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An Improved Energy Balance Routing Protocol based on LEACH Protocol

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Abstract

LEACH algorithm is a classical hierarchical routing algorithm; it uses the cluster head rotation mechanism to allocate the energy consumption to the whole network. But because of the randomness of the cluster head selection, the optimal number of cluster heads cannot be obtained, at the same time, its position cannot do the best, some regions of the cluster head may be more concentrated, some areas may not cluster head, lead to the distance of non-cluster head node and cluster head node is too large, the energy consumption is too large. So an improved routing algorithm based on LEACH algorithm is proposed, the basic idea is to determine the optimal number of cluster heads, non-uniform clustering, at the same time, the threshold is added in the LEACH algorithm, the nodes with high residual energy become cluster heads, in the process of transmission, multi hop transmission mechanism is adopted among cluster heads. Simulation results show that, this algorithm further reduces the energy consumption in the network, effectively extending the life cycle of the network.

Keywords*: Wireless Sensor Networks; clustering route algorithm; energy balance； LEACH;*

1. Introduction

Wireless sensor network technology is a modern sensor technology, microelectronics technology, communication technology, network technology and distributed information processing technology, such as the integration of multiple disciplines, with cheap, unattended, can be dynamic configuration, self-organization and good scalability. However, the battery energy of sensor node is limited and it is difficult to replace the battery due to its environment, so the energy consumption of sensor nodes is a great challenge for the sensor nodes [1]. So how to effectively extend the life cycle of the whole WSN becomes the main technical difficulty in wireless sensor networks.

The topology of WSN nodes can be divided into planar routing protocol and hierarchical routing protocol, the planar routing protocol is simple and robust, but its scalability is very poor. Hierarchical routing protocol is generally divided into initialization phase and data transmission phase [2]. In the WSN hierarchical structure, LEACH (low energy adaptive clustering hierarchy) clustering algorithm is representative. Based on the LEACH protocol, this paper adds the threshold, add the optimal number of cluster heads, energy factor and scale factor, the nodes with high residual energy become cluster heads, in the process of transmission,
multi hop transmission mechanism is adopted among cluster heads. This algorithm can make the selection of cluster head of the sensor network more reasonable, and further optimize the cluster structure, balance the network energy consumption, compared with the traditional LEACH algorithm, it can prolong the network life cycle.

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2. LEACH Protocol and Energy Consumption Model

2.1. LEACH Protocol

LEACH（Low Energy Adaptive Clustering Hierarchy）algorithm is used for wireless sensor networks. The basic idea of the algorithm is that, random selection of cluster head nodes in a cyclic manner, the energy load of the whole network is distributed on average to each sensor node, so as to achieve the goal of reducing network energy consumption and improving the overall survival time of the network [3,4].

The LEACH algorithm first defines the concept of "round "and "period", the every round is composed of two stages: cluster head election and stable work, And a work cycle consists of [N/K] wheel,N is the number of nodes in the network is the number of cluster heads that are expected to be generated in the middle of each round.

In the cluster head election stage, sensor nodes to generate a range of [0, 1] on the random number. If this random number is less than a preset threshold value T(n), the node is elected as cluster head(n) calculation methods such as the formula (1):

$$T(n)=\begin{cases}\dfrac{1}{1-p*\left[r \bmod (1/p)\right]} & n\in G \\ 0 & other\end{cases} \quad (1)$$

P is the number of cluster heads in the network, which accounts for the percentage of all nodes,r is the current number of rounds is a node set that has not recently become a cluster head[5].

After cluster head selected, new elected cluster heads broadcast their message to all nodes, the non-cluster head node is added into its cluster and return its message of the cluster to the corresponding cluster head. During the stable operation stage, the node collects the monitoring data to transmit to the cluster head, cluster head to receive, and then send the data to the base station.

LEACH protocol shows its advantages in many aspects, but also found its shortcomings, mainly lies in:

(1)The cluster head is randomly selected in the LEACH protocol, the number of options cannot be guaranteed, simultaneously, its position cannot do the best, some regional cluster heads may be more concentrated, some areas may not have a cluster head, lead to the distance of non-cluster head node and cluster head node is too large, the energy consumption is too large [6].

