# Research on Energy Saving Routing Algorithm of Cluster Wireless Sensor Networks

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Abstract: Based on the analysis of LEACH protocol, this paper proposes an improved algorithm: taking into account the two factors of node energy and distance, we improve the probability of cluster head selection. The probability formula of the cluster head selection of the original protocol is modified by using the weighting factor. According to the improved algorithm proposed in this paper, simulation experiments are carried out respectively upon different adjustment parameters selected. The results show that the improved algorithm can avoid the existence of extremely large and small clusters compared with the LEACH protocol, which will balance the energy consumption of network nodes, reduce the network energy consumption, improve energy efficiency and extend the network's life cycle.

## 1 INTRODUCTION

At present, many clustering algorithms are based on Low Energy Adaptive Clustering Hierarchy (LEACH) (Deepshikha, 2017) routing protocol. These routing protocols focuse on different optimization targets according to different application requirements. They have their own advantages and disadvantages according to their different performance in energy efficiency, data fusion and network scalability. Clustering routing algorithm has obvious advantages in reducing energy consumption and prolonging network lifetime. Therefore, the improvement research on clustering-based low energy routing protocol has become a hot and developing trend in this field.

Energy-efficient routing algorithm based on clustering of WSN has obvious advantages on reducing energy consumption and prolonging network lifetime. This is the focus of this paper.

## 2 ENERGY CONSUMPTION ANALYSIS

Energy consumption of network nodes is one of the most important issues in WSN. The network nodes are composed of four modules, sensing, processing, wireless communication and energy supply. Energy consumption comes from the first three modules.

The energy consumption of each component of the sensor node is as shown in Fig. 1.

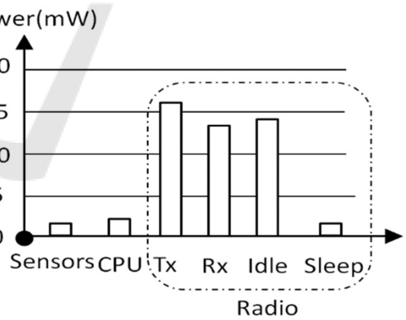


Fig.1 Energy consumption distribution of each component

## 3 ANALYSIS OF DEFECTS OF LEACH ALGORITHM

The traditional LEACH protocol is easy to implement and has strong addictiveness.. Each node in the run time takes turns as the cluster head,



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averaging the energy consumption of the entire network. Compared with the surface routing protocol, it has a longer network lifetime. Through the simulation analysis of the LEACH protocol, we find some shortcomings of the LEACH protocol.

(1) In the selection of cluster heads, the LEACH protocol cannot produce a fixed number of cluster heads in each round because of the uncertainty of the random number produced by the node itself. The instability of cluster number will lead to the situation that some network rounds may generate more cluster heads while the other rounds may produce less cluster head. When the number of cluster heads is very small, the cluster member nodes in the network are usually more. Cluster heads require more time and energy to deal with data processing, which eventually leads to a sharp energy drop of cluster heads. If there are a large number of cluster heads, there are few member nodes within clusters or even there are cluster head nodes left in clusters. As the cluster head conducts direct communication with the base station, too many nodes' long-distance communication with the base station will lead to the increase of the energy consumption of the whole network.

(2) The number of nodes in each round of cluster is greatly different. Some clusters are very large with more node members. Some clusters have few or even no member nodes. In this way, it is very easy to cause the load imbalance of the whole network. In the end, this situation will cause some nodes to die because of the premature exhaustion of energy.

(3) The location of the cluster head nodes is unevenly distributed. Some cluster heads are too concentrated or adjacent, while some cluster heads are distributed on the edge of the entire network area. In this way, the member nodes in some clusters have to communicate with the cluster heads through long distance transmission, resulting in a large amount of energy consumption.

(4) With the operation of the network, some nodes may have undertaken too many tasks in advance and have little residual energy. Some other nodes may have more residual energy due to the opposite situation. If we do not consider the residual energy of nodes, and when the residual energy of nodes in the later stage is generally low, we will unfortunately choose the nodes with extremely low energy in the cluster head selection. They will not be able to undertake the related tasks and lead to the failure of communication.

