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Leach-H: An Improved Routing Protocol for Collaborative Sensing Networks*

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Abstract—**In order to prolong the WSN's lifetime, a refined protocol named LEACH-H (Hybrid Cluster Head Selection Leach) is proposed in this paper. In the first round of Leach-H, the base-station selects a cluster head set through adopting Simulated Annealing Algorithm; in the followed rounds, the cluster heads will select new cluster heads in their own cluster. This will not only solve the problem that the cluster heads are unevenly distributed in LEACH, but also maintain the characteristics of distribution. The energy consumption of the network is cut down and the live time of WSN is extended in Leach-H.**

***Keywords*—Leach, Annealing Algorithm, Cluster Head, Reconstruc-tion, NCH (cluster member)**

Ⅰ. INTRODUCTION

With the development of wireless sensor network, many routing protocols have been proposed at home and aboard. From the perspective of network topology, we can divide them into plane routing protocols and level routing protocols. Typical plane routing protocols are DD [1], SAR [2], SPIN [3], RomorRouting[4] and etc; Typical level routing protocols are LEACH[5], LEACH -C[6], PAGASIS[7], and TEEN[8] etc.

LEACH is a more mature clustering routing algorithm, but it still have defect of short survival time and is low degree of load-balancing. The cluster head is selected randomly in Leach, and this is likely to bring some of the inefficient sub-clustering schedules. LEACH-C resolves the problem of the uncertain number of cluster heads in Leach effectively through using simulated annealing algorithm [9]. And the cluster head selection is optimized in Leach-C. But Leach-C is centralized, not suitable for large-scale networks.

Leach-H which is proposed in this paper combines advantages of LEACH and LEACH-C. Cluster head is selected in the first round by base station in Leach-H, which effectively resolves the problem that the number of cluster head is uncertain in Leach. In the second round and follows, the new cluster head used in the next round is selected in their own cluster by the current cluster head in Leach-H, which resolves the issue of the dependence on the base station in Leach-C.

The finally simulation experiment shows that, Leach-H can significantly increase the survival time of the network and the extent of load-balancing.

The probability for a node to become a cluster head is the same in Leach. And nodes with lower energy, once selected as the cluster head, are easy to run out of energy and die. LEACH ignored the distribution of network nodes and different communication distances between cluster heads and cluster members, which will easily lead to low degree of the loading balance of the network.

Unlike Leach, Leach-C performed in a centralized style. This can make up for deficiencies in Leach.

But LEACH-C requires the BS (Base station) to control the whole network. In the distributed environment for wireless sensor networks, the nodes may not send their own information to the base station due to some uncertain environment factors. Thus BS will not be able to elect the optimized cluster head according to the situation of the network. At the beginning of each round, base station will run the simulated annealing algorithm to choose a new cluster head set. This process will increase the energy consumption and time expenses. Leach-C network is incapable in fault-tolerant and less robust. It is not suitable for large-scale deployment of WSN.

Ⅱ. IMPROVED PROTOCOL LEACH-H BASED ON LEACH

In this paper, a new protocol named Leach-H which is based on LEACH is proposed. Leach-H use simulated annealing algorithm to select the optimized cluster head set in the first round. After the first round of clustering, the new cluster head is selected in their own cluster by the former cluster head in Leach-H.

A. Initialization of cluster

In the initialization phase, we use simulated annealing algorithm to optimize the distribution of cluster division. Base station run the simulated annealing algorithm to decide which nodes will serve as the Q cluster heads in the first round. These cluster heads will ensure that this round of the entire network performed in a low power consumption. In the iterative process, we suppose that collection C represents the

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current cluster head set, and collection C' represents the new cluster head set. f(c) stands for the energy consumption of the network whose cluster heads set is collection C. f (C') stands for the energy consumption of the network whose cluster heads set is collection C'. If f (C ') <f(c), Leach-H will assign C' as the next cluster heads set. Otherwise, Leach-H will determine C ' to become the next cluster heads set in accordance with the probability P_k. P_k is calculated as follows:

$$p_k = \begin{cases} e^{\frac{-(f(C')-f(C))}{\alpha_k}} & f(C') \geq f(C) \\ 1 & f(C') \leq f(C) \end{cases} \qquad (1)$$

f(c) is defined as follows:

$$f(C) = \sum_{i=1}^{N} \min d^2(i,c)$$

d(i,c) stands for the distance between node I and node c; α_k is a control parameter ,and it is used to ensure the convergence of the algorithm .

