The Research for the Least Energy Cost Optimization Algorithm Based on the LEACH Protocol

Zhong-lin Xia[1,2,a] , Xin-lian Zhou[1,b]

[1] Hunan University of Science and Technology, Xiangtan City, Hunan China

[2] Huaihua Medical College, Huaihua City, Hunan China

E-mail: [a] wind.xia@126.com , [b] xlzhou2@hnust.cn

Abstract. The paper proposes a new least energy cost optimization algorithm for the deficiency of the low energy adaptive clustering hierarchy (LEACH) protocol. In the perspective of the energy, the algorithm uses the least energy cost to decide whether the network clustering is on the optimal state, meanwhile the status of the cluster energy cost is imported to conduct clustering gradually towards minimizing energy consumption. Based on the theoretic analysis of the energy consumption, it is proved to have a longer network lifecycle which performs better than the LEACH.

Introduction

The wireless sensor node is used to power by the battery. Due to the limit of the battery energy, the runtime of the network is also limited. So how to decrease the energy consumption to prolong the lifecycle of the whole sensor network is the most important issue in the research. Currently, the common method is to use the node average consumption of energy and the data fusion to prolong the lifecycle of the network effectively. Meanwhile, the LEACH is a typical protocol to solve the problem. From the view of energy, the paper proposes a new algorithm on the base of the LEACH.

The optimization algorithm of the minimal energy consumption.

The paper proposes an improved algorithm based on the LEACH, which conduct the unreasonable energy consumption clusters towards the optimal state, according to the analysis and judgment of the energy consumption of the cluster at each round. In this way, the energy consumption of the whole network tends to be minimal, thus the lifecycle of the network is prolonged.

There are three main problems: the minimal cost value of the cluster energy, the control mechanism of the pointed cluster head and the energy state of the cluster.

The minimal cost value of the cluster energy. In the LEACH, the formula of the energy cost is base on the first order radio model[2]. Meanwhile, to simplify the algorithm, here to presume the number of the nodes inside each cluster is the same, and there are N nodes distributed average in the $M \times M$ area. Also the energy cost of the node in the transmitting circuit as well as the receiving circuit is presumed to be equivalent.

The node of the cluster head for the collection of the information inside the clusters as well as the correspondence with the base station, at the same time is presumed to be 100 percent data fusion, and then the energy cost E_{ch} within a frame would be:

$$E_{ch} = lE_{elec}(\frac{N}{k} - 1) + lE_{da}\frac{N}{k} + lE_{elec} + l\varepsilon_{amp}d_{BS}{}^4 \tag{1}$$

So a normal node which is not the head of the cluster would just need to transmit the data to the head cluster. For the nodes distributed probability is presumed to be $\rho(x,y)$, and the coverage of the network would be a round area, then:

$$E_{cn} = lE_{elec} + l\varepsilon_{fs} \frac{M^2}{2\pi k}$$

(2)

So the energy cost of the cluster within a frame would be:

$$E_{cluster} = E_{ch} + (\frac{N}{k} - 1)E_{cn} \approx E_{ch} + \frac{N}{k}E_{cn}$$

(3)

Finally, the sum energy cost of the whole network would be:

$$E_{total} = kE_{cluster} = l(E_{elec}N + E_{da}N + E_{elec}N + k\varepsilon_{amp}d_{BS}^4 + \varepsilon_{fs}\frac{M^2}{2\pi k}N)$$

(4)

Calculate the extremum through the first order derivative spectrophotometry of k for E_{total}, the result would be the optimal number k of the cluster head, so the least energy cost of a cluster would be：

$$E_{opt} = \frac{ld_{BS}^2}{M^2}\sqrt{\frac{2\pi\varepsilon_{amp}}{\varepsilon_{fs}}}(2E_{elec} + E_{da} + d_{BS}^2\sqrt{\frac{\varepsilon_{amp}\varepsilon_{fs}}{2\pi N}} + d_{BS}^2M^2\sqrt{\frac{\varepsilon_{amp}\varepsilon_{fs}}{2\pi N}})$$

(5)

Considerate the difference between theoretical value and the practical value, an energy weights C is imported to adjust the difference:

$$E_{TOR} = CE_{opt}$$

(6)

The control mechanism of the pointed cluster head. The number control of the cluster head relates to the cost energy and the life cycle of the whole the network. While the selection of the cluster head in the LEACH would be unstable for the number, which would result in the rapid increase of the energy cost. To solve the problem, the sudden death of the cluster head is imported in the least energy cost algorithm to control the number of the pointed cluster head. The process is as follows:

①The base station broadcasts the number k of the pointed cluster head to the nodes within a specific range.

②The nodes compete for the cluster head freely according to the threshold value $T(r)$.

③The node which has the random value less than the threshold value $T(r)$ monitors the channel according to the CSMA-MAC, ready for the broadcast to be the formal cluster head.

④After the k nodes broadcasting to be the formal cluster head, the rest nodes ready to broadcast give up the opportunity to be the cluster head, and join the nearest cluster head with the rest nodes together according to the broadcast signal strength of the k cluster head.

