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LEACH-A: An Adaptive Method for Improving LEACH Protocol

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Abstract: Energy has become one of the most important constraints on wireless sensor networks. Hence, many researchers in this field focus on how to design a routing protocol to prolong the lifetime of the network. The classical hierarchical protocols such as LEACH and LEACH-C have better performance in saving the energy consumption. However, the choosing strategy only based on the largest residue energy or shortest distance will still consume more energy. In this paper an adaptive routing protocol named "LEACH-A" which has an energy threshold E0 is proposed. If there are cluster nodes whose residual energy are greater than E0, the node of largest residual energy is selected to communicated with the base station; When all the cluster nodes energy are less than E0, the node nearest to the base station is select to communication with the base station. Simulations show that our improved protocol LEACH-A performs better than the LEACH and the LEACH-C.

Keywords: Wireless sensor network, LEACH, LEACH-C, Energy efficient.

1. Introduction

Wireless Sensor Network (WSN) is a kind of self-organizing network system, which consists of a large number of distributed sensor node. Sensors are usually powered by batteries which energy is limited. Hence, research on energy efficient communication protocol or algorithm to save energy have become one of the main problem in sensor networks [1].

Low Energy Adaptive Clustering Hierarchy (LEACH) is proposed as a WSN clustering routing protocol with low consumption. Its clustering structure has good extensibility used and inherited in most existing clustering routing protocol. However, LEACH and some improvement protocol for example LEACH-C also have some shortcomings, because there is no guarantee for balance of consumption between cluster nodes. This condition may result in some cluster nodes to die earlier and shorten the lifetime of the network. Thus, an adaptive routing protocol named "LEACH-A" is proposed to balance the energy consumption between cluster nodes. In section 2 the classical routing protocols of LEACH and LEACH-A are introduced and their shortcomings is analyzed. In section 3 we give the detail of the improved routing protocol LEACH-A. In section 4 two classical routing protocols and LEACH-A are simulated in NS2 and their performances are compared with each other. At last, we give the summary of this paper.

2. Analysis of LEACH and LEACH-C

2.1 LEACH Protocol Algorithm

LEACH is designed for wireless sensor network. The basic idea is to divide network into different clusters, random selection of cluster head node, and other nodes join the cluster by the principle of proximity, and then form a cluster. Within the cluster nodes will send data to cluster head node, then cluster head node can compress the data and send to the Sink node [2].

LEACH chooses cluster heads using the method of "round". Its operation is divided into two stages: the first stage is establishing a cluster and the second stage is the stable data transmission. All the nodes can be divided into several clusters, and each cluster select a cluster head node randomly. Generated a random number between 0 and 1, if each node's random number is less than the certain threshold T(n), then the node becomes the cluster head nodes. The threshold T(n) is defined as below:

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

where p is the percentage of cluster nodes in the network accounting for the total number of nodes; r is the number of completed rounds; G is a collection, the nodes of a collection is the nodes whose previous r rounds do not act as nodes of cluster nodes [3].

2.2. The Disadvantage of LEACH

LEACH has good performance in terms of energy consumption, but there are still shortcomings:

1) In the LEACH algorithm, random selection of cluster head nodes can't guarantee the uniform distribution of the space, which leads to part of the cluster nodes can't join into any cluster member or members of the node, and the cluster head nodes consume too much energy during the data transmission.

2) Cluster head node and Sink node take use of direct communication which cause the sensor far away from Sink node consume more energy [4].

3) Cluster head selection does not consider the residual energy of the nodes, which make the nodes with less residual energy as the cluster head possible, in this case, it can accelerate the death of the node, thus reduce the network lifetime.

2.3. Analysis of the Improved Scheme

Since this paper is based on the improved LEACH-C protocol, herein is the protocol introduction.

LEACH-C algorithm well uses the characteristics of the base station, which is responsible for the selection of cluster head, at the beginning of each round, all nodes will send their own energy and position information to the base station, the stations uses simulated annealing algorithm, each round of selection is no longer a random selection of cluster head, but through control valve value, on condition that the result of the node value is greater than the threshold, the node can be selected as the cluster head.

Communication of second cluster heads with the base station BS is no longer a single jump way, but multiple jumps.

