Poster Abstract: An Energy-Balanced Transmission Scheme for Sensor Networks

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ABSTRACT

Low energy consumption is one of the design challenges for data transmission for sensor networks. We identify the drawbacks of two conventional data transmission protocols, in terms of balance of energy consumption. We propose an approach to balance energy consumption, and present the theoretical analysis and approximate methods of our approach. Preliminary simulation results show that our approach can achieve a longer overall lifetime of a sensor network.

Categories and Subject Descriptors

C.2.2 [**Computer-Communication Networks**]: Network Protocols -- *Routing protocols.*

General Terms

Algorithms, Design, Management.

Keywords

Wireless, Sensor networks, Energy Balance, Data Transmission.

1. INTRODUCTION

Recent advances in microprocessor and wireless communication technologies have enabled the deployment of large-scale sensor networks [1]. Sensor networks need to be energy-efficient. One of important research areas for energy-efficient sensor networks is energy-efficient routing. Researchers have proposed a lot of energy-efficient routing protocols for sensor networks [1,4]. However, a more useful metric for routing protocol performance should be network survivability [3,5]. One important concern on network survivability is energy-balance. If sensor nodes consume energy more equally, the chance that some nodes use up their energy much earlier and therefore the network is partitioned becomes lower, so the overall lifetime of the network becomes longer.

We present a scheme called Energy-Balanced Transmission (EBT) for balanced energy consumption on data transmission and receiving in sensor networks. EBT balances the routed data density with the energy consumption rate in the network through the combination of direct transmission and multi-hop transmission protocols.

2. MOTIVATION

There are many possible infrastructures for sensor networks [1]. We consider sensor networks where the base station and sensor nodes are all static and all sensor nodes in the network are homogeneous and energy constrained. We aim to make energy consumption balanced for data transmission and receiving in sensor networks. This is the major portion of power consumption by sensor nodes [2], in addition to energy consumed on computing, sensing and other activities.

We use the following scenario to illustrate the importance of energy-balance in sensor networks. Consider a sensor network in which sensor nodes are deployed with a unit density in a circle field with radius D. The base station is located at the center. Sensor nodes know their locations and the base station's location [6]. Data is distributed and collected by nodes at a unit rate. To simplify our analysis, we assume the energy for a node to transmit one bit through distance x is $E_{Tx}= x^2$, and the energy to receive a bit is $E_{Rx}=r$. Among many routing protocols, we examine two, namely direct transmission and hop-by-hop routing protocols.

With direct communication protocol, each node sends data directly to the base station. For a node k hops from the base station, the power consumption rate is: $E(k)= x^2$ per bit. Nodes far from the base station consume energy much faster and use up energy earlier than nodes near the base station. Therefore, after some time, the network fails to monitor the outer part of the field and the network topology is broken.

With hop-by-hop routing protocol, each node sends data to the closest node towards the base station. Nodes transmit data gathered locally and received from nodes farther from the base station. The closer a node is to the base station, the more data it receives from outer nodes, and thus more energy it needs to transmit and receive data. For a node k hops from the base station, the total data density is: $d_k = (D^2-(k-1)^2)/(2k-1)$. The energy to receive and transmit data is:

$$E_k = r(D^2-k^2)/(2k-1) + k^2(D^2-(k-1)^2)/(2k-1).$$

With D=100, r=0.3, the energy consumption rate increases from 1 to 13000 when k decreases from 100 to 1. The lifetime of nodes near the center is much shorter than that of nodes far from the base station. When the nodes near the center die, the network topology breaks, and the whole network fails.

3. EBT TRANSMISSION SCHEME

From the above analysis, we can see that data density and transmission distance are two major factors to energy consumption rate. Our approach coordinates these two factors to balance the energy consumption rate in the network. It works as follows: Each node transmits one part of data directly to the base station and the other part to the next hop according to these two factors. For a node far from the base station that needs more energy to transmit data directly, it sends larger percent of data to

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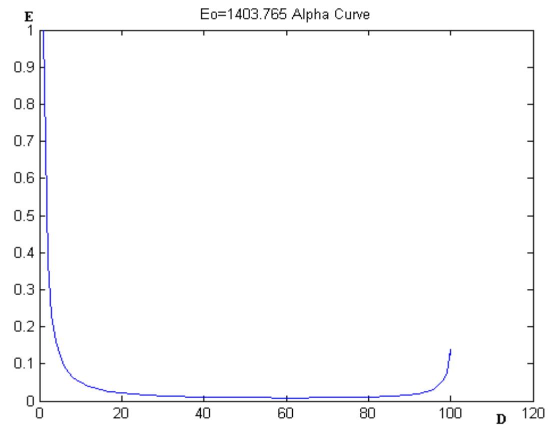