The energy state of the cluster. The energy state of the cluster which is defined by the base station shows the relation between the energy cost value and the least energy cost value of the cluster would be stable state or unstable state. Here presume the base station can calculate the position of the cluster through the signal strength and the angles.

When the energy cost value of the cluster is equal to the least value, it is said it is the stable state. The state directs that the value of the cluster energy cost is the least and the cluster would not dissolve in the order of the base station in the next round. Also the new cluster head would be the node which has the most rest energy in the original cluster.

When the energy cost value of the cluster is less or more than the least value. It is said the unstable state. The state directs that the value of the cluster energy cost is not the least. To make the energy of the cluster become stable, the base station should conduct the clusters to merge or dissolve according to the position of the clusters around and the energy state. The mergence and the dissolution between the clusters can be described as follows:

①If the energy cost value of the cluster m itself, or plus with the value of the neighbor clusters $n1, n2...$ could be k times of the least energy cost value of the cluster, the base station conducts them to merge to produce k clusters in the next round.

②If the energy cost value of the cluster *m* itself is *k* times of the least value, the base station conducts them to merge to produce *k* clusters in the next round.

③The clusters dissolve in the other situation, and the base station would conduct the nodes to compete freely to establish the suitable number of the clusters according to different position information and the best number of the cluster head kopt.

The work process of the least energy cost optimization algorithm. The least energy cost optimization algorithm import the energy information in the transmission of the data information. The cluster head could establish the rest energy table of the node within the cluster according to the energy information. So the base station could get the energy cost value of the cluster according to the energy information, and add the following assumptions base on the original set of the LEACH:

①The energy of the base station is infinite.

②The base station can calculate the position of the cluster head according to the signal strength and the angle of the cluster head.

The life cycle of the wireless sensor network could be divided into two phase in the work process of the least energy cost optimization algorithm:

The first phase: the first test run phase.

Similar with the LEACH, the first test run phase starts from the construction of the wireless sensor network: Firstly the construction of the cluster is performed, and then the stable work phase of the cluster is entered. Meanwhile the cluster head establishes the rest energy table of the nodes within the clusters and the base station calculates the position of the cluster head according to the signal strength and the angle of the cluster head.

The second phase: the least energy evaluation run phase.

The least energy evaluation run phase starts from the dissolution of the first test run phase and end with the death of the network. In the phase it would repeat 3 steps as follows:

①The base station calculates the best number of the cluster head within the current exist notes and the least energy cost value. According to the least energy cost value, the energy states would be judged as stable or unstable, and the clusters in different states would be conducted to establish a suitable number of the clusters based on the position information of each cluster head.

②With the end of the previous round, each cluster performs a new round for the selection of the cluster head base on the order of the base station. The nodes would join the new cluster and complete the construction of the clusters.

③The clusters enter a new round of the stable work phase and establish the rest energy table of the nodes according to the energy cost of the nodes within the cluster.

The analysis of the energy consumption

In the least energy cost optimization algorithm, the base station is responsible for the calculation and the conduction. Due to the infinite energy of the base station, it is just need to considerate the extra energy consumption of the nodes in the network compared with the LEACH: add the energy information in the data transmission; establish the rest energy table of the nodes within the cluster head; evaluate and run the cluster base on the energy state.

①Add the energy information in the data transmission. Because the energy consumption of the clusters includes the consumption of the clusters construction and the data transmission, meanwhile the length of the energy information data is relative small compared with the data package, the influence of adding the energy information into the data transmission would not be obvious. The position of the nodes in the network is fixed considerately as well as the special environment is ideal, there is no need to increase the transmit power suddenly because of the undesired signal. So the energy data is a fixed cost value after the clusters construction. In this way, the energy data just needs to be transmitted a few times in each stable work phase, avoiding adding the energy data transmission every time. Based on the above consideration, it could be ignored to produce extra energy cost for adding energy data.

②Establish the rest energy table of the nodes within the cluster head. Because the energy consumption of 1kb data package to transmit 100 meters is equal to that of 300 million comments to perform by the CPU with 100MIPS/W calculation capacity, it could be ignored to produce extra energy cost for establishing the rest energy table of the nodes within the cluster head.

③Evaluate and run the cluster base on the energy state. Though the average number of the cluster head could insure to be equal to the best number of that in the selection of the cluster head in LEACH. The number of the cluster head produced in each run is unstable, and the probability of the number equal to the best value is less than 25%[4]. While it could control the number of the clusters head according to the energy cost state of the cluster in the least energy cost optimization algorithm. So the energy consumption of the whole network decreases rapidly compared with LEACH.

Upon inspection, the least energy cost optimization algorithm is proved to decrease the energy consumption compared with LEACH. Through minimize the energy consumption of the whole network, the purpose to prolong the life cycle of the network is achieved.

Conclusion

Based on the LEACH, the paper proposes a method to evaluate whether the network runs on the minimal energy consumption state according to the energy cost. To prolong the life cycle of the network, the number of the cluster is adjusted to minimize the energy cost of the network automatically according to the energy cost state of the cluster in the network. There is only the theoretical analysis of the algorithm, the best value of the energy weights is still needed to be defined based on abundant experiments.

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