Efficient Routing Protocol Based on Distance Vector in the Wireless Sensor Networks

Yong-Zhen Li, Hyung-Jin Mun

Abstract: ***The purposes of this paper are to lower the energy consumption in the wireless sensor network and to prolong network lifetime. Based on the maximum power a node can transmit, so we proposed multi-hop routing algorithm in this paper on the basis of gradients. Compared to Leach algorithm and Heed algorithm, the algorithm we proposed is 40% and 16% more efficient respectively in terms of Network Lifetime. We conducted a simulative experiment on the improved algorithm we proposed through MATLAB, and the results indicate that compared with LEACH algorithm and HEED algorithm, algorithm proposed we proposed is greatly improved in terms of network energy consumption and network life cycle.***

Keywords: WSN, Clustering, Topology control, Broadcast, Gradient, Multi-hop transmission

I. INTRODUCTION

At present, studies of wireless sensor routing protocol have aroused many scholars' attention, yet the results are not remarkable. Except for classical routing algorithms about a decade ago, there has not been an improved routing protocol in recent years which is able to obtain support and affirmation at home and abroad [1, 2]. Therefore, there is still much to study in wireless sensor routing protocol. Since battery energy in wireless sensor network is limited and cannot be charged [3, 4], and hardware resources and node computing abilities are all restrained, we can only seek improvements in algorithm under the circumstance that it is impossible to improve the sensor node from hardware.

Routing protocols are divided into the following types: the plane protocol, the position-based protocol, and the hierarchical protocol. Nodes in the plane routing play the same role and each node shares the same status in the network. Flooding and Gossiping [5] are two classical algorithms in plane routing of wireless sensor network. Flooding is easy to operate, and there is no need to consume additional energy to maintain invariant topology and to achieve routing; in Gossiping, nodes are selected randomly during data transmission for relay data transmission, which avoids the information internal explosion. Yet this method takes more time for information transmission.

In routing network based on position, nodes are distinguished according to their position. Distance between the nodes is calculated according to the signal length; the longer the signal, the shorter the distance between the nodes. In some protocols, nodes are allowed to sleep when there is no operation; for instance, GEAR and GPSR [6, 7]. In hierarchical protocol, nodes are divided into clusters and the highest energy node is selected as the cluster_head. Classical algorithms of mainstream protocols in hierarchical protocol include: LEACH, LEACH-C [8], LEACH-M [9], HEED [10], PEGASIS, etc. LEACH is a cluster protocol whose main purpose is to realize the balanced load among sensor nodes in order to prolong network life cycle. Yet there are still several problems in LEACH algorithm, which are as follows [11-13]. LEACH-M [9] adopts the same algorithm and mechanism as those of LEACH to form clusters; at the same time, cluster_head nodes record all the locations and energy information of cluster_head nodes. In HEED [10] algorithm, energy consumed by the average communication in clusters is taken as the criterion to evaluate the communication cost in clusters. Key of HEED algorithm is that nodes decide the cluster_head node through comparison of cost values between themselves and surrounding nodes.

Transmission distance of classical network protocol sensor nodes is limited, hindering it from transmitting at any distance. Based on this drawback, multi-hop transmission research method with gradients is proposed in this paper for the transmission distance between the nodes, so as to lower the energy consumption in the network and prolong the failure round of the first network node.

II. OUR PROPOSED METHOD

Wireless sensor routing algorithm, which is designed in this article based on gradients, improves the algorithm mainly in terms of cluster stage and data transmission stage.

2.1. *Cluster stage*

2.1.1. Gradient partition

Different from the concentric circle division method of "ring-section", gradient division method which improves the algorithm was proposed based on the concentric circle division method in this paper. It recorded the number of neighboring nodes in gradient division stage, and selected intermediate nodes to forward data within the broadcast radius.

We divided the gradients in the area under the circumstance where area dimension and node number

Revised Manuscript Received on May 22, 2019.

