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# A Distance Clustering Routing Algorithm Considering Energy for Wireless Sensor Networks

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***Abstract***

*Due to the limited energy resources of sensor node, energy conservation has become one of the key in the design of route in wireless sensor networks (WSNs). In this paper, we propose a distance clustering routing algorithm considering energy (DCE), which selects cluster heads and construct multi-hop route according to the distance factor and the energy factor. Simulation results show that DCE can save energy and the saving energy can contribute to prolonging the network lifetime. Compared with LEACH, DCE has a better performance in energy consumption and network lifetime.*

***Keywords:*** *wireless sensor networks, cluster, distance factor, energy factor*

## 1. Introduction

Wireless sensor networks (WSNs) have been proposed for the observation of events and environments in sensing areas over a long period of time. A typical wireless sensor network always consist of a large number of tiny sensor nodes, which have limited energy resources, and can carry out sensing, processing and transmitting. These sensor nodes are usually deployed randomly or artificially [1, 2].

Routing technology is one of the key technologies in the study of sensor networks, and clustering routing algorithms have been proved to be suitable to save energy and become an active branch of routing technology. Due to the battery capacity of sensor nodes is difficult to reinforce, minimizing the energy consumption and maximizing the network lifetime under limited energy are important goals in the routing design.

Clustering routing protocols select cluster heads from all sensor nodes and group a number of sensor nodes to form clusters. Cluster heads will manager their member sensor nodes and aggregate the received data to reduce network load. The selection of cluster heads has an important impact on the life cycle of the sensor network. The reasonable selection of cluster heads can significantly prolong the network lifetime.

In this paper, we propose a distance clustering routing algorithm considering energy (DCE) for the wireless sensor network. We want to balance the energy consumption and prolong the network lifetime through this clustering algorithm in the sensor network. The sensor network we adopt here is made up of one static sink node and several sensor nodes. In DCE, cluster heads are selected based on the energy of sensor nodes and clusters, and the distance between sensor nodes, including the static sink node. Simulation results show that our algorithm DCE can achieve our goal to improve the network performance.

The rest of the paper is organized as follows. Section 2 presents a literature survey about related clustering protocols for static wireless sensor networks. Section 3 gives the detailed explanations about our algorithm and then provides simulation results. Section 4 concludes this paper.

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## 2. Related Work

Many correlation studies have shown that hierarchical routing protocols are very suitable for static sensor networks, and an excellent clustering algorithm is the premise and key of the research of hierarchical routing protocols.

Low energy adaptive clustering hierarchy (LEACH) [3] is a classic clustering routing protocol. It utilizes randomized rotation of cluster head nodes to balance the whole network load, and consists of the set-up phase and steady-state phase. Compared with ordinary routing protocols, LEACH can reduce communication energy as much as 8 times and thus significantly improve the network performance. However, LEACH protocol does not consider the location of sensor nodes, and the selection of cluster head nodes is random, causing the uneven distribution of cluster head nodes. Besides, the single hop communication manner will increase the cost of the long distance communication. Thus, the corresponding improved algorithm, called LEACH-C algorithm, was proposed in [4]. This algorithm centralized to choose cluster head nodes through the static sink nodes.

To prolong the network lifetime, A hybrid, energy efficient, distributed (HEED) [5] clustering protocol was proposed and was proved that it can minimize the control overhead and prolong the network lifetime due to the well distribution of cluster heads. HEED protocol considered the residual energy of sensor nodes and the cost of communication within the cluster during the selection of cluster heads.

An energy efficient heterogeneous clustered scheme was proposed in [6], which was effective in prolong the network lifetime. The impact of heterogeneity of sensor nodes was studied in terms of their energy, and this clustered scheme was based on the weighted election probabilities of each node to become a cluster head according to the residual energy.

A novel distributed clustering algorithm was proposed in [7], where cluster head nodes were selected following a three-way message exchange. The eligibility to be elected cluster head node was based on its residual energy and its degree. An energy efficient clustering protocol (EECPL) was proposed in [8], which organized sensor nodes into clusters and used the ring topology to send data. Thus each sensor node can receive data from a previous neighbor sensor node and can transmit data to a next neighbor sensor node. An energy efficient routing technique, called energy aware intra cluster routing (EAICR) was proposed in [9], which has increased energy efficiency up to 17% and increased the network lifetime up to 12%. EAICA considered the number of packets sent in the network, energy consumed, and residual energy level of sensor nodes at specific time and network lifetime.

An efficient approach for clustering aggregation based on data fragments was proposed in [10], which can improve the network performance and reduce the computational complexity. In fragment-based approach, a data fragment is any subset of the data that is not split by any of the clustering results.