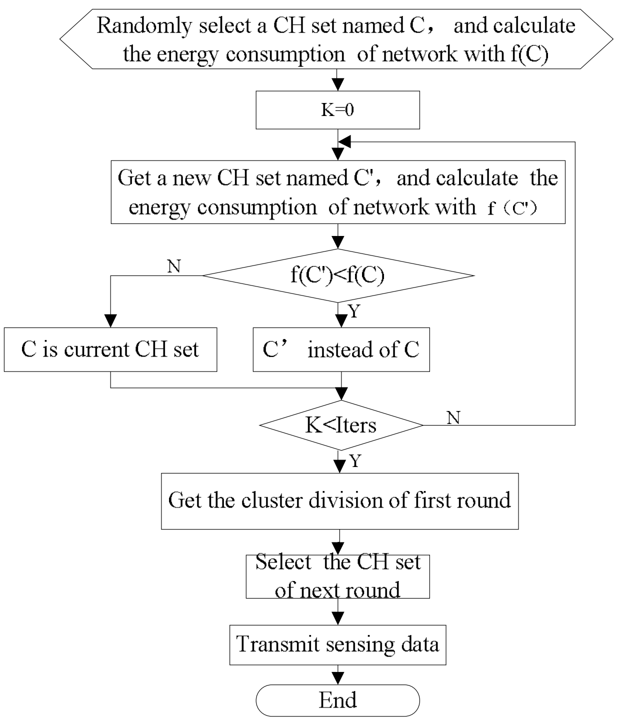

Figure1. Process in the first round

B. Reconstruction of cluster

In the second rounds and follows, the new cluster head used in the next round is selected in their own cluster by the current cluster head in Leach-H. If the cluster member wants to be elected as the cluster head in the next round, they should meet the principles as follows:

1) The node should not be the cluster head in the current round.
2) Its residual energy should be more than the average energy of the network.
3) It should be close to the center of the cluster.

If the above conditions can not be satisfied at the same time, the node which is most close to the center of the cluster will be elected as cluster head for the next round.

Because the CH (Cluster Head) node consume more energy than NCH node, the CH node of the current round is not appropriate to become the CH node of the next round. In addition, the CH node must have a relatively more residual energy. The data transmission will be affected if the CH node runs out of energy. In order to reduce the transmission distance between the CH and NCH, it is necessary to select the node which is near the center of the cluster as the CH node for the next round.