However, the result of clustering is centrally controlled by the base station, base station needs to know the location and energy information of each node, at the same time the nodes need to know how to cluster through message sent from the base station, which limits the usage scope into a certain range, so that is a good choice for the small-scale network [5]. But the algorithm in the improvement of the network node does not contribute a lot in energy saving, as the clusters energy consumption is larger, similarly, the probability of network traffic, signal interference and time delay will increase.

3. The Improved of LEACH Protocol

Focus on the shortcoming of LEACH and LEACH-C protocol, we proposed an adaptive improved routing protocol LEACH-A. Its selection phase of cluster head retains the simulated annealing algorithm of LEACH-C protocol, the selection of cluster head in each round is no longer a random selection, but follow the control threshold, only when the nodes of the resulting value is greater than the threshold, the node can be selected to be the cluster head.

This protocol is mainly improved to the hop count of transmitted data in the transmission phase of cluster head nodes to the BS (Base Station) so as to keep the balance of energy consumption and prolong the survival time of network. LEACH-A not only guarantees the rational distribution of cluster heads, but also adopts the adaptive transmission through intermediate nodes, taking much progress in terms of network node energy saving. The improved algorithm has following two cases [6].

Both the following two different cases happen when cluster head selection finished in data transmission phase.

1) While the residuary energy of the existing cluster nodes is greater than the E0 (E0 is a ratio of initial energy of node, E0=3/5 the best effect is obtained by experiment), we need to find the cluster head with the largest energy to be the cluster leader, other cluster heads send data to the leader, then, the leader send the fused data to BS [7]. As it is shown in the Fig. 1.

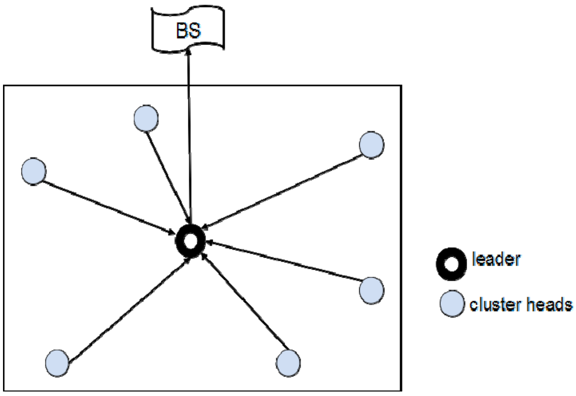

Fig. 1. Case of maximum residual energy selection.

2) When the residual energy of the selected cluster head nodes is less than E0, we need to find a nearest cluster head to BS as leader, The rest of the cluster heads will find out their shortest path to the leader by its algorithm, send data through the shortest path to leader, leader send fused data to BS. As shown in the Fig. 2.

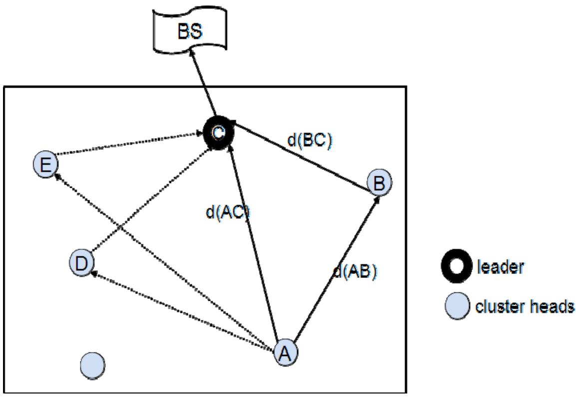

Fig. 2. Case of nearest node selection.

Node C as a leader. If the cluster heads A send data to BS, we will find out all of y-axis is greater than A node in the area of cluster head nodes (except leader), above, there are three nodes in the y-axis is greater than A cluster head node, the node B, D, E. Choose a shortest path in the distance from A to B, D E and B, D, E to C, it can be seen that d(AB)+d(BC) is the shortest from figure and compare the shortest path to A node directly to leader distance d(AC). Then when: d(AB)+d(BC)<d(AC), the node A will choose B to transfer data to the C. On opposite, A sends the data to leader directly [8].

4. Simulation Experiment and Analysis

4.1. Simulation Model

The experiment is under NS-2 simulation platform of Ununtu10.04 system version 2.27, some of the network Settings are shown in Table 1.

Table 1. Simulation parameters.

