Energy Balanced Clustering Protocol for Wireless Sensor Networks

Lihong Wang, Ping Liu
Department of Computer and Information Engineering, Heihe University, Heihe 164399, China
116560629@qq.com

Abstract. Wireless sensor network is composed of a large number of sensor nodes by self-organization in the monitoring area. The energy, computing and communication capabilities of sensor nodes are very limited, and therefore a good routing protocol is very important to prolong the lifetime of the network. An energy-balanced clustering protocol is proposed to solve the inequality problem of consumption in routing protocol. Clustering protocol considers the residual energy of nodes and the distance between sink nodes in the selection of cluster head node, which can be more evenly distributed cluster head. On the basis of estimating the optimal cluster number, the clustering method is improved, the number of clustering is reduced, and the network energy consumption is saved. The simulation experiment shows that the Clustering protocol makes the whole network energy consumption more balanced and increases the life cycle of the wireless sensor network.

1. Introduction
Wireless Sensor Networks (WSN) is a wireless communication network composed of a large number of randomly distributed sensor nodes[1]. The sensor node is small, the energy is very limited, and it is difficult to supplement in the later stage[2]. The energy consumption of WSN is mainly divided into three parts: communication energy consumption, perceived energy consumption, and computational energy consumption, among which the communication process consumes the most energy, so reducing the communication energy consumption can extend the network life[3].

LEACH[4-7] is a classical clustering routing protocol. It makes random selection of cluster head nodes, which will cause individual nodes to fail prematurely, resulting in a shortened network life cycle.[8] And ... Literature[9] By estimating the residual energy, the mechanism of cluster selection is optimized. With the dormancy and working state of sensor nodes are carried out through evolutionary rules, the node dormancy is also carried out according to certain rules, which not only extends the survival time of wireless sensor network but also increases the data transmission. Literature[10] The selection at the beginning of the cluster heads is improved, the residual energy of the nodes and the average residual energy of the network are considered, and weighted factors are introduced. Literature[11] , literature[12] Based on the LEACH protocol, ant colony algorithm is introduced to improve the routing scheme, so as to find the optimal transmission path between the cluster head node and the base station, thus balancing the energy consumption of the cluster head node. In order to reduce the network communication energy consumption and prolong network life, the residual energy and current position of the cluster head in this paper are taken into account comprehensively in the selection of cluster head node. On the basis of estimating the number of optimal cluster heads, the clustering method is improved and the number of classification time is reduced.
2. LEACH Protocol

2.1. Selection Method of Cluster Head
In order to avoid premature death of sensor nodes due to excessive energy consumption in the wireless sensor network, LEACH protocol periodically randomly selects cluster-head nodes. After selecting cluster-head nodes, the other sensor nodes select corresponding cluster heads according to a certain set of rules and join to form clusters.

When the LEACH protocol selects the cluster head, each of the sensor nodes randomly generates a number between \([0,1]\), comparing the number to the set threshold. If the number is less than the threshold value \(T(n)\), then the corresponding node will be selected as the cluster head [13]. The computational formula of threshold \(T(n)\) is as follows:

\[
T(n) = \begin{cases} 
0 & n \in G \\
 p & n \notin G \\
1 - p * \left( \frac{r}{P} \right) \mod \left( \frac{1}{p} \right)
\end{cases}
\]  

(1)

Where \(G\) is a collection of nodes that have not been selected as a cluster head in a cycle, \(P\) refers to the percentage of cluster heads among all nodes, and \(r\) is the number of selected rounds.

2.2. Formation process of clusters
When a node becomes a cluster head node, a message is broadcast to tell the other nodes that it is the cluster head of this round, which contains the location information of the cluster head node. The non-cluster head node selects the node source of the best received node as the cluster head node in receiving multiple messages and sends the request message of joining to the cluster head node. The cluster head, after receiving a request from the member node, sets up a TDMA schedule for each node, and transmit the schedule to each member node. The specific process is shown in Figure 1.

![Fig.1 The formation of clusters in LEACH protocol](image)

2.3. Data transmission process
The nodes transmit the collected data to the cluster head according to the TDMA schedule, and each node sends the data information within the time slot assigned to it. In order to save energy, it should remain dormant in the non-time slot. The cluster head node is always active in order to guarantee the accuracy of the receiving data. The cluster head receives the data for data fusion, removes redundant information, and sends it to the sink node. The specific process is shown in Figure 2.
2.4. Deficiencies of LEACH Protocol

LEACH protocol can allocate energy consumption to all sensor nodes of the entire network as much as possible so as to reduce energy consumption of the network and improve network performance. However, there are still some deficiencies, mainly as follows:

1. Failing to consider the location of nodes, by setting the threshold value to select cluster head, so that the cluster head nodes cannot be evenly shared to the entire network and cannot form the optimal.