(2) LEACH protocol in the electoral cluster head, does not consider the current energy status of cluster head nodes, which affects the whole network's survival time. To minimize the energy consumption of the cluster is the fundamental choice of cluster head node, in addition, dynamic selection of cluster head nodes can effectively avoid the energy depletion of a single cluster head node[7].LEACH protocol can prolong the lifetime of nodes, balance the network load and so on, mainly because it uses a clustering algorithm and the cluster head rotation algorithm, but the LEACH protocol in the selection of cluster heads is random, this is likely to result in some small residual energy nodes, but it is selected as the cluster head, this leads to the disappearance of these nodes, which may be due to the depletion of energy, so as to affect the survival time of the network.

(3) Node in LEACH protocol through the single hop communication way to contact, such mechanism limits the size of WSN [8]. LEACH at the stable stage of the cluster, the cluster head is not passed through the intermediate nodes, direct communication with the base station, this also leads to excessive energy consumption of cluster head, which affects the network lifetime.

2.2. Existing Improved Algorithms and their Advantages and Disadvantages

Currently relevant researchers from the cluster head election threshold T(n), network energy and other aspects of this algorithm and they have been improved. Literature [9-10] use time delay mechanism to choose the cluster head, by setting a smaller waiting time for a larger energy node, so that the nodes with more residual energy have higher probability to become cluster heads. However, Literature [9] has not studied the number of cluster heads produced in each round, if the number of cluster heads is not stable, cluster head energy consumption is too large, and then affect the overall performance of the network. Literature [10] proposed algorithm, although the number of cluster heads is fixed, but the cluster head position is not good designed, so the network survival time is not effectively extended. In literature [11] the cluster head selection method of LEACH was improved, the method of single hop and multi hop is used to improve the energy efficiency of the system. Therefore, clustering of wireless sensor networks, with the goal of balancing the energy of nodes, try to propose an improved low power clustering algorithm.

2.3. Radio Communication Model

Wireless sensor networks use radio for transmission, including free space propagation model and multipath attenuation model, set threshold d_0 ,when the distance between sender and receiver d< d_0 ,The sender sends data and the energy consumption is proportional to the square of the distance of d, and the four party or is directly proportional to the distance d[12].

Node sends k bit data to a place where the distance is d, The energy consumed is formed by the emission circuit loss ε_{fs}, power amplifier loss ε_{amp},

$$E_{Tx} = \begin{cases} k*E_{elec} + k*\varepsilon_{fs}*d^2 & d < d_0 \\ k*E_{elec} + k*\varepsilon_{amp}*d^4 & d \geq d_0 \end{cases} \quad (2)$$

d_0 is defined as follows,

$$d_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{amp}} \quad (3)$$

The total energy for a receiver to handle a k-bit message is,

$$E_{Rx} = k*E_{elec} \quad (4)$$

According to the results obtained from the simulation experiments, the value of the communication energy parameters is constant.

3. Improved LEACH Routing Algorithm (My Leach Algorithm)

3.1. The Selection of Optimal Cluster Heads and Region Division

For LEACH protocol, the number of cluster heads is different, the energy consumption of the whole network is also different, and the total energy consumption gap is obvious. Therefore, it is significant to find the optimal cluster head with the minimum total energy consumption. In literature [6], the optimal number of cluster heads can be obtained by simulation experiments(5):

$$K_n = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}} \frac{M}{d_{to-BS}^2} \quad (5)$$

$d_{to\text{-}BS}$ is the distance between the node and the base station. N is total number of nodes, M is area for the monitoring area. The optimal number of cluster heads required by the current monitoring area can be determined by the formula. According to the optimal

number of cluster heads, the monitored area is divided. Division rule, According to the location of the base station, the whole area is divided into two equally large areas from the center line, which is closer to the base station area of S1,another area is defined as S2,then the optimal number of cluster heads is allocated to S1 and S2,ensure the S1 assigned the cluster head number is one more than S2 distribution of the cluster head. According to the number of cluster heads, the average distribution of their respective areas, through this way make sure non uniform clustering.