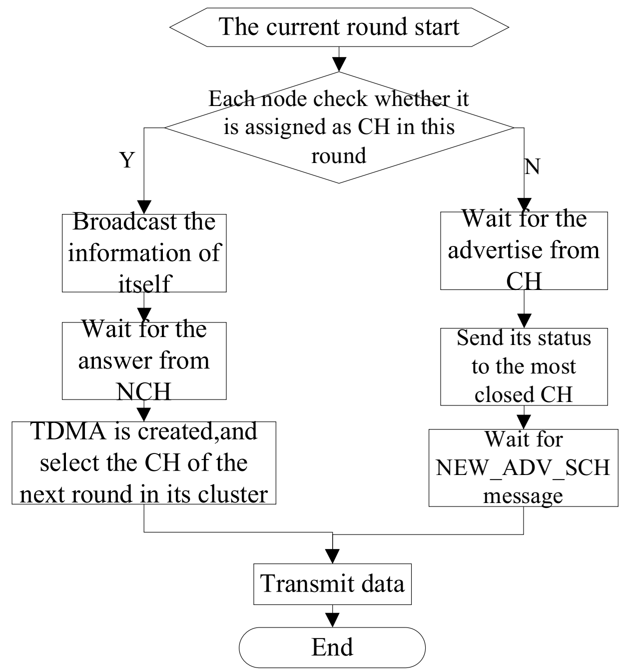

Figure2. Reconstruction of cluster

C. Workflow details of Leach-H

In this paper, the LEACH-H combines the advantages of Leach and Leach-C. In the initial stage of the establishment of clusters, BS selects k (k is the optimal number of clusters) cluster heads to divide clusters. According to the information of the current nodes, the next round CH node will be assigned by the BS also. Before the data transmission, the information of the first round CH and the second round CH will be advertised into the network. At the beginning of the second round, each node will check whether it is assigned to become a CH in the former round. If it is the CH in this round, it will decide which node can become the next round cluster head in its own cluster, according to the current distribution and energy of NCH. Later the result of selection will be sent to the NCH nodes. Then the following rounds will repeat the same process of the second round.

The process of Leach-H is listed as follows:

Step1. Each node sends the information (INFO) of its condition to BS. The information includes the location of the nodes and the remaining energy.

Step2. Other nodes and the BS receive the information (INFO) and store it.

Step3. Base station run the simulated annealing algorithm to decide which nodes will serve as the k cluster heads in the first round. The next round CH nodes in the divided clusters is assigned by the base station also. The message (BS_CH_INFO) included with these results will be broadcasted later.

Step4. Nodes which receive the messages will check their current status. If it is chosen as CH nodes, it will wait for the data sent from the NCH nodes; if it isn't chosen as CH nodes, it will sends the Collecting data to its CH node in its slot. After the first round, Leach-H will go to Step5.

Step5. Each node will check whether it has been selected as the CH node in the first round. If it is chosen as CH node, Leach-H will go to Step6. Else it will go to Step7.

Step6.CH broadcasts its own information (ADV_CH) to the network, and listens to NCH's access message. If the CH node has already received the message, Leach-H will go to Step8.

Step7. NCH listens to the ADV_CH from the CH. If NCH receives the ADV_CH, NCH will send the message (NEW_JOIN_CH) contained with its remaining energy to the CH. Then NCH listens to the scheduling message (NEW_ ADV _CH) generated by the CH. If the NCH receives the scheduling message, Leach-H will go to Step 9.

Step8. According to the NCH's location and residual energy, the current cluster head selects the new cluster head used in the next round in their own cluster, and sends the scheduling message (NEW_ADV_CH) to them.

Then CH waits for the Sensing Data from NCH. After this round, Leach-H goes to Step 9.

Step9. After NCH receives NEW_ADV_CH, NCH will record its status in next round and transmit the sensing data to CH in schedule. If this round is over, Leach-H will go to Step5.

Ⅲ. Message structure

A. BS_CH_INFO

The value of one section represents the ID of this node's CH (Fig 3).We suppose that CH (i) is the value stored in block i and CH (j) is the value stored in block j. Then we can infer that:

1）If CH(i) is equal to CH(j),it says that node i and node j is in the same cluster.

2）If CH(i) is equal to i, it says that node i is a CH in its cluster.

For example, structure [list 0 1 0 0 0 1 0 7 1 0] represents that there are 10 nodes and 3 clusters in this network. Node 0, node 1 and node 7 are CH nodes. Node 0 is the cluster head of node 0, 2, 3,4,6,9. Node 1 is cluster head of node 1, 5, 8. Node 7 is cluster head of its own, and it has no cluster members.

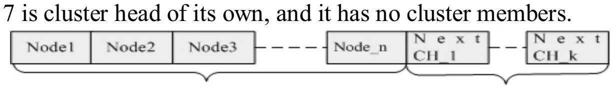

Figure3. BS_CH_INFO message structure

B. NEW_ ADV_ SCH

This structure is shown in Fig4. One part is the scheduling list of the NCH in their cluster. Another part is the Id of the CH in the next round.

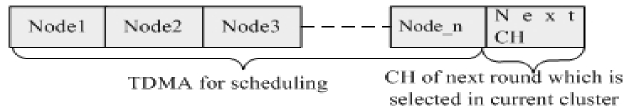

Figure4. NEW_ADV_SCH message structure

For example, CH 0 advertises a structure as [list [list 2 3 4 6 9][list 4]]. It means that the NCH will be scheduled in accordance with the order of 2, 3,4,6,9. In the meantime, NCH 4 is assigned as CH of the next round.