2. Failing to take into account the residual energy of the node, the random probability of each node being selected as a cluster head is equal. If a low-energy node is selected as a cluster head, it will lead to its premature death, which affects the life of the entire network.

3. The cluster head node communicates directly with the sink node, and the data information fusion is not much. The farther the cluster head node is from the base station, the faster the energy consumption will be, resulting in shortened network life cycle and less coverage area.

3. Improved protocol of cluster

3.1. Deficiencies of LEACH Protocol

In order to make the energy loss of each node in WSN relatively balanced, the threshold value of nodes with relatively more residual energy and better location should be increased in the selection of cluster head nodes. In other words, the residual energy of nodes and the distance from sink node should be considered in the calculation formula of cluster head selection. The specific formula is as follows:

\[
T(n) = \begin{cases} 
0 & \text{if } n \in G \\
\frac{p}{1-p^{\{r \mod (1/p)\}}} \frac{E_0}{E_0 + (1-p^p)} \frac{D_n}{D_{max}} & \text{if } n \notin G 
\end{cases}
\]  

(2)

Where \( \rho \) is the weighted factor of energy and distance, \( E_0 \) is the node initialization energy, \( D_{max} \) is the maximum distance from the sensor node to the sink node.

3.2. Deficiencies of LEACH Protocol

A key parameter in the application of the LEACH protocol is the number of cluster head nodes. If the number is few, the task of cluster head nodes will be aggravated, leading to large communication energy consumption and shortened network life. Instead, with too many clusters, the amount of data transmitted to the sink node will be large and the data fusion rate will be reduced. However, since the energy consumed by the cluster head node is much higher than that of the nodes in the cluster, it increases the energy consumption of each round of network, and accelerates the destruction of the network.
In the LEACH protocol, the idea of selecting the optimal cluster head number is that N sensor nodes are randomly distributed in an area with a radius of R, divided into k sub-clusters, and the number of nodes within each cluster is equal. The optimal cluster head number k is:

$$k = \sqrt{\frac{\pi N}{2} \frac{\frac{\sigma}{\xi f_c}}{\frac{R^2}{d_{toBS}}}}$$

(3)

Where \(\frac{\sigma}{\xi f_c}\) is a constant, which is related to the selected channel model; \(d_{toBS}\) is the distance from the cluster head node to the base station.

3.3. Improved Clustering method

The specific process of the improved clustering method is as follows, and the flowchart is shown in Figure

Step 1: Estimate the optimal number \(K\) of cluster heads

Step 2: Setting the maximum number \(M\) of nodes in clustering

Step 3: Counting neighbor node value \(M_j\) of each node

Step 4: \(M_j > M\)?

Yes → Abandoning this group of nodes and clustering automatically

No → Sort nodes according to the number of neighboring nodes

Step 5: Are there adjacent nodes in the sequence?

Yes → Abandoning the least number of adjacent nodes

No → The whole network is divided into \(K\) clusters

Fig.3 Improved clustering process

Step 1: Estimate the optimal cluster head number \(K\) based on the specific situation of the node distribution in the wireless sensor network according to formula 2, set the maximum value of nodes as \(M\) in the clustering structure, and count the number of adjacent nodes in the network as \(M_j\).

Step 2: If \(M_j > M\), abandon this group of nodes to form a cluster automatically; If \(M_j < M\), sort by the size of the number of adjacent nodes of each node.

Step 3: Judge whether there are adjacent nodes in the sequence, and if not turn to step 4. In contrast, discard the least number of adjacent nodes, turn to step 4.

Step 4: Divide the entire network into \(K\) sub-clusters according to the order of the number of adjacent nodes in the sequence

4. Simulation experiment and result analysis

In this paper, the simulation experiment scene is designed as follows: the monitoring area size is 100m*100m, the number of sensor nodes is 100, the energy of each sensor node is equal to 0.5j, the sink node is (50,50). The node distribution is shown in the figure 4. The red * represents the sink node, the red * represents the cluster head node and the blue ○ represents the ordinary node.

The paper makes a comparison on the number of dead nodes. It is clearly shown from the figure 5 that the death time of the first node of LEACH protocol is about 180 rounds, and all nodes died about 370 rounds. The first node death time of the improved LEACH protocol is about 240 rounds, and all
nodes died about 500 rounds. It shows that the improved LEACH protocol makes the node fail slowly, improves the network lifetime and prolongs the network life.