Parameter Name	Symbol	Parameter values
Number of nodes	Nodenums	100
Experimental area length	AreaR	200
Initial energy/J	InitEn	0.5
Relative position of the base station	Bx,By	100, 250
Proportion of cluster head nodes	P	0.05

4.2. Performance Evaluation Index

The length of network time is based on the number of survival nodes. The improved protocol is designed with main goal of balancing the energy consumption of all the nodes, prolonging the survival time of network, increasing network data traffic. Therefore three methods can be used to measure the performance of the routing protocols.

1) The survival nodes of network: in the life cycle of network, the more of the surviving nodes, the longer survival time of network.

2) Residual energy of nodes: remaining energy of all nodes in the current round of number. The higher the residual energy of nodes, the slower speed nodes die, which prolongs the survival time of the network [9].

3) Network data: the sending amount of data is received by all nodes in the current round number collection of network. The bigger quantity of network data, the better connection of network and the less quantity of nodes will lose connection.

4.3. Simulation Results

1) Comparative analysis of remaining live node and number of round

Fig. 3 illustrates the changeable situation of the remaining node number of wheel along with the LEACH, LEACH-C and the improved LEACH-A deal in the process of running. From Fig. 3, we can see that the appeared time of the first dead nodes for LEACH algorithm is probably around 200 rounds. LEACH-C is probably about 370 rounds, and the first dead node of the improved algorithm LEACH-A occurs about in 500 rounds, which is 300 rounds later than LEACH algorithm and 100 rounds later than LEACH-C. It is proved that the efficiency loss of improved algorithm LEACH-A nodes is slow, which increases the efficiency of the network energy, prolongs the survival time of network.

2) Comparative analysis of surplus energy and the number of chakra

Fig. 4 shows that as the increase of round number, the residual energy of each node for all algorithms is reduced, the residual energy of the improved agreement for LEACH-A is the maximum, far higher than that of LEACH, LEACH-C algorithm [10]. It means that LEACH-A effectively reduces the overall energy consumption of network.

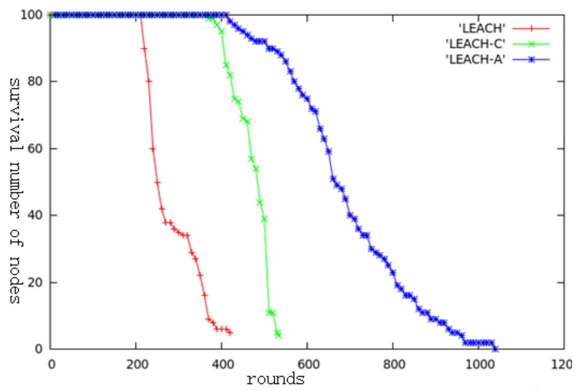

Fig. 3. The survival number of nodes and rounds.

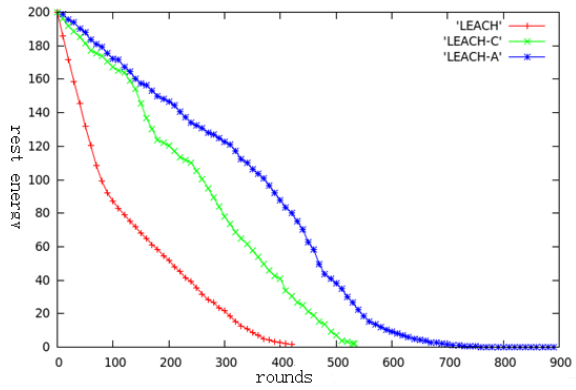

Fig. 4. The residual energy and rounds.

3) Network data volume and comparative analysis of the number of round

In Fig. 5 LEACH-A algorithm in the current round of the network receives more data than LEACH and LEACH-C algorithm, the improved algorithm obviously helps to increase the volume of data transmission for network.

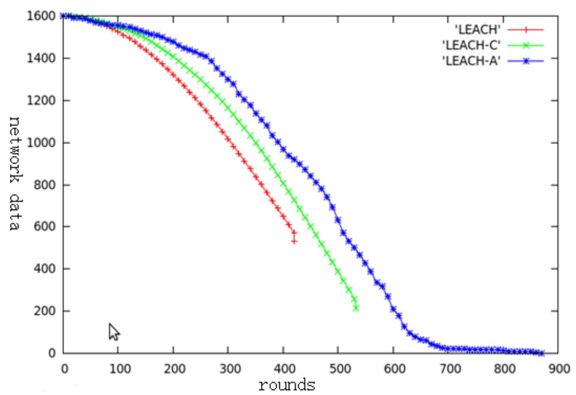

Fig. 5. The network data volume and rounds.