## 3. Our Proposed Algorithm

### 3.1. Basic Assumptions

We construct the rectangular sensor network which consist of one static sink node and several sensor nodes, and make several basic assumptions for sensor nodes.

- All sensor nodes, including the sink node, remain static once deployed;
- All sensor nodes are homogenous and location-aware;
- Each sensor node has a unique identifier (ID), and the same initial energy;
- Sensor nodes can adjust their transmission power;
- Links are symmetric.

### 3.2. Selection of Cluster Heads and Multi-hop Routing Set-up

In our algorithm DCE, we consider the distance factor and the energy factor to choose cluster heads and relay nodes. The static sink node is located in the center of the rectangle sensor network, and sensor nodes are randomly deployed in this rectangle area. Each sensor node calculates the distance $d_{i\_j}$ to other sensor nodes and the distance $d_{i\_sn}$ to the static sink node. Each sensor node will set up a table to store the residual energy, the distance $d_{i\_j}$ and the relative node ID and the information of the distance $d_{i\_sn}$ will be kept in the sink node. Thus the maximum distance to the sink node $d_{\max}$ and the minimum distance to the sink node $d_{\min}$ can be found. Thus the distance factor $D_i$ of each sensor node can be defined as the following formula.

$$D_i = \frac{d_i - d_{\min}}{d_{\max} - d_{\min}} \quad (1)$$

The initial energy of sensor node is same, but the energy consumed by transmitting data of each sensor node is different. The residual energy $re_i$ of sensor node and the average energy $re_{average}$ of the whole sensor network can be calculated. Thus the energy factor $E_i$ can be defined as the following formula.

$$E_i = \frac{re_i}{re_{average}} \quad (2)$$

Thus the sensor node with the high energy will have a more chance to be selected as cluster heads, and when the energy consumption of sensor node $s_i$ and $s_j$ is same, the sensor node which is more close to the sink node will be likely to be selected as cluster head to forward data.

After completing the selection of cluster heads, cluster heads will broadcast a message to inform other normal sensor nodes, and then each normal sensor node analyzes the receiving signal strength and knows which cluster it is in. Thus, clusters of the sensor network are established.

If the distance between nodes is too far, sensor node will consume more energy to transmit data and may cause data loss due to the shortage of the subsequent energy. To ensure the integrity of data transmission and reduce the energy cost of long distance communication, multi-hop transmission manner is more suitable than the single-hop transmission manner.

If the value of $d_{i\_j}$ is smaller than the distance threshold $d$, the corresponding sensor node will transmit data to cluster head directly; otherwise, it need to look for a suitable forwarding node. Here we define the distance threshold $d = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}}$. Thus the cost of the link between node $s_i$ and $s_j$ is defined as the following formula. The node with the minimum link cost will be chosen to act as the relay node so that the multi-hop route can be constructed.

$$lc_{(i,j)} = (1-\omega) * \frac{d(s_i, s_j)^2 + d(s_j, s_{chk})^2}{\max(d(s_i, s_j)^2 + d(s_j, s_{chk})^2)} + \omega * \frac{(E_j - E_i)}{\max(E_j)}, \omega \in [0,1] \quad (3)$$

### 3.3. Performance Evaluation

To evaluate the performance of our algorithm, we use the Matlab simulator to network. There are 200 sensor nodes randomly deployed in a $200 \times 200m^2$ rectangle network which has only one sink node located in the network centre. The initial energy of sensor node is $2J$, and each sensor node can adjust its transmission range. In this paper, we mainly compare our algorithm with the classical LEACH algorithm in terms of the energy consumption and the network lifetime.

Based on the distance factor and the energy factor, cluster heads and relay nodes are selected to balance and reduce energy to a certain extent. Figure 1 shows the comparison of DCE and LEACH in terms of energy consumption in each round. We can observe that after the round 14, DCE consume less energy than LEACH. And in Figure 2, we show the residual energy of the two algorithms after 50 rounds, and can observe that the sensor network adopting DCE has higher energy than the same network adopting LEACH protocol. Thus the saving energy in DCE contributes to prolonging the network lifetime.