3.2. Select Cluster Head

The cluster head is randomly selected in the LEACH protocol. In the new algorithm, energy factor and node scale factor are simultaneously introduced. Through the energy factor, we can make the nodes with less energy consumption per round; At the same time, it can make the nodes in the densely distributed area have more opportunities to become cluster heads.

According to the formula (5) can be obtained:

$$P_O = \frac{K_n}{N} \tag{6}$$

So the formula (1) is modified:

$$T(n) = \begin{cases} \dfrac{P_0}{1 - P_0 * (r \bmod \frac{1}{P_0})} * (\alpha \dfrac{E_{current}}{E_{average}} + \beta \dfrac{N(n) - 1}{S}) & n \in G \\ 0 & other \end{cases} \tag{7}$$

P_0 is percentage of cluster heads in the network; $E_{current}$ is Residual energy for the current node; $E_{average}$ is average energy of all the surviving nodes in the cluster after this round; $N(n)$ is number of neighbor nodes for node; S is monitoring area; α and β are Regulation factor, and $\alpha + \beta = 1$ .After the cluster head election, the cluster head broadcasts the message to the cluster head in the other common nodes in the communication radius thereof, these common nodes receive this message, according to the received broadcast signal strength to choose to join the strongest signal of the cluster, and return to the cluster head.

3.3. Improved Communication between Cluster Head and Base Station

After selecting the cluster head, data transmission, will be used multi hop transmission, multi hop transmission path, you can use the two fork tree method to calculate. The principle of the algorithm [13] is as follows:

(1)N is Total number of cluster heads selected for each round, V is a set of other cluster heads in addition to the path starting cluster head O,S is the shortest path to the cluster head set,E(i) is energy consumption of the cluster head to the base station,E(i,j) is energy consumption of i from cluster head to cluster head j,node_id save id of the best path cluster head,the initial value of node_id is the value of the cluster head which ID is O.

(2)Find cluster head j in V,make E(0,j)＝Min{E|V j ∈V},then cluster head j is the next hop head of the minimum energy consumption of cluster head O,The path is E(O,j),the cluster head j into set S:S=S∪{j}.

(3)Find the next hop cluster head node j,starting from the cluster head J to continue to search for the next cluster head n,make cluster head n send data to the cluster head node j minimum energy consumption.

(4)Repeat steps(2),(3) until the arrival of the base station.

Through this algorithm, we can choose the best path, avoid the hot spot problem, and reduce the energy consumption of cluster head in communication.

3.4. Network Model

(1)N homogenous and energy-constrained wireless sensor nodes are distributed randomly in A*A region, the nodes cannot be moved and can sense their location information

(2)The base station is located far from the sensors and immobile.

(3)Each cluster head can know the other cluster heads ID and the distance to the base station (Cluster head can broadcast a building cluster message with its ID and the distance to the base station).

4. Simulation and Results

Using MATLAB tool to simulate LEACHED algorithm and LEACH algorithm, and to compare LEACHED algorithm with LEACH algorithm.100 nodes are distributed randomly in (0,0) and (100,100) of two-dimensional area, the base station in (100,240), relevant parameters are listed in Table 1.

Table 1. Simulation Parameters

parameter	value
Radio	1
Best cluster radius R[6]	15
Cluster formation time	35
Length of the fused data	10000
Initial energy of node /J	0.25
E_{elec}/nJ(bit) $^{-1}$	50
ε_{fs}/nJ(bit/m^2) $^{-1}$	0.0013
ε_{amp} /pJ(bit/m^4) $^{-1}$	10