Yong-Zhen Li, Dept. of Computer Science & Technology, Yanbian University, 133002, P.R. China
Hyung-Jin Mun, Dept. of Information & Communication Engineering, Sungkyul University, 14097, Korea
E-mail :jinmun@gmail.com

were fixed. Detailed steps of gradient division are listed as follows:

1) Initialized the gradient value of each node into 0. Firstly, the base station delivered broadcast signal with a radius of R, and the message was Broadcast message (level:1). Nodes receiving the message from base station set their gradient as 1;

2) Nodes whose gradients were 1 in the last step continued to deliver broadcast signal with a radius of R, and the message was Broadcast_message(level:2). Nodes who received this message and whose gradient values were 0 set their gradient as 2;

3) Circulated Step 2; divided the gradients; when each node in the network had a gradient value other than 0, the division was finished.

4) Gradient division was over. Each node recorded the number of other nodes within its broadcast radius. This figure was the neighboring node number of each node, Ni.

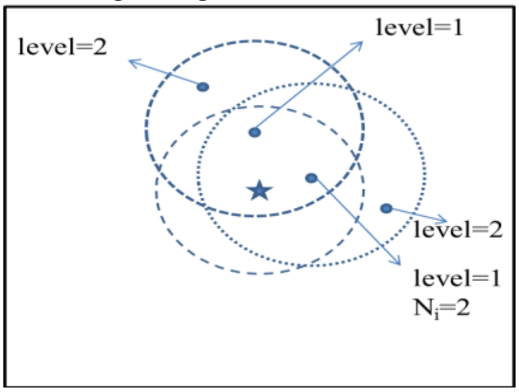

Figure 1. Sketch map of level division

[Figure 1] shows how to determine the gradient. Asterisk represents base station nodes, located at the center of the area. In the circle which takes the base station as the center and the broadcast radius R as the radius, the circle is the range which the broadcast signal can reach. Dividing all the regions in the whole network into different gradients according to the steps above, each node has a gradient.

2.1.2. Cluster head selection

So as to reduce the energy consumption, it is necessary to choose nodes with high remaining energy and suitable position as the cluster_head nodes.

In classical LEACH algorithm, nodes select a random figure ranging from 0 to 1 when choosing the cluster_head node, and compare it by the threshold. If the selected figure ranging from 0 to 1 is smaller than the threshold, it will become the cluster_head node. This is the drawback of LEACH algorithm, and improvements on it are made in this paper. Steps of cluster_head selection algorithm in this paper are as follows:

1) In every round of cluster_head selection, each node selected a random figure from 0 to 1, and compared it with the threshold T(n) in formula (1). Nodes smaller than the threshold were selected to becluster_head nodes;

2) Selected cluster_head nodes according to the method in Step 1. Cluster_head nodes delivered the broadcast message that they had become the cluster_head nodes with a radius of R, including their identifying ID value and gradient: CH_MES(My_ID, My_Level). Other nodes which were not selected as cluster_heads entered Step 3;

3) Nodes failing to be the cluster_heads in Step 2 could decide which cluster to join on the basis of the broadcast message’ssignal strength. They entered the cluster_head nodes close to themselves, and became member nodes of the cluster_head node;

4) Member nodes sent the message that they had become member nodes of the cluster_head nodes to them, including identifying ID value of the cluster_head and their own ID values: Join_REQ(CH_ID, My_ID);

5) Member nodes in the cluster waited for the cluster node head to receive the information ACK, as well as the time slot TDMA the cluster_head nodes distribute. Then one round of cluster_head selection is over.

Threshold formula *T(n)* is as follows:

$$T(n) = \begin{cases} \frac{p}{1-p\left(r \bmod \left(\frac{1}{p}\right)\right)}\left(\alpha * \frac{E_i}{E_{ave}} + \beta * \frac{N_i}{N_{ave}}\right), & n \in G \\ 0, & else \end{cases} \quad (1)$$

P is the percentage of cluster_head node number in the number of all the sensor nodes in the network (normally 5%); α and β are energy influence factor and density influence factor, and their sum is 1. E_n is the residual energy of node n; E_{avg} is the mean residual energy of node n’ neighboring nodes; N_n is the neighboring node number of node n; N_{avg} is the ideal neighboring node number. Common nodes decided which cluster to join on the basis of the signal strength, and they joined the closest cluster_head node.