# 4 IMPROVEMENT SCHEME AND ANALYSIS

This paper optimizes the algorithm based on the shortcomings of the LEACH protocol. A series of improvements are proposed. The simulation and analysis are carried out according to the improved scheme.

## 4.1 Evaluation standard of network energy consumption performance

In order to compare the improved protocol with the original LEACH protocol, we need to propose an evaluation criterion for measuring the performance of the network. In the evaluation criteria of energy consumption of sensor networks, the two common indicators refer to the network life cycle and the total energy consumption per round of network.

### 4.1.1 The network lifetime

As an important evaluation index, the network lifetime cycle is now widely used to measure the performance of a WSN.

The most widely defined definition: the network lifetime is defined as the time from network starting to work, to the death of the first node in the network, or to the energy exhaustion of any node in the network.

The network lifetime is in fact closely related to the number of surviving nodes in the network. During the simulation test, we will use the number of remaining surviving nodes in each round of network or the percentage of remaining surviving nodes in each round network as a more objective criterion.

### 4.1.2 Total energy consumption per round

The total energy consumption of every node in every network per round or the total residual energy of every node in the whole network per round can also be used as an index to measure the energy consumption of the whole network and to illustrate the setup of sensor network. In the comparison of the simulation experiments in this paper, we will measure the residual total energy of all nodes in the whole network per round.

## 4.2 LEACH Protocol Improvement Scheme

In this section, we will propose some improved algorithms for some of the defects. The main purpose is to improve the threshold T(n) of the cluster head election to reduce the energy consumption of the network and improve the network performance.

The improved algorithm also takes the round as the smallest cycle unit. Each round is divided into the initialization stage established by the cluster group and the stable work stage for data transmission. Among them, the cluster establishment stage includes the election of cluster heads and the formation of clusters. The stable transmission phase of data mainly completes the two tasks of node routing and data forwarding between nodes.

### 4.2.1 Improved scheme based on residual energy and distance

One of the shortcomings of the LEACH protocol: in the process of network operation, the residual energy of each node fails to be considered. When the next round of cluster heads is re-selected, the distribution of energy consumption in the network is uneven, leading to the premature death of some nodes. Now we bring the residual energy into the scope of the cluster head election, and improve the original protocol.

The cluster head nodes selected randomly are usually not well distributed because of the location distribution. Some are too concentrated. Some are too scattered or even on the edge of the network area. There are often more clusters where the cluster heads are too concentrated. A large number of cluster heads and remote base stations will consume a lot of energy when communicating, and the cluster heads distributed at the edge of the network will consume a lot of energy because of the long-distance transmission with the remote member nodes.

We add the distance D(n) to all nodes in the regional centre as a measure. The basic goal of the scheme is to maximize the coverage area of the selected cluster heads as far as possible. The probability of reducing the cluster head marginalization is reduced. Let the cluster head close to the centre of the whole region to shorten the data transmission distance (Takhellambam S. S., 2016).

The calculation of the center of mass in the region surrounded by clusters: for simplicity, we will use the arithmetic mean of all node coordinates within the cluster to replace the centroid location.

The following is the centroid formula, and D ($X_d$, $Y_d$) is the centroid position:

$$D(X_d, Y_d) = \begin{cases} \dfrac{\sum_{i=1}^{N} X(i)}{N} \\ \dfrac{\sum_{i=1}^{N} Y(i)}{N} \end{cases} \quad (1)$$

In formula (1), (X (i), Y (i)) is the coordinate position of the internal nodes of the cluster, and N is the number of all the nodes within the cluster.

Considering the influence of two factors on the threshold T(n), such as the residual energy of nodes and the distance from nodes to centers, an optimization scheme based on residual energy and distance factors is proposed.

The calculation formula of the cluster head threshold T (n) of the optimization scheme is:

$$T(n)=\begin{cases} \dfrac{p}{1-p\times(r * mod \frac{1}{p})} \cdot \left( q_i \dfrac{E_r(n,r)}{E_i(n)} \cdot t_i \dfrac{d_m - d(n)}{d_m} \right); & if(n \in G) \\ 0 & ; otherwise \end{cases} \quad (2)$$

In the formula (2), p is the percentage of cluster heads in the expected network. R is the number of the current running rounds, and n is the number used to identify nodes in the network. The meaning of G is LEACH, which does not act as a set of cluster head nodes in the past $1/p$ rounds.

