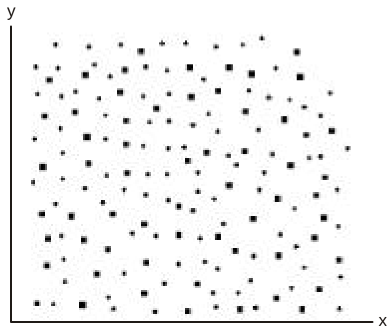

Fig. 1. Heterogeneous nodes deployed over region X-Y.

In a heterogeneous exploitation, devices with high capability can be considered to increase the quality and quantity of data processing inside network and extend network lifetime through high energy capacity as in [2, 3]. Since these nodes dissipate different amount of energy thus probability of a node which dissipate more energy to die is greater than that of a node which dissipate less energy. The nodes which dissipate less energy during communication remain alive for longer period of time as in [7].

III. BACKGROUND KNOWLEDGE

A. Basic assumptions

(*i*) All the nodes are stationary and deployed randomly.
(*ii*) Initial energy of all nodes is same.
(*iii*) Nodes are heterogeneous on the basis of energy they dissipate while sending data to base station.
(*iv*) Base station is fixed and not located between sensor nodes.
(*v*) All nodes transmit sensory data directly to base station that is many to one communication taken place.
(*vi*) One round is the time taken by sensory data to reach to the base station.

One of the challenges of successful exploitation of nodes is energy consumption problem. Sensor nodes dissipate energy while Sensing, Processing and Communication as in [6]. In this paper we only consider energy consumption during communication part.

B. Energy model

In order to estimate energy dissipation by nodes while sending sensory information to base station it is important to have a good model for all aspects of communication as in [8, 9]. Here we assume a simple model where the transmitter, power amplifier and the receiver dissipate energy to run radio electronics (transmitter and receiver circuitry). We can use both free space model and multi path fading model, depending on the distance between the transmitter and receiver. If the distance between the transmitter and receiver is less than a certain cross-over distance ($d_{crossover}$), the Friss free space model is used (d^2 attenuation), and if the distance is greater than $d_{crossover}$, the two-ray ground propagation model is used (d^Aattenuation).

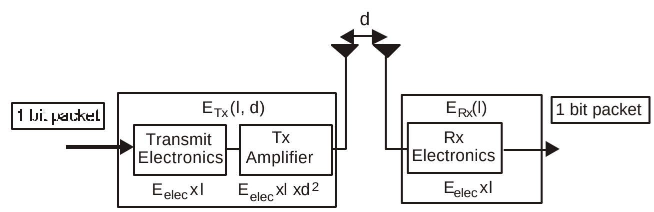

Fig. 2. Radio energy dissipation model.

Energy expended in transmitting l bit massage to a distance d is expressed by the following equations:

$$E_{Tx}(l, d) = E_{Tx-elec}(l) + E_{Tx-amp}(l, d) \quad ...(1)$$

$$E_{Tx}(l, d) = \begin{cases} lE_{elec} + l_{\in friss-amp} d^2 & : d < d_{crossover} \\ lE_{elec} + l_{\in two-ray-amp} d^4 & : d \geq d_{crossover} \end{cases} \quad ...(2)$$

The electronic energy ($E_{elec)}$ depends on factors such as digital coding, modulation, filtering and spreading of the signal. For the experiments described in this paper, we have set the energy dissipated per bit in the transceiver electronics as shown in table 1.

Table 1 : Radio parameters.

Parameter	Definition	Unit
E_{elec}	– Energy dissipation rate to run the transmitter and receiver circuit.	50, 30 and 20nJ/bit
$\in_{two\ ray-amp}$	– Energy dissipation rate to run transmit amplifier when ($d>d_{crossover}$)	0.0013pJ/bit/m^4
$\in_{friss-amp}$	– Energy dissipation rate to run transmit amplifier($d<d_{crossover}$)	10pJ/bit/m^2
l	– Packet size	2000 Bit

C. Problem statement

Let us consider the following situation. Given is a randomly deployed heterogeneous sensor network, in which all nodes dissipate different amount of energy while sending data to base station. The question arises as to how we should provide the heterogeneity in nodes in terms of energy so that the overall lifetime of sensor network increases. An attempt has been made to seek an answer to the questions in the following sections.

IV. SIMULATIONS AND RESULTS

A. Exploitation of heterogeneous node with different dissipation energies

We assume that for sending sensory information to base station sensor nodes takes 200 seconds i.e. one round of communication is completed in 200 seconds. We deploy total of 100 nodes, initial energy of all nodes is same and is equal to 100 nJ. These 100 nodes are divided into ratio of 50, 30 and 20 with dissipation energy of 50 nJ, 30 nJ and 20 nJ as shown in table 2. Now by using this ratio of nodes we make six possible combinations and estimate average energy dissipation due to all combinations and also find out which combination is optimum and which one is worst in terms lifetime of network.

Table 2 : Heterogeneous combination of nodes with different energies.

Combination	Number of nodes	Node energy (NJ)
1	50, 30, 20	50 , 30, 20
2	50, 30, 20	30 , 20 , 50
3	50, 30, 20	20 , 50 , 30
4	50, 30, 20	30 , 50 , 20
5	50, 30, 20	50 , 20 , 30
6	50, 30, 20	20 , 30 , 50

By using equation (2) for ($d < d_{crossover}$) we can calculate average energy dissipation in all the six combinations of nodes as shown in Table 3. The plot of these results is shown in Fig 3.

Table 3 : Average energy dissipation for all six combinations of nodes.