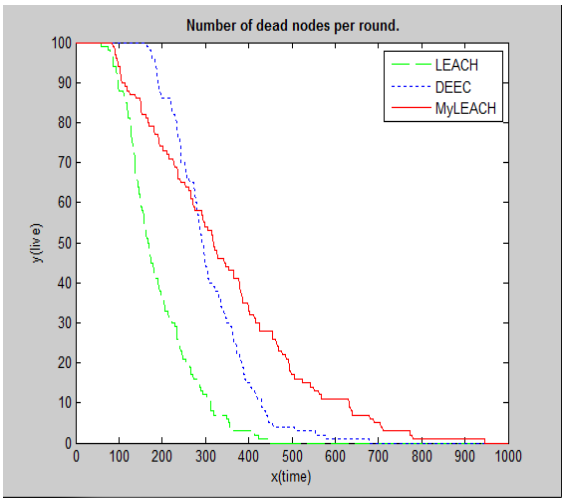

Figure 1. Number of Dead Nodes Per Round

Figure 1 can be seen, with the change of cycle, the other two algorithms consume all of the nodes in the 500th round and the 600th round, MyLeach algorithm has the long life of the node, at the same time, it shows that the improved algorithm can prolong the survival time of the network nodes.

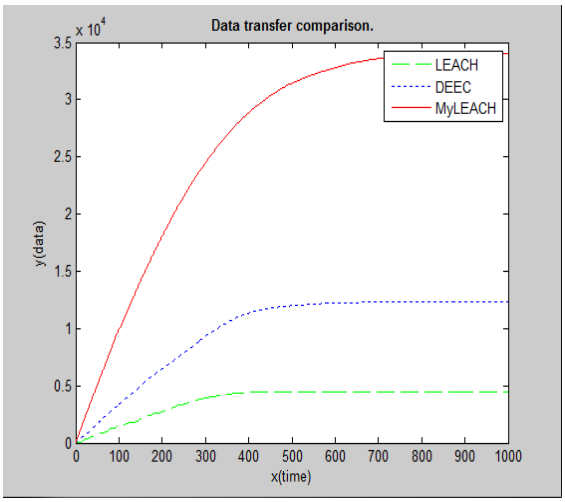

Figure 2. Data Transfer Comparison

Figure 2 can be seen, with the change of cycle, MyLeach algorithm in the data transmission of the amount of data with a greater amount of data transmission. Mainly because, MyLeach algorithm using multi hop transmission mechanism, this will reduce the energy consumption of cluster head, and has higher efficiency and ability in the data transmission.

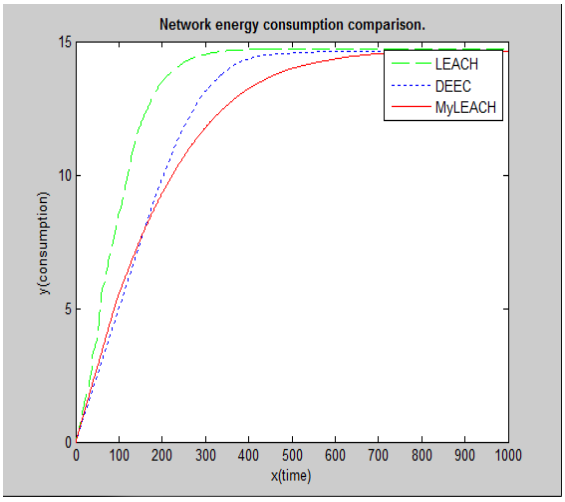

Figure 3. Network Energy Consumption Comparison

Figure 3 can be seen, with the change of cycle,MyLeach algorithm can be improved obviously in the energy consumption, because MyLeach algorithm determines the optimal number of cluster heads, and non-uniform clustering, cluster heads are selected according to the energy and other factors in each cluster, multi hop mechanism is adopted in the transmission process, compared with the other two algorithms, the energy consumption of the whole network is better balanced and the network lifetime is prolonged.

5. Conclusions

In this paper, based on the original LEACH algorithm, get the optimal number of cluster heads, non-uniform clustering, energy factor and scale factor are added in the cluster head election, during data transmission, multi hop data transfer between cluster heads and cluster heads. Simulation results show that the improved algorithm can prolong the network lifetime more effectively than LEACH.But there are some technical problems to be solved in this paper, for example, when the cluster head is in the multi hop transmission, the optimal path is selected, but it is possible that the energy of the node on the path is insufficient, at this time, considering the optimal path, the energy factor of the node on the path should be considered, in this respect also remains to be studied. In addition, in this paper, we use the data fusion technology, however, the impact of different data fusion technologies on data transmission and network life cycle is not discussed, these also need to focus on the content of the study in the future.

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