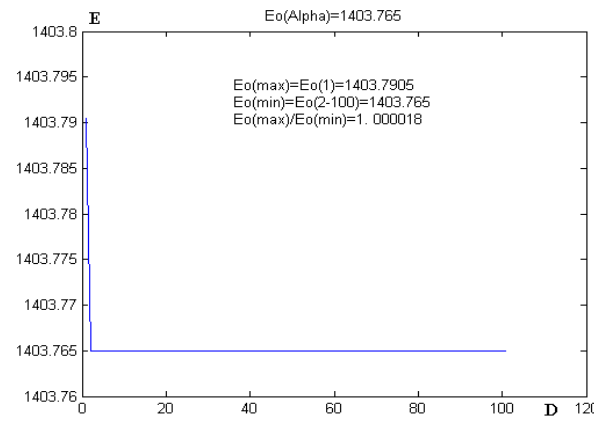

the next hop, therefore reduces the total energy consumption rate. For a node near the base station, it sends more data directly to the base station. By adjusting the ratio between direct transmitting and next-hop transmitting, we can get an even curve of energy consumption rate across the network. We term our approach as Energy-Balanced Transmission (EBT) scheme. Our scheme is general and independent of routing protocols. It can be applied to concrete routing protocols to balance the energy consumption rate in various topologies and applications.

We use above circle field scenario to illustrate our scheme. For a node k hops from the base station, it collects data at a unit rate, and receives data from outer nodes. It transmits α_k percent of its data to the base station and the rest to the next hop. Define μ_k as the total amount of data of all the nodes that are k hops away from the base station: $\mu_k = \pi(2k-1) + (1-\alpha_{k+1})\,\mu_{k+1}$ k=1,2,…D

Define d_k as the total data density at a node k hops from the base station, and d_k' as the data density received from the previous hop:

$$d_k = 1 + \mu_{k+1}(1-\alpha_{k+1})/(\pi(2k-1)). \qquad k=1,2,\ldots D$$

Define E_k as the energy consumption rate at a node k hops from the base station:

$$E_k = (r\mu_{k+1}(1-\alpha_{k+1}) + (\alpha_k(k^2-1)+1)(1 + \mu_{k+1}(1-\alpha_{k+1})))/(\pi(2k-1)) \qquad k=1,2,\ldots D$$

Assuming $E_k = E_0$, we can get α_k from E_k by iteration, with boundary conditions of $\mu_{D+1}=0$, $\alpha_{D+1}=0$, and $\alpha_1=1$:

$$\alpha_k = (E_0 - rd_k' - d_k)/(d_k(k^2-1)) \qquad k=2,\ldots D$$

$$d_k' = \mu_{k+1}(1-\alpha_{k+1})/(\pi(2k-1)) \qquad k=1,2,\ldots D$$

$$d_k = 1 + \mu_{k+1}(1-\alpha_{k+1})/(\pi(2k-1)) \qquad k=1,2,\ldots D$$

$$\mu_k = \pi(2k-1) + (1-\alpha_{k+1})\,\mu_{k+1} \qquad k=1,2,\ldots D$$

4. PRELIMINARY RESULTS

Using MATLAB, we calculate α_k based on the above equations. With D=100, $\mu_{D+1}=0$, $\alpha_{D+1}=0$, $\alpha_1=1$, r=0.3, we get the α_k curve by iteration (Fig. 1). With this α_k curve, we get the energy assumption rate almost constant. From Fig. 2, we can see the ratio of maximum energy consumption rate to minimum energy consumption rate is very close to 1. For the direct transmission, this ratio is 10000, and for the hop-by-hop protocol, this ratio is 13000.

5. CONCLUSIONS AND FUTURE WORK

We exploit the transmission characteristics of sensor nodes to balance the energy consumption across a sensor network. We propose an approach for energy-balanced transmission in sensor networks, by adjusting the portion of data transmitted to the next hop. We present the theoretical analysis and approximate methods of our approach. Our calculation shows that our approach balances the rate of energy consumption across the whole network well and extends the overall lifetime of the network. In our future work, we will apply our approach to different topologies with non-uniform data traffic.

6. REFERENCES

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