Ⅳ. Simulation

A. Experimental model

Leach utilizes energy consumption model of wireless. The model [10] is shown in Fig5.

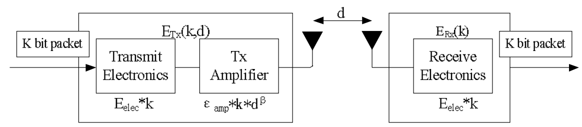

Figure5. Energy consumption model

B. Experimental scene

Berkeley's NS-2 is utilized for the simulation on Leach-H. The main parameters used in simulation are listed in Table 1.

TABLE 1. EXPERIMENTAL SCENE

Parameter	**Value**
Number of node	100
Optimized number of cluster head	5
Number of iterations in Simulated Annealing Algorithm	1000
Initial energy	2J
Bandwidth	1Mbps
The duration of each round	20s
The region deployment	100m*100m
size of packet	500Bytes
size of packet head	25Bytes
The time of establishment: The time of stability	1：19

In order to fully evaluate the effect of the agreement, the experiment will compare LEACH-H with LEACH and LEACH-C in respects like the nodes death rate, the amount of data received by the base station and changes in the number of cluster heads。

C. Simulation results

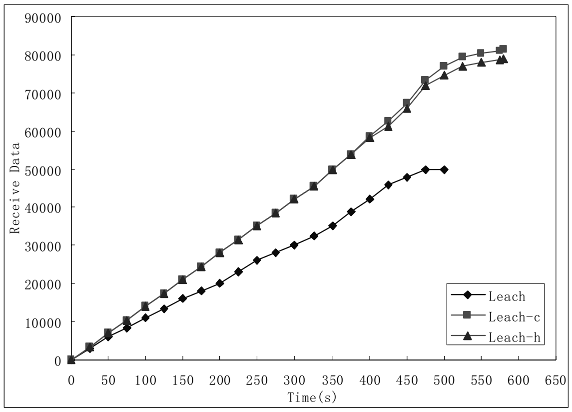

Figure6. Time VS Receive Data of LEACH，LEACH-C&LEACH-H protocol

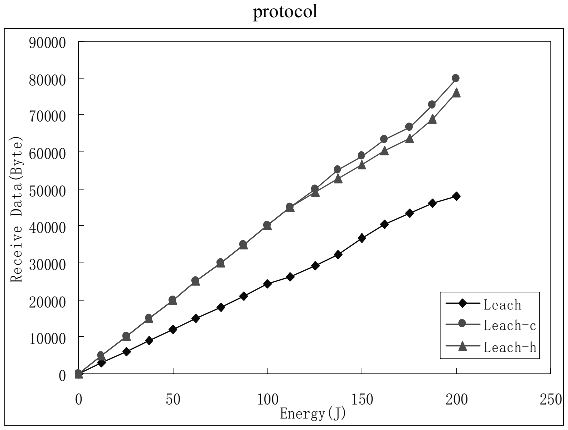

Figure7. Energy VS Receiving Data of LEACH，LEACH-C&LEACH-H protocol

Fig 6 is the Time VS Receiving Data graph of LEACH，LEACH-C and LEACH-H; Fig 7 is the Energy VS Receiving Data of LEACH，LEACH-C and LEACH-H. We can infer that the receiving data in Leach-H is better than Leach definitely, and is as good as Leach-C roughly. Because the receiving data in Leach-H is close to centralized Leach-C, as a combination of centralized and distributed protocol, Leach-H has a substantial edge in realistic application.

