WSN Routing Algorithm Based on Energy Approximation Strategy

Yuexia Zhang[1,2(✉)], Hang Chen[1,2], and Tianrun Gao[1]

[1] School of Information and Communication Engineering, Beijing Information Science & Technology University, Beijing, China
zhangyuexia@bistu.edu.cn, chenhang813@163.com, gaotr2009@126.com

[2] Beijing Key Laboratory of High Dynamic Navigation Technology, University of Beijing Information Science & Technology, Beijing, China

Abstract. In the routing protocol of wireless sensor networks, the traditional LEACH algorithm is too random, and the cluster head selection of it is not ideal. To solve this problem, it proposes a WSN routing algorithm based on energy approximation strategy. It chooses a series of nodes with high energy and high density to form cluster candidate clusters, and then selects the farthest node as the cluster head from the candidates by using the energy approximation strategy. The algorithm is simple and easy to implement, and the cluster head selection of it is ideal. Using Matlab software for simulation, the results show that it is less energy consuming than the LEACH algorithm, and the lifetime of the whole network is prolonged.

Keywords: Wireless sensor network · Routing algorithm · Cluster head Energy approximation

1 Introduction

Wireless sensor network (WSN) is a network system composed of many different types of sensor nodes [1, 2]. It can collaboratively sense, collect, and process the relevant information in a specific area by using these different functions, self-organized sensor nodes. And finally the information are sent to the observer of the network system. WSN can be widely used in national defense and military, modern medical, intelligent transportation and environmental monitoring and many other fields. However, the energy of sensor node in WSN networks is very small due to the size and other factors. Therefore, it is important to reduce energy consumption and extend the life cycle of the network.

Routing protocol is one of the key technologies of WSN, which can be classified into four types: hierarchical, data center, geo-location and energy-aware routing protocols. LEACH algorithm is the first cluster-based routing protocol [3, 4], it choose the cluster head through the relationship between the node generated random number and threshold. The LEACH algorithm has a longer life cycle than planar routing protocol [5]. However, the randomness of the LEACH algorithm cluster-head selection is too large, it may cause the cluster head node to be distributed unevenly in the network

B. Li et al. (Eds.): ChinaCom 2017, LNICST 237, pp. 3–12, 2018.
https://doi.org/10.1007/978-3-319-78139-6_1

system and increase the energy loss of the network [6, 7]. The LEACH algorithm does not take into account the current density of the node itself, energy status and other factors, and its cluster head selection is not reasonable that would affect the network system life cycle. Therefore, the traditional LEACH algorithm has been unable to meet the needs of efficient use of WSN system. Literature [8] proposed a self-configuring cluster head fault detection mechanism based on LEACH algorithm. This mechanism can replace the fault cluster head node in time and effectively prolong the network lifetime, but it does not fundamentally the cluster head selection and can not effectively reduce the energy consumption of the network. Literature [9] proposed a routing algorithm that uses the energy delay index to select the cluster head. This algorithm improves the cluster head selection mechanism and improves the network energy utilization rate, but it does not take into account the cluster information path, and the selected cluster head may not be the optimal cluster head on the network communication path. Literature [10] proposed a fuzzy C-means algorithm for the optimum number of the cluster head and its location. It is greatly increasing the complexity of the algorithm although the algorithm increases the lifetime of the network.

In this paper, a new routing algorithm named Routing Algorithm for Energy Approximation Strategy (RA-EAS) is proposed to solve the shortcomings of existing routing protocols. RA-EAS chooses a series of nodes with high energy density and high density to form cluster candidate groups, and then selects the farthest node as the cluster head from the candidates by energy approximation strategy. RA-EAS algorithm is simple and easy to choose, and its cluster-head selection is ideal. RA-EAS algorithm can effectively save the residual energy of network and prolongs the network life-cycle than the LEACH algorithm through the simulation experiments.

2 Traditional LEACH Algorithm

Traditional LEACH algorithm is presented in the form of "round" [11]. Each round includes the cluster head creation phase and the information transmission phase. The traditional LEACH algorithm chooses the nodes as cluster heads randomly in each round, and repeats the process of creating cluster heads.

In the initial stage of cluster head establishment, the traditional LEACH algorithm establishes a threshold $T(i)$ first, which is defined as:

$$T(i) = \begin{matrix} p/(1 - p.(n \mod (1/p))), i \in G \\ 0, other \end{matrix} \tag{1}$$

Where p is the ratio of the number of clusters in the network to the number of whole nodes in the network, n is the number of cluster head selections. And G is the group of cluster selections that are not selected as cluster for $1/p$ times.