The experiment shows that the improved LEACH-A protocol is superior to the original LEACH protocol, LEACH-C protocol, manifested in the survival time of network, the residual energy of all nodes and the total amount of network data collection. This indicates that the improved protocol points to select a transmission mode in the inter-cluster transmission basing on the intermediate node, finding the shortest path, effectively shortening the communication distance between cluster head nodes, which makes the communication between the cluster head node and the base station consume less energy, thereby reduce the network energy consumption and prolong the survival time of the network, so as to extend the lifetime of the network.

Finally, the simulation results show that the new protocol can effectively balance the network energy consumption and prolong the network lifetime, better meet our expectations [11].

5. Summary

Energy efficiency has become one of the most important constraints on wireless sensor networks. Hence, many researchers in this field focus on how to design a routing protocol to prolong the lifetime of the network. The classical hierarchical protocols such as LEACH and LEACH-C have better performance in saving the energy consumption. However, the choosing strategy only based on the largest residue energy or shortest distance will still consume more energy. In this paper an adaptive routing protocol named “LEACH-A” which has an energy threshold E0 is proposed. If there are cluster nodes whose residual energy are greater than E0, the node of largest residual energy is selected to communicated with the base station; When all the cluster nodes energy are less than E0, the node nearest to the base station is select to communication with the base station. Simulations show that our improved protocol LEACH-A performs better than the LEACH and the LEACH-C.

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References

[1]. L. Wang, W. Ye, H. Wang, et al., Optimal node placement of industrial wireless sensor networks based on adaptive mutation probability binary particle swarm optimization algorithm, *Computer Science and Information Systems*, Vol. 9, Issue 4, 2012, pp. 1555-1578

[2]. F. Dressler, R. Koch, M. Gerla, Path Heuristics using ACO for inter-domain routing in mobile ad hoc and sensor networks, *Bio-Inspired Models of Network, Information, and Computing Systems*, *Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, Vol. 87, 2012, pp. 128-142.

[3]. Yan Zhongjiang, Shen Zhong, Chang Yilin, A minimum sensor deployment algorithm for non-connected wireless sensor network, *Journal of Beijing University of Posts and Telecommunications*, Vol. 34, No. 5, 2011, pp. 15-18.

[4]. Z. Zhou, S. Zhou, S. Cui, et al., Energy-efficient cooperative communication in a clustered wireless sensor network, *IEEE Transactions on Vehicular Technology*, Vol. 57, Issue 6, 2008, pp. 3618-3628.

[5]. Y. Lin, J. Zhang, H. S. H. Chung, et al., An ant colony optimization approach for maximizing the lifetime of heterogeneous wireless sensor networks, *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, Vol. 42, Issue 3, 2012, pp. 408-420.

[6]. R. V. Kulkarni, A. Forster, G. K. Venayagamoorthy, Computational intelligence in wireless sensor networks: A survey, *IEEE Communications Surveys & Tutorials*, Vol. 13, Issue 1, 2011, pp. 68-96.

[7]. W. Guo, J. H. Part, L. T. Yang, et al., Design and analysis of a MST-based topology control scheme with PSO for wireless sensor networks, in *Proceedings of the IEEE Asia-Pacific Services Computing Conference (APSCC' 11)*, 2011, pp. 360-367.

[8]. W. Li, W. Shen, Swarm behavior control of mobile multi-robots with wireless sensor networks, *Journal of Network and Computer Applications*, Vol. 34, Issue 4, 2011, pp. 1398-1407.

[9]. Z. Ali, W. Shahzad, Critical analysis of swarm intelligence based routing protocols in adhoc and sensor wireless networks, in *Proceedings of the IEEE International Conference on Computer Networks and Information Technology (ICCNIT)*, 2011, pp. 287-292.

[10]. J. Chen, J. Li, S. He, et al., Energy-efficient coverage based on probabilistic sensing model in wireless sensor networks, *IEEE Communications Letters*, Vol. 14, Issue 9, 2010, pp. 833-835.

[11]. R. V. Kulkarni, G. K. Venayagamoorthy, Particle swarm optimization in wireless-sensor networks: A brief survey, *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, Vol. 41, Issue 2, 2011, pp. 262-267.