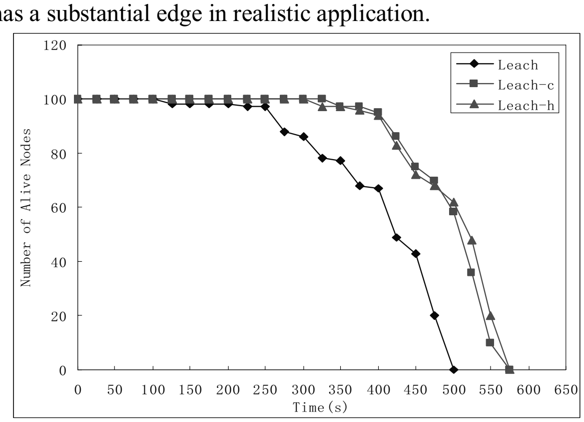

Figure8. Time VS Alive Nodes Number of LEACH，LEACH-C&LEACH-H protocol

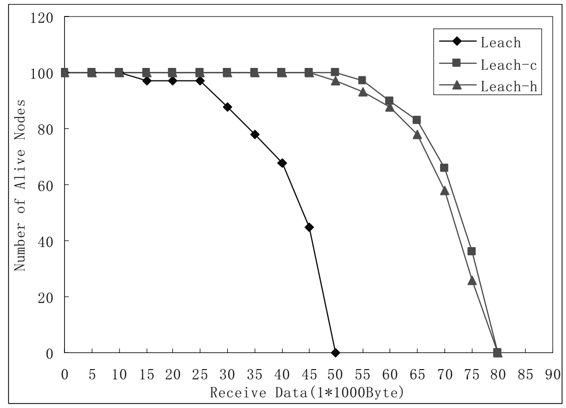

Figure9. Receive Data VS Alive Nodes Number of LEACH，LEACH-C&LEACH-H protocol

Fig 8 is the Time VS Alive Nodes Number graph of LEACH，LEACH-C and LEACH-H; Fig 9 is the Receiving Data VS Alive Nodes Number graph of LEACH，LEACH-C and LEACH-H. From the first moment of the dead nodes, we can conclude that the LEACH-H is much longer than LEACH, and slightly shorter than LEACH-C. So LEACH-H extends the network's life cycle effectively.

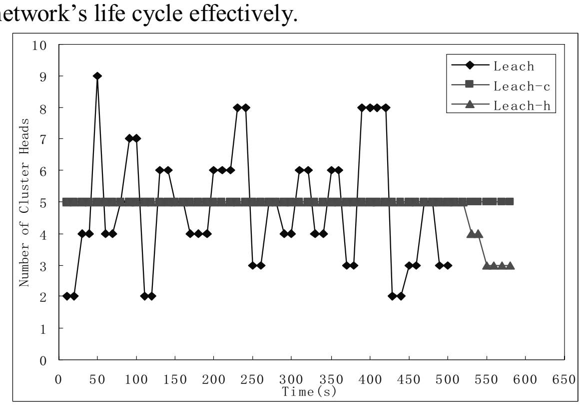

Figure10. Time VS CH Number of LEACH，LEACH-C and LEACH-H protocol

Fig10 is the Time VS Number of CH graph of LEACH，LEACH-C and LEACH-H. The CH in Leach is assigned randomly by comparing to a threshold, so the number can only be approximate equivalent to the optimal number. From the picture, we can see that the number of CH in Leach is around 5, and the number of CH in Leach-C is always 5. LEACH-H network have maintained the number of clusters in optimal most of the time. But in the latter part the number of cluster head is reduced. The reason is that the CH runs out of energy before the CH of next round is selected. In generally, LEACH-H ensures the number of cluster heads in optimal.

We can conclude that Leach-H is better than Leach definitely. It effectively resolves the problem that the number of cluster head is uncertain in Leach. Compared with centralized Leach-C, Leach-H has a slight lack of performance in all aspects. But, Leach-H needn't to run simulated annealing algorithm in every round. It is suitable for large-scale networks. As a combination of centralized and distributed protocol, LEACH-H achieves a balance in the anti-interference, fault-tolerant and energy efficiency.

Ⅴ. CONCLUSIONS

LEACH and LEACH-C are analyzed in this paper. They are the classic WSN cluster routing protocols. Combined with the characteristics of these two agreements, an improved protocol Leach-H is proposed later. In the first round of Leach-H, the base-station selects the cluster head set through the Simulated Annealing Algorithm. That has maintained the number of clusters in optimal most of the time. According to principles mentioned in part 3.2, the cluster heads will select new cluster heads in field of their own cluster for the followed rounds. So Leach-H is less depended on BS than Leach-C. As a result, Leach-H achieves better performance, and has good robustness and adaptability also. It is suitable for applications in the large-scale WSN.

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