Every sensor node randomly generates a value RN that between 0 and 1, and then compare with the value RN and the threshold value $T(i)$. If $RN < T(i)$, this sensor node can be regarded as the cluster head; otherwise, the node is not selected as cluster head.

In the information transmission phase, sensor node that selected as the cluster head sends broadcast information to all normal nodes within its own coverage. According to the strength of the received signal, the normal node judges to join the appropriate cluster and sends the join request. After receiving the request, the cluster head makes a TDMA schedule for all nodes in its own cluster, and all nodes send information to the cluster head by according this schedule.

After the above, the cluster head processes the data fusion and send it to the base station through the multi-hop transmission between others cluster heads to finish one round of information transmission. In the traditional LEACH algorithm, the cluster head is chosen according to the relationship of the generated value RN and the threshold value [12, 13]. All nodes in the network are selected as cluster heads with equal probability in each round, and new cluster head is selected for each round.

It is too random to select the cluster head in each round of LEACH algorithm, and the selection of the cluster head is not reasonable. Traditional LEACH algorithm does not consider the actual situation of every sensor node, these factors have a direct impact on the advantages and disadvantages of cluster head selection. It would increase the energy consumption of network systems and shorten the life cycle if inappropriate nodes are selected as the cluster head.

3 RA-EAS Algorithm

In RA-EAS algorithm, WSN network distribution diagram shown in Fig. 1. The Cartesian coordinate system is established with the known base station position as the coordinate origin. The WSN network is composed of known base station and N sensor nodes that randomly distributed around the known base station. The coordinate of the base station is $(0, 0)$, the coverage network radius is R, and the coverage radius of all the sensor nodes is $r, r < R$.

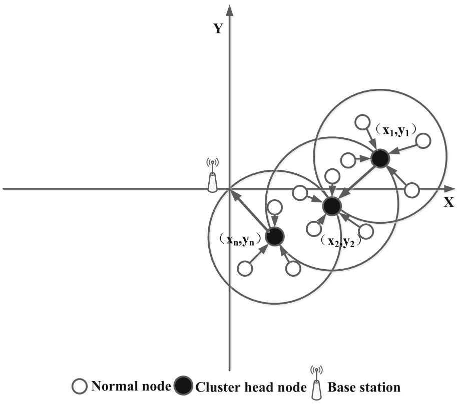

Fig. 1. WSN network distribution diagram

The probability value $P(i)$ of each node selected as cluster head can be calculated by using the residual energy of surviving nodes and the density of surviving nodes in the coverage radius. The value $P(i)$ is:

$$P(i) = c_1 \frac{E(i)}{E_{ave}} + c_2 \frac{N_{neigh}(i)}{N_{alive}} \tag{2}$$

Where c_1, c_2 are the proportional coefficient. $E(i)$ refers to the current node itself carries the remaining energy value. E_{ave} represents the average remaining energy of all surviving nodes in the WSN network. $N_{neigh}(i)$ refers to the intensity of the current node that the number of surviving nodes within its coverage radius r. N_{alive} is the number of surviving nodes in the current network.

The probability value of every nodes selected as cluster heads can be calculated by formula (2). A probability threshold is set in advance, when $P(i) > V$, then the node i is selected as the candidate group of cluster heads.

In order to avoid the high complexity of the algorithm due to the Sub-region selection of the cluster head, and the chosen cluster head in the current region is not necessarily the best cluster head in the whole network, which brings about extra energy consumption. Therefore, the RA-EAS algorithm adopts cluster head selection method based on energy approximation strategy, a series of nodes that can cover the whole area and are farthest from each other are selected as cluster heads in the candidate group of cluster heads.