After member nodes joined the clusters, cluster_head nodes distributed TDMA time slot towards member nodes, and broadcast the time slot of each node to member nodes in the cluster, including: TDMA(CH_ID, M_1:slot1, M_2:slot 2, …, M_n:slot n). As shown in [Figure 2], the unit of wireless sensor in network routing stage is round. Each round includes set-up and steady state of data transmission. For a particular cluster, each round is composed of its data frames, in which each cluster member corresponds to a frame slot; and the cluster_head node uses the last slot in each frame to communicate with base station.

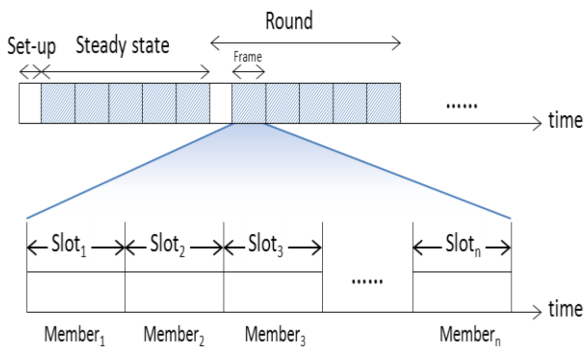

Figure 2. Sketch map of TDMA allocation process

After the cluster_head node received the message monitored by its member nodes, it integrated the information and removed the redundant message to avoid energy consumption caused by transmitting repeated message.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

2.2. Data Transmission Stage

2.2.1. Intra-cluster transmission:

[Figure 3] shows the diagram of intra-cluster transmission. The black block is a cluster_head node; the dotted circle is the assumed cluster range of this cluster_head node, which is not necessarily the actual radius of this cluster_head node. Cluster range of each cluster_head node is not fixed, and it is only assumed here that the dotted circle is the cluster range. Each cluster transmits according to the diagram in Figure 3, after receiving member node messages, cluster_head nodes integrate the data and intra-cluster transmission is over.

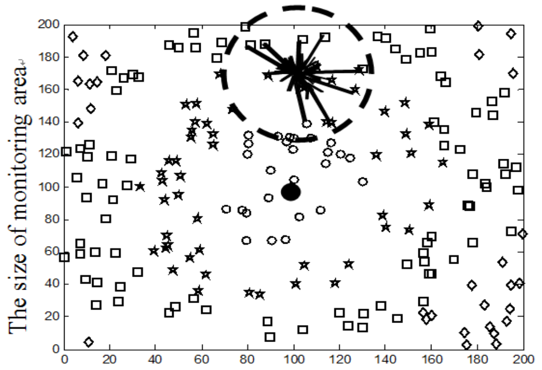

Figure 3. Sketch map of transmit within the cluster

2.2.2. Transmission outside the Cluster

In this paper, intermediate forwarding node was selected in the transmission outside the cluster, to forward the information from areas with large gradients into those with small ones, and eventually to the base station. Transmission algorithm outside the cluster is described as follows:

1) After intra-cluster transmission, member nodes had already sent the data to the cluster_head. Cluster_head nodes needed to transmit the integrated information to sink nodes through transmission outside the cluster. Cluster_head nodes whose gradients were 1 delivered the integrated information directly to sink nodes;

2) Cluster_head nodes whose gradient was not 1 selected close nodes which were smaller than themselves within the broadcast radius as intermediate nodes to forward data;

3) Circulated Step 2. Selected intermediate nodes to send the data until data was transmitted to the intermediate nodes whose gradient was 1. Transmitted the message to sink nodes directly in the end;

4) All cluster_head nodes forwarded data in multi-hop according to steps above until monitored information was all transmitted to sink nodes. The transmission outside the cluster in a round of data transmission was over.