Er(n, r) represents the residual energy of node n in the current r round. Ei(n) represents the initial energy of node n when the network starts running. qi is an energy-related regulation parameter, which is used to regulate the influence of the node energy consumption factor on the threshold T(n).

The two parameters of Er and Ei are the internal information of the node itself. It is maintained by the node itself and does not need to communicate with other nodes. Through adjusting the threshold T(n) by $Er/Ei$, the nodes with large energy consumption ratio can reduce their probability of becoming cluster heads by decreasing the value of T(n). On the contrary, for smaller nodes whose energy consumption is smaller, the probability of cluster head will be increased by increasing the value of T(n).

Dm represents the maximum distance between all nodes in the network to the center of the network area. D(n) represents the distance from a node n to the regional center in the network. Ti is a distance dependent regulation factor, which is used to regulate the proportion of distance factor in the cluster head threshold T(n) calculation.

We use $(dm-d(n))/dm$ to adjust the threshold T(n). The probability of a node at the edge of a cluster to become a cluster head is reduced, and the probability of raising the node in the cluster's endoplasmic reticulum becomes the cluster head. Through the adjustment of probability, the covering area is maximized and the cluster head is marginalized as much as possible when the cluster head is selected, so the cluster head is closer to the center of the region.

$w_i = q_i * t_i$, formula (2) can be reexpressed as:

$$T(n)=\begin{cases}\dfrac{p}{1-p\times(r \bmod \frac{1}{p})}\cdot\left(w_i\dfrac{E_r(n,r)}{E_i(n)}\cdot\dfrac{d_m-d(n)}{d_m}\right); & if(n\in G)\\ 0 & ;\ otherwise\end{cases} \quad (3)$$

In formula (3), $q_i$ is a parameter of energy regulation and ti is a range adjustment parameter. By changing the values of these two parameters, the proportion of the energy factor and the distance factor in the cluster head threshold T(n) can be dynamically adjusted.

Here, $w_i$ is a synthetic parameter. It weighs the influence of the proportion of energy and the specific gravity of the distance on the T(n) of the cluster head threshold. A suitable $w_i$ value can make the network performance to the best state.

## 4.3 Simulation analysis

### 4.3.1 Simulation test scene and parameter setting

In order to compare the experiment results of the improved scheme and the traditional LEACH protocol, we adopted the same network model assumption as LEACH protocol, wireless communication model between nodes, data fusion model and so on(Heinzelman W. B., 2002; Say S., 2014). Among them, the formula of energy is still used in the first order radio model in the LEACH protocol.

It is assumed that 225 nodes in the network are randomly distributed in the area of 150m*150m, and all nodes have the same initial energy. The network simulation parameters are shown in table 1.

Table1 network simulation parameters

| | |
|---|---|
| Network coverage area | 150m×150m |
| Total number of nodes N | 225 |
| Base station coordinates (located in the center of the network) | (75m，75m) |
| Expected cluster head percentage P | 0.1 |
| Parameter $\varepsilon_{fs}$ | 10pJ/bit/m$^2$ |
| Parameter $\varepsilon_{amp}$ | 0.0013pJ/bit/m$^4$ |
| Energy consumption for receiving and receiving $E_{elec}$ | 50nJ/bit |
| Cluster head data fusion energy consumption $E_{DA}$ | 5nJ/bit/signal |
| Packet size L | 400byte |
| Node initialization energy E0 | 1.5J |

### 4.3.2 Simulation and analysis

For the improved scheme of considering the energy factor and the distance factor in the calculation of the cluster head threshold, the simulation experiment is carried out by using the formula (3). The experimental results are analysed from two aspects of the total residual energy of the network and the number of survival nodes.

a. Comparison of total residual energy of network

In Figure 4.10, the blue solid line reflects the relationship between the energy of the LEACH protocol and the number of running rounds. The red point line indicates the relationship between the energy of the improved scheme and the number of running rounds. The black dotted line at the top of the graph represents the total energy of the entire network node that is initialized at the time of initialization.