Combination	Number of Nodes	Node energy (NJ)	Average energy dissipotion
1	50, 30, 20	50, 30, 20	0.0078
2	50, 30, 20	30, 20, 50	0.0064
3	50, 30, 20	20, 50, 30	0.0064
4	50, 30, 20	30, 50, 20	0.0070
5	50, 30, 20	50, 20, 30	0.0076
6	50, 30, 20	20, 30, 50	0.0060

From table 3 it is clear that the combination with 50 nodes of 50 nJ of energy, 30 nodes of 30 nJ of energy, and 20 nodes of 20 nJ of energy has maximum average energy dissipation, which is worst case of exploitation, and the combination with 50 nodes of 20 nJ, 30 nodes of 30 nJ, and 20 nodes of 50 nJ of energy has minimum average energy dissipation thus taken as optimum case exploitation. This is therefore, optimum case for exploitation of sensors.

B. Analysis for optimum and worst case network on the basis of energy dissipation by nodes.

We can calculate energy dissipation for each round in optimum and worst case exploitation by using equation (2). Energy dissipation in each round is shown in table 4. Same results have been plotted and shown in Fig 4.

Table.4 : Comparison of energy dissipation in optimum as well as worst cases of exploitation.

S.No.	Number of round	Energy dissipation in optimum case (J)	Energy dissipation in worst case (J)
1	Round 1	0.0202	0.0202
2	Round 2	0.0144	0.0126
3	Round 3	0.0086	0.0050
4	Round 4	0.0048	0.0024
5	Round 5	0.0022	0.0010
6	Round 6	0.0000	0.0000

C. Analysis for optimum and worst case network on the basis of network lifetime

Lifetime of sensor network is the time up to which last node survives. Here network will remain alive up to fifth round. From the simulation results it is clear that in optimum case of exploitation, 50 nodes remain alive up to fifth round, while in worst case only 20 nodes will be expected to remain alive up to fifth round, thus 80% of nodes will die earlier in worst case. Lifetime for both cases is shown in table 5. Graphical representation is given in Fig 5.

Table 5 : Comparison of lifetime in both optimum and worst cases of exploitation.

S.No.	Number of round	Nodes alive in optimum case	Nodes alive in worst case
1	Round 1	100	100
2	Round 2	100	100
3	Round 3	80	50
4	Round 4	50	20
5	Round 5	50	20
6	Round 6	0	0

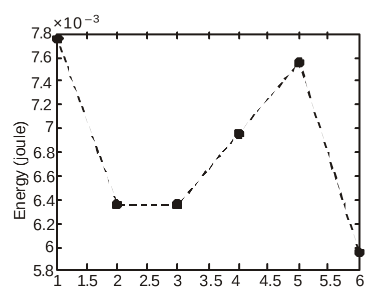

Fig. 3. Result for energy dissipation for different combination of node.

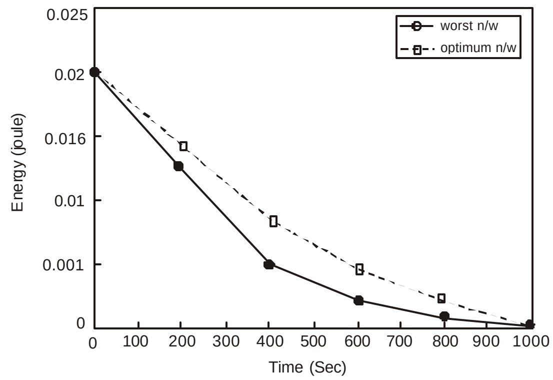

Fig. 4. Result for comparison of energy estimation in both cases

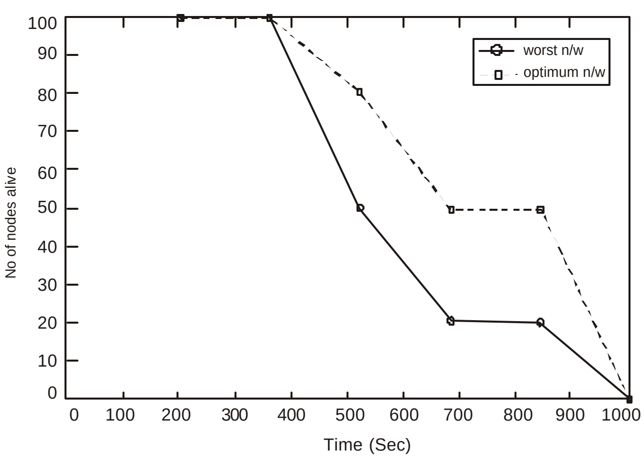

Fig. 5. Result for comparison of network lifetime in both cases.

V. CONCLUSIONS AND FUTURE WORK

From the above results it may be concluded that although total time for the termination of communication is not different between optimum exploitation and worst case exploitation scenarios. Their is a remarkable improvement in the intermediate stages, it can be seen from tables and figures at the end of 5th round that the 80 out of 100 nodes remain alive for optimum exploitation where as in worst case scenarios only 20 nodes survive after 5th round. Also with the simulations performed on the basis of comparison made, one interesting thing is found that while the energy dissipation was higher in optimum case but the ratio of nodes alive per communication rounds was more in that case. This proves our simulation for optimum and worst case and results are beneficial and practically applicable to the generalize exploitation strategy to any heterogeneous wireless sensor network.

In future we can extend this idea for the selection of cluster head. The objective of this study is to make the list of cluster heads. They are deployed for actual use from the available nodes with the minimum energy. Once the list is prepared, temporary cluster head would decide the priority list for the next possible cluster heads. This will eliminate the need to find cluster head after every communication round. It would save energy, make the communication process faster and more informed network in terms of neighboring nodes and network lifetime.

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