Suppose the coordinates of cluster head from far to near are $(x_1, y_1), (x_2, y_2) \cdots (x_i, y_{\text{i}}) \cdots (x_l, y_l)$, then the coordinates of cluster head satisfy the following conditions:

1. Every selected cluster head position is closer to the known base station position than the previous one. So, the absolute value of the vertical and horizontal coordinates of the current cluster head is smaller than that of the last selected cluster head in the Cartesian coordinate system. That is:

$$\begin{cases} R > |x_1| > |x_2| > \cdots > |x_l| > 0 \\ R > |y_1| > |y_2| > \cdots > |y_l| > 0 \end{cases} \tag{3}$$

2. The distance between adjacent cluster heads must less than the coverage radius r in order to meet the basic communication requirements between cluster heads, That is:

$$\sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} < r \tag{4}$$

3. In order to make the distance between the adjacent cluster heads farthest for the optimal information transmission path, the position of the current cluster head is at the coverage of the overlap between the previous cluster head and the latter cluster in the Cartesian coordinate system. That is:

$$\begin{cases} |x_{i-1}| - r < |x_i| < |x_{i+1}| + r \\ |y_{i-1}| - r < |y_i| < |y_{i+1}| + r \end{cases} \tag{5}$$

4. When the known base station lies within the coverage radius of the selected cluster head, it is not necessary to continue selecting the cluster head any longer. That is:

$$\begin{cases} 0 < |x_l| \le r \\ 0 < |y_l| \le r \end{cases} \tag{6}$$

5. The sum of the distances between all adjacent cluster heads is greater than R that in order to satisfy all the nodes within the coverage radius R of known base station can complete the information transmission. That is:

$$R \le \sum_{i=2}^{n} \left(\begin{array}{c} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} \\ + \cdots \sqrt{(x_l)^2 + (y_l)^2} \end{array} \right) + r \tag{7}$$

In summary, the coordinates of cluster head must meet the following constraints:

$$\begin{cases} R > |x_1| > |x_2| > \cdots > |x_l| > 0 \\ R > |y_1| > |y_2| > \cdots > |y_l| > 0 \\ |x_{i-1}| - r < |x_i| < |x_{i+1}| + r \\ |y_{i-1}| - r < |y_i| < |y_{i+1}| + r \\ \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} < r \\ 0 < |x_l| \le r \\ 0 < |y_l| \le r \\ R \le \sum_{i=2}^{n} \left(\begin{array}{c} \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2} \\ + \cdots \sqrt{(x_l)^2 + (y_l)^2} \end{array} \right) + r \end{cases} \tag{8}$$

When one cluster head is selected from the candidate group of cluster heads, the others nodes within its coverage become the normal nodes automatically. The cluster head sends broadcast messages to all normal nodes within its own coverage radius r, and the normal nodes choose to join the appropriate cluster according to the information received. At this point, clustering is completed, and RA-EAS algorithm clustering process flow diagram shown in Fig. 2.

The clustering process of RA-EAS algorithm is described as follows:

Step 1. Establishing the Cartesian coordinate system by using the known base station position as the coordinate origin.
Step 2. Calculating the probability value $P(i)$ that the node is elected as cluster head by using formula (2).
Step 3. Determining the cluster head candidate group though the pre-set probability threshold V.
Step 4. Judging energy approximation of constraint conditions in the candidate group of cluster heads. The cluster head is selected as the cluster head if the constraint condition is satisfied, otherwise it becomes the normal node.

Step 5. Every node completes its own task according to the routing protocol after determining the cluster head node and the normal node. The cluster head sends a broadcast message to all normal nodes within the coverage radius of r that cluster itself as the center. And the normal nodes select join into a suitable cluster according to the strength of the broadcast information received.

Step 6. At this point, a complete cluster structure assignment end up.

Then, steps 4 and 5 are repeated to complete the subsequent clustering steps. And cluster-based cooperative communication centered on cluster-head is realized in the WSN network finally. Every cluster-head receives the information of the normal node in the cluster and fuses the information to transmit to the base station in multi-hop mode. Thus, a complete round of information transmission end up. Cycle to carry out the above steps to complete each round of the cluster process and information transfer process.

