Optimization of Cluster Head Rotation in Self-Organizing Wireless Sensor Networks

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Abstract

A Wireless Sensor Network (WSN) consists of several sensor nodes deployed over a geographical area for the purpose of target tracking, monitoring physical phenomena like temperature, vibration, and humidity and so on.

In WSN, the sensor nodes are extremely energy constrained. In some cases it is possible to use external energy sources (e.g., solar or vibration). However, external power suppliers often exhibit non-continuous behaviors so that energy buffers (batteries) are needed as well. Therefore, minimizing energy dissipation and maximizing networking lifetime are the major challenges in WSNs. In this research, we propose an energy efficient Continuous Working Time (CWT) strategy that could apply to the data transmission phase of the LEACH algorithm1 to improve its performance and save more energy.

Introduction

In few past years, Wireless Sensor Networks (WSNs) have become one of the most interesting areas of research. A WSN consists of a number of sensor nodes working together to monitor a region to obtain data about the environment or to detect some event and report it to the base station through single-hop or multi-hop wireless routing.

Clustering is a key technique used to both extend the lifetime of WSN and make them scalable by forming clusters. However, clustering in WSNs faces several challenges such as proper cluster formation, optimum selection of cluster heads, maintaining intra- and inter-cluster connectivity and establishing cluster head rotation frequency to prevent rapid discharge of cluster heads.

LEACH, algorithm is one of the fundamental clustering protocols proposed for WSNs. It uses random cluster head selection and frequent cluster head rotation strategy to distribute the energy load uniformly among all sensor nodes.

In this research, we take the advantages of LEACH algorithm our base model and propose CWT strategy that could apply to the data transmission phase of the LEACH algorithm to improve its performance.

Approach

Energy Consumption Model

In WSN, the main energy consumption of the active nodes is made up of three parts: message sending, message receiving and data signal processing. Our model is similar to Heinzelman et al.’s. Since all nodes have a uniform data generation rate and the amount of energy consumed by sensing has been balanced among all sensor nodes, it is not necessary to consider the energy consumption for the data sensing.

Continuous Working Time Model

The LEACH algorithm expends some energy for the new cluster head establishment at the end of each round. If the current cluster head acts continuously as the local control center, then the frequency of the cluster head update would be reduced. On the other hand, once the cluster head is depleted, the whole cluster loses connection to the base station. Therefore, keeping the cluster head alive (operational) is the main goal for keeping the connectivity of the network. Thus, the lifetime of a cluster is defined as the time interval between the selection and death (losing the remaining energy) of its cluster head.

Considering this tradeoff we propose an analytical iterative model that takes into account the working process of sensor networks in a time round manner. In this method, time is partitioned into fixed intervals of equal lengths called rounds. The residual energy parameter of current cluster head is considered to determine the suitable round to call for the new cluster head set up phase.

Table 1. Experiment simulation parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
<td>300</td>
</tr>
<tr>
<td>Monitoring area</td>
<td>(100,200) m²</td>
</tr>
<tr>
<td>Position of sink node</td>
<td>(0,150) m</td>
</tr>
<tr>
<td>Initial energy</td>
<td>0.5 J</td>
</tr>
<tr>
<td>Length of Data packet</td>
<td>100</td>
</tr>
<tr>
<td>Simulation end condition</td>
<td>Number of nodes &lt; 3</td>
</tr>
<tr>
<td></td>
<td>500 m/min</td>
</tr>
<tr>
<td></td>
<td>1000 m/min</td>
</tr>
<tr>
<td></td>
<td>0.0013 S/10¹³ J²</td>
</tr>
</tbody>
</table>

Figure 1. A wireless sensor network

Figure 2. Potential uses of WSNs

Figure 3. Example of a sensor node

Figure 4. Radio energy consumption model

Figure 5. Data transmission phase

Figure 6. Comparison histogram of FND and HNA parameters

Figure 7. Number of active (live) nodes per round

Figure 8. Number of clusters saved at the end of each round

Results

In this section, we evaluate the performance of our model by applying it on both LEACH and one of its recent improvement called S-LEACH algorithm2 and evaluated their performance by comparing with the original ones.

To illustrate the performance of “continuous Working Time” model, the simulations are performed in MATLAB and utilized a network with 100 sensor nodes.

The simulation parameters are presented in Table1.

To be able to compare these algorithms in our simulation we need to run them on the same networks. This is achieved by using equal random seeds for each run in all algorithms.

Conclusion

In this paper we employ a Continuous Working Time model in the data transmission phase of the LEACH algorithm. In LEACH the cluster head is replaced dynamically at the end of each round which entails additional energy dissipation for new cluster setup and cluster head establishment. In CWT model the cluster head keeps working continuously until its residual energy reaches a pre-defined threshold. If the cluster head works continuously as a local control center, then the frequency of cluster updating and the amount of energy consumed for new cluster head establishment is reduced. Therefore the lifetime of the networks is increased. The performance evaluation shows that by applying our model to the data transmission phase of both LEACH and S-LEACH, the lifetime of the network in terms of FND and HNA is increased effectively.

References


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