As you can see in Figure 2, the improved scheme has obvious advantages over the LEACH protocol in terms of energy consumption. For example, it can be obtained from the data that the improved scheme postpones the $\Delta$r=2507 round in comparison with the LEACH protocol under the same energy consumption of only 10% of the remaining energy. From figure 2, it is obvious that the red dot is on the right side of the solid blue line. The red point line drops slower than the blue line. It shows that the energy consumption per round of the improved scheme is less than LEACH.

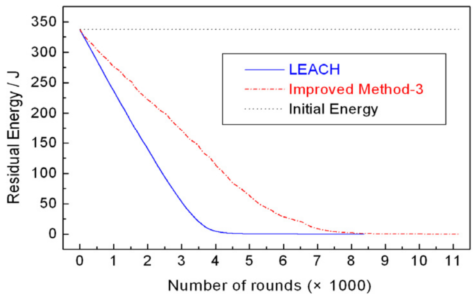


Fig. 2 Network running round number

b. Comparison of the number of surviving nodes

Fig. 3 can be seen that the improvement scheme for the LEACH protocol has obvious superiority in the network lifetime. The number of death rounds of the first node, the improved scheme increases the delta r=1054 round than the LEACH, and the number of all nodes of the network nodes is increased by the Δr=2790 round. From fig. 3 can be seen, the improved scheme of LEACH protocol in solid blue red dotted right, that improved scheme prolongs the network life cycle.

Through the analysis, it is not difficult to draw the conclusion that the improved scheme has lower energy consumption and longer network lifetime than the LEACH protocol.

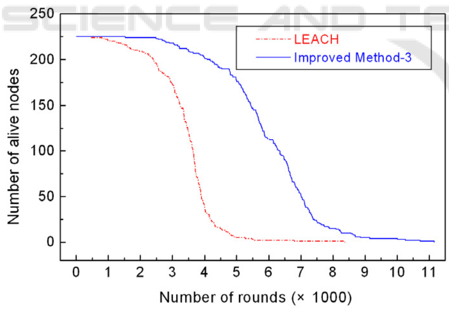


Fig.3 Comparison of network life cycle

c. Influence of adjustment parameter $w_i$

The influence of the parameter $w_i$ on the total energy consumption of the network: in Fig. 4, it can be seen that the smaller the $w_i$ value, the lower the total energy consumption of the network. At $w_i$=0.24, the energy consumption is the lowest; when $w_i$=2.0, the energy consumption is the largest.

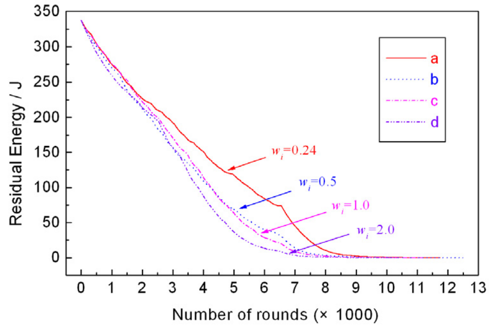


Fig.4 Relationship between the residual energy and rounds r

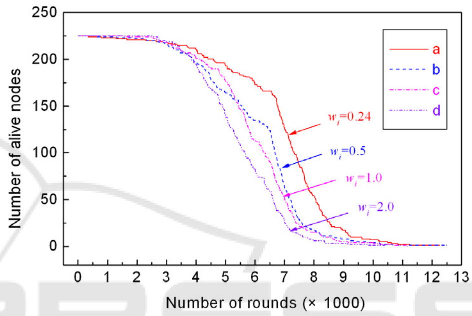


Fig.5 The relationship between the network surviving node and the number of r



From fig. 5, we can see that when $w_i$=2.0, the number of the first dead node in the network is the largest, the number of r=2540 rounds is the largest. When $w_i$=0.5, the number of death nodes of all nodes in the network is the largest, which is r=12491 round.

If the number of running cycles of only 10% (or death 90%) nodes is defined, the parameter $w_i$=0.24 in the improved scheme has a longer network lifetime.

## 5 Conclusions

According to the improved algorithm proposed in this paper, different parameters $w_i$ ($t_i$ and $q_i$) are chosen to go through simulation experiment respectively. The simulation results show that the improved algorithm can avoid the existence of a extremely large and clusters compared with the LEACH protocol and it can also better balance the energy consumption of nodes in the network, reduce energy consumption, improve energy efficiency, and prolong the network life cycle.

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