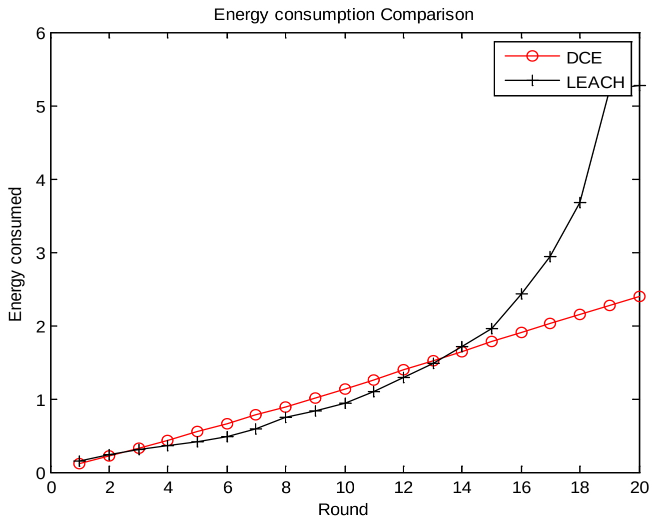


**Figure 1. Energy Consumption**

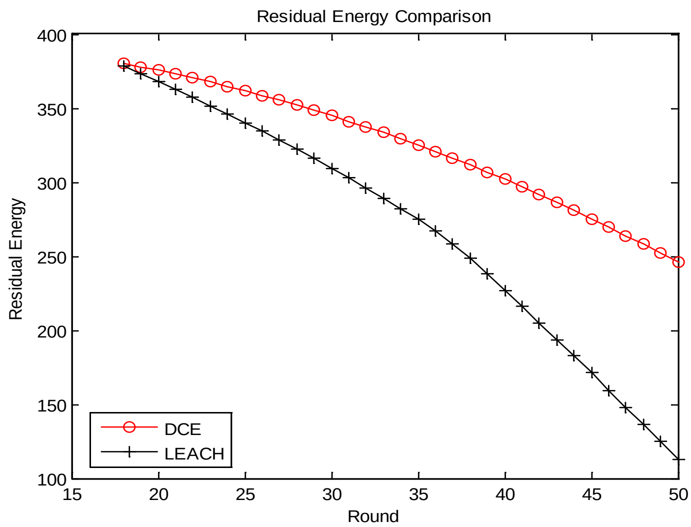


**Figure 2. Residual Energy**

To evaluate the network lifetime, we define the network lifetime as the simulation time when the first sensor node depletes its energy and fails to transmit data. In Figure 3, we show the lifetime of the sensor network using DCE. In order to facilitate the experiment, the initial energy of each sensor node is set to $1J$. During the 120 rounds, the first failure sensor node in DCE appears in the 113 round and the first failure sensor node in LEACH appears in the 31 round.

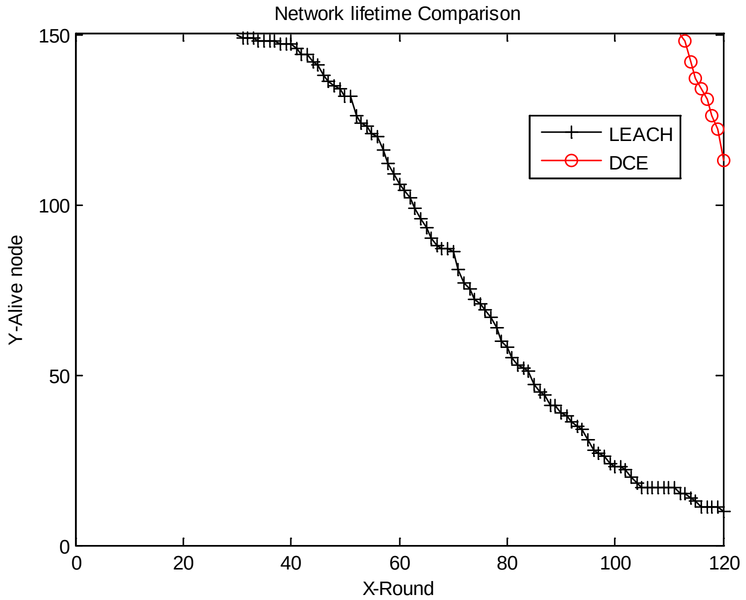


**Figure 3. Network Lifetime**

## 4. Conclusions and Future Work

In this paper, we propose a distance clustering routing algorithm considering energy (DCE) to save energy so that the network lifetime can be extended to a certain extent. Based on distance and energy, cluster heads are selected in each round, and relay sensor nodes are also selected so that multi-hop route can be constructed. Simulation results show that DCE outperforms LEACH in terms of energy consumption and network lifetime.

However, in this paper, we make several assumption and our experiments are conducted in an ideal environment. Thus we will strive to make the algorithm applications tending to more realistic.

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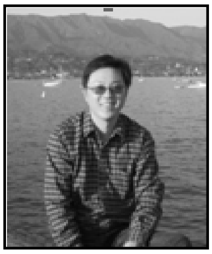

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