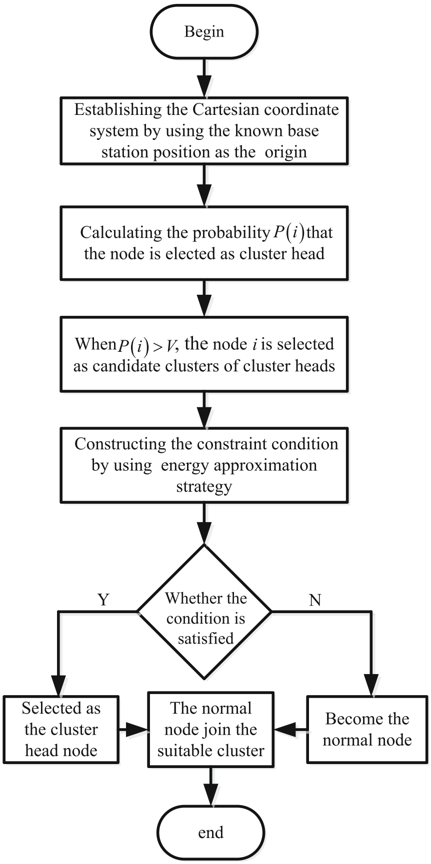

Fig. 2. RA-EAS algorithm clustering process flow diagram

4 Performance Analysis

The number of dead nodes and the energy consumption between traditional LEACH algorithm and RA-EAS algorithm are simulated to verify the effectiveness of RA-EAS algorithm. The experimental parameters [14] in the simulation environment are shown in Table 1.

Table 1. The experimental parameters in the simulation environment

Parameters	Symbol	Value
Number of nodes	N	100
Initial energy	E_0	0.5 J
Proximal energy consumption coefficient	E_{fs}	10 pJ/bit/m^2
Remote energy consumption coefficient	E_{amp}	0.0013 pJ/bit/m^4
Transmit and receive energy consumption	E_{elec}	50 nJ/bit
Packet size	k	4000 bits
Control packet size	L_{ctrl}	100 bits
Data aggregation energy	E_{da}	5 pJ/bit/report
Cluster head probability threshold	V	0.05
Network area	$M \times M$	100 m $\times$ 100 m

100 nodes are randomly distributed in WSN network area which area is 100 m 100 m. Figure 3 shows the distribution of nodes in this network area, and the origin of Cartesian coordinate system is the known base station location.

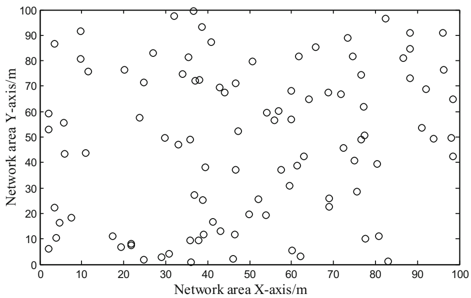

Fig. 3. The distribution of nodes in the network area

Figure 4 gives the comparison between the number of network death nodes and the rounds of selection in LEACH algorithm and EA-RAS algorithm. The network life cycle is defined as the dead time of the first network node. The first death node in the LEACH algorithm network in Fig. 4 appears in 946 rounds, while the RA-EAS algorithm appears in 1189 rounds. The RA-EAS algorithm prolongs the lifetime of the network system by 26% compared with the LEACH algorithm. This is because the

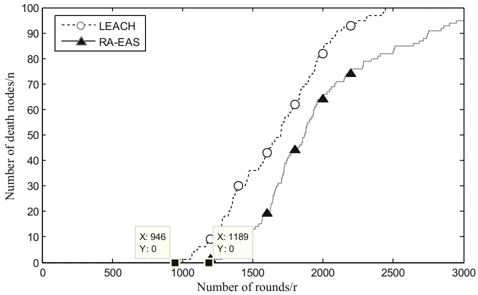

Fig. 4. The comparison between the number of network death nodes and the rounds of selection

LEACH algorithm selects the cluster head randomly, but the RA-EAS algorithm has taken into account the current node's own energy and density in the selection of cluster head, makes that the preferably nodes become cluster heads.

Figure 5 shows the comparison between the number of surviving nodes in the network and the rounds of selection in the cluster. It can be seen that the nodes in RA-EAS algorithm begin to die are later than that in LEACH algorithm, so that the RA-EAS algorithm prolongs the network life cycle than LEACH algorithm.

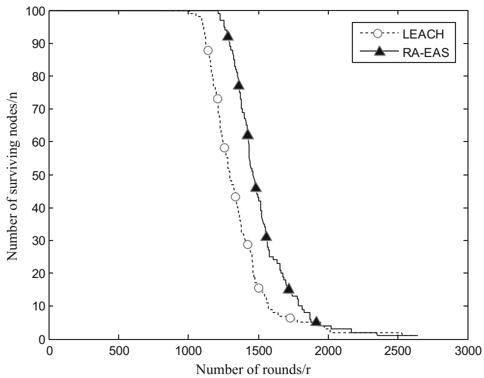

Fig. 5. The comparison between the number of surviving nodes and the rounds of selection

Figure 6 exhibits the network energy consumption comparison between LEACH algorithm and EA-RAS algorithm. It can be seen that the energy consumption per round of the network system in the EA-RAS algorithm is less than that in the LEACH algorithm under the same conditions. The network energy consumption of both algorithms tends to be stable after 2500 rounds, this is because most of the nodes in the network are dead at this time. It is also shows that the total energy consumption in the EA-RAS algorithm is lower than that in the LEACH algorithm. That is, the EA-RAS algorithm can more save the residual energy of the network than LEACH algorithm.