Fig. 4 Distribution of Sensor Nodes

Fig. 5 Network lifetime comparison

After the network has been running for a period of time, part of the node dies due to the energy consumption. The death nodes of the LEACH protocol are the furthest from the sink node, that is, because the distance to sink nodes is not taken into account in the selection of cluster head nodes, sensor nodes far from sink nodes die prematurely due to energy consumption. The improved LEACH protocol takes into account the distance of sink nodes, and the distribution of dead nodes is relatively scattered. The red ★ represents the sink node, the red * represents the cluster head node, the red ○ represents the former cluster head node, the blue ○ represents the ordinary node and the black ● represents the dead node. The distribution of dead nodes in LEACH protocol is shown in Figure 6, the distribution of dead nodes of improved LEACH protocol is shown in Figure 7.

Fig. 6 Dead Node Distribution of LEACH

Fig. 7 Dead Node Distribution of Improved LEACH

5. Conclusion

Aiming at the deficiency of LEACH protocol in the selection of cluster head node and the improvement of clustering method, a wireless sensor network routing protocol based on the improved LEACH protocol is designed. By comparing with LEACH protocol through simulation experiment, it is clear from the comparison result that the improved LEACH algorithm delays the death time of nodes, so as to improve the survival rate of nodes. The location of the death node is dispersed, which makes the network energy load more balanced and extends the life cycle of the network.

Acknowledgments

This work was financially supported by the Young Scholars with Creative Talents of Heilongjiang Education Department (2017-KYYWF-0360).
References

[1] Kalpna Guleria; Anil Kumar Verma. An energy efficient load balanced cluster-based routing using ant colony optimization for WSN. International Journal of Pervasive Computing and Communications, 2018, 08: 233-240.

[2] LIN Y H, CHANG S Y, SUN H M. CDAMA: Concealed data aggregation scheme for multiple applications in wireless sensor[J]. IEEE Transactions on Knowledge and Data Engineering, 2013, 25(7): 417-483.

[3] LI Lanying, LIU Changdong. An Improved Algorithm of LEACH Routing Protocol in Wireless Sensor Networks [J]. Journal of Harbin University of Science and Technology, 2015, 20(2): 75-79.

[4] J Changjiang, S Wenren, X Min, et al. Energy-balanced Unequal Clustering Protocol for Wireless Sensor Networks [J]. The Journal of China Universities of Posts and Telecommunications, 2010, 17(4): 94-99.

[5] DONG Guo-yong, PENG Li, WU Fan, et al. Energy-balanced Uneven Clustering Routing Protocol Based on Ant Colony Optimization for Wireless Sensor Networks [J]. Journal of Chinese Mini-Micro Computer Systems, 2015, 36(7): 1565-1568.

[6] LIU Lin-feng, GUO Ping, et al. Data Collection Strategy Based on Improved LEACH Protocol [J]. Computer Science, 2015, 42(6): 299-302.

[7] CHEN Bingcai, YAO Huazhuo, et al. A Inter-Cluster Multi-Hop Routing Protocol Improved Based on LEACH Protocol [J]. Chinese Journal of Sensors and Actuators, 2014, 27(3): 373-377.

[8] FENG Yan-fen, LIU Yan-bing. Low energy-consuming cluster-based private data aggregation [J]. Application Research of Computers, 2013, 30(3): 885-888.

[9] WANG Baiting, ZHOU Zhanying, et al. Multi-Hop Unequal Clustering Routing Protocol Based on Energy Consumption Balance [J], Journal of Jilin University (Information Science Edition), 2016, 34(2): 174-181.

[10] Tan Jun. LEACH Routing Protocol in Wireless Sensor Network Based on Improvement of Cluster Head Selection [J]. Computer Applications and Software, 2015, 32(6): 171-173.

[11] MEN Shunzhi, SUN Shunyuan, XU Baoguo. Wireless Sensor Networks Non-Uniform Clustering and Delustering Heads Routing Algorithm Based on PSO [J]. Chinese Journal of Sensors and Actuators, 2014, 27(9): 1281-1286.

[12] WANG Lingjiao, et al. An Optimal Clustering Selection Strategy Study on the Weighted NCHS-Leach Protocol [J]. Chinese Journal of Sensors and Actuators, 2015, 28(12): 1846-1850.

[13] YANG Geng, et al. An Energy-Saving Privacy-Preserving Data Aggregation Algorithm [J]. Chinese Journal of Computers, 2011, 34(5): 792-800.