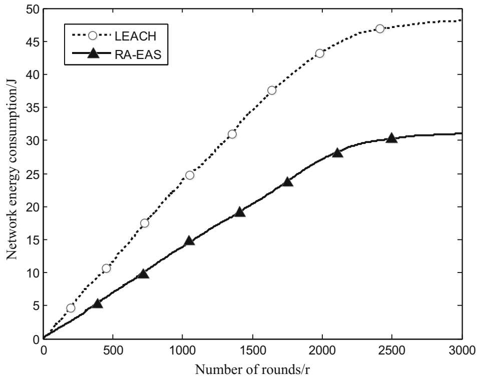

Fig. 6. The network energy loss comparison between LEACH and EA-RAS

5 Conclusions

This study proposes a WSN routing algorithm of EA-RAS that based on energy approximation strategy. The EA-RAS algorithm is simple and the cluster-head selection is ideal. And the RA-EAS algorithm is more effective in extending the life cycle of the network system and saving the residual energy compared with the LEACH algorithm that simulation results show.

References

1. Pantazis, N.A., Nikolidakis, S.A., Vergados, D.D.: Energy-efficient routing protocols in wireless sensor networks: a survey. IEEE Commun. Surv. Tutor. **15**(2), 551–591 (2013)
2. Borges, L.M., Velez, F.J., Lebres, A.S.: Survey on the characterization and classification of wireless sensor network applications. IEEE Commun. Surv. Tutor. **16**(4), 1860–1890 (2014)
3. Dhawan, H., Waraich, S.: A comparative study on LEACH routing protocol and its variants in wireless sensor networks: a survey. Int. J. Comput. Appl. **95**(8), 21–27 (2014)
4. Lee, W.S., Ahn, T.W., Song, C.Y.: A study on improvement of energy efficiency for LEACH protocol in WSN. J. Inst. Electron. Inf. Eng. **52**(3), 213–220 (2015)
5. Nayak, P., Devulapalli, A.: A fuzzy logic-based clustering algorithm for WSN to extend the network lifetime. IEEE Sens. J. **16**(1), 137–144 (2016)
6. Han, Z., Wu, J., Zhang, J., et al.: A general self-organized tree-based energy-balance routing protocol for wireless sensor network. IEEE Trans. Nucl. Sci. **61**(2), 732–740 (2014)
7. Zhang, D., Li, G., Zheng, K., et al.: An energy-balanced routing method based on forward-aware factor for wireless sensor networks. IEEE Trans. Ind. Inform. **10**(1), 766–773 (2014)
8. Izadi, D., Abawajy, J., Ghanavati, S.: An alternative clustering scheme in WSN. IEEE Sens. J. **15**(7), 4148–4155 (2015)
9. Thakkar, A., Kotecha, K.: Cluster head election for energy and delay constraint applications of wireless sensor network. IEEE Sens. J. **14**(8), 2658–2664 (2014)
10. Bouyer, A., Hatamlou, A., Masdari, M.: A new approach for decreasing energy in wireless sensor networks with hybrid LEACH protocol and fuzzy c-means algorithm. Int. J. Commun. Netw. Distrib. Syst. **14**(4), 400–412 (2015)

11. Long, C.Z., Lin, H., Huang, C.H., et al.: Improved LEACH multi-hop algorithm based on residual energy and region distribution. J. Inf. Comput. Sci. **11**(9), 2955–2964 (2014)
12. Dong, S., Li, C.: The improvement of LEACH algorithm in wireless sensor networks. Int. J. Online Eng. (iJOE) **12**(11), 46–51 (2016)
13. Mottaghi, S., Zahabi, M.R.: Optimizing LEACH clustering algorithm with mobile sink and rendezvous nodes. AEU-Int. J. Electron. Commun. **69**(2), 507–514 (2015)
14. Fu, C., Jiang, Z., Wei, W.E.I., et al.: An energy balanced algorithm of LEACH protocol in WSN. Int. J. Comput. Sci. **10**(1), 354–359 (2013)