III. SIMULATIONS AND ANALYSIS

3.1. Initialization

In this paper, we used MATLAB to simulate the algorithm and make comparisons between the proposed algorithm with LEACH and HEED algorithms, and verified the efficiency and rationality through study result analyses. Parameters used in the improved algorithm experiment are as follows:

Table 1: Radio Model & Network Configurations

Parameter	VALUE
Area size	200*200m
Sink position	(100m,100m)
Number of sensor nodes	200
Ration of cluster_head nodes in the total number p	0.05
Data package length	4000 bit
Control package length	200 bit
Node initial energy	1.0J
Energy consumption of sending and receiving circuits	50 nJ/bit
Free magnification	10 pJ/bit.m-2
Multi-path magnification	0.0013 pJ/bit.m-2
Energy consumption of data integration	5 nJ/bit.signal-1

3.2. Comparison of Network Survival Time

According to the parameters in [Table 1], the certain broadcast radius, R, is 41m, energy influence factor, α, is 0.5, and node density influence factor, β, is 0.5. The protocol proposed by us is therefor compared to LEACH algorithm and HEED algorithm on network survival time.

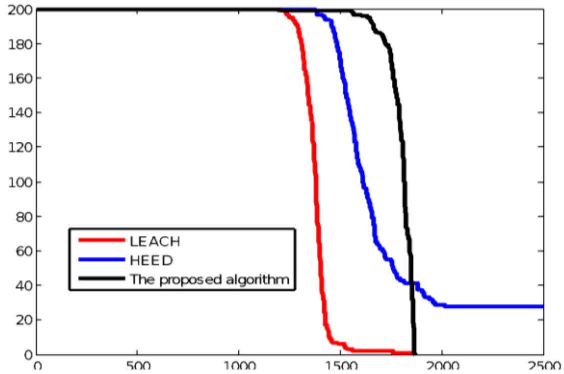

Figure 4. Lifetime comparison of three algorithms

[Table 2] shows the rounds in which the first node is invalidated of the three algorithms.

Table 2: The Comparison Results of Network Lifetime

Routing Algorithm	Lifetime(round n)
LEACH	1219
HEED	1473
The proposed algorithm	1711

From the slopes of the curves in [Figure 4], that of the algorithm in this paper is steeper than those of LEACH and HEED. With the increase of round number, the full consumption speed of node energy is slower. Advantages of the algorithm in this paper over LEACH and HEED in terms of life circle can be seen more directly from Table 2. Analyzed from the perspective of network life cycle index, that of the improved algorithm raises 40.4% and 16.2% respectively, compared with LEACH and HEED. Therefore, algorithm in this paper is better than the two whether

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

in curve slope or in detailed network life cycle.

3.3. Comparison of Energy Consumption in the Network

Figure 5 is the comparison between the improved algorithm we proposed and the classic Routing Algorithm in the energy consumption of network.

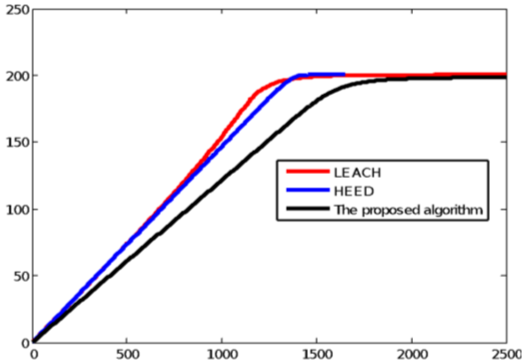

Figure 5. Energy consumption comparison of 3 algorithms

From Figure 5, curve change of this algorithm is the smoothest, that is, it has the lowest network energy consumption after the same rounds. Algorithm in this paper is more advantageous than LEACH and HEED from the round number, since as the number of round increases, cluster_head nodes in LEACH have too little energy to transmit information; or cluster_head nodes are distributed in areas with small or large density, which fastens the cluster_head's energy consumption. When selecting cluster_head nodes, this algorithm considers both the node remaining energy density among the nodes, balancing the cluster_head node location distribution and cluster_head node number.

IV. CONCLUSION

In this paper, improvements are made on routing algorithm in cluster selection stage and data transmission stage, and a cluster multi-hop routing algorithm is proposed by gradients. On the basis of simulative experiments, we analyzed property comparison of this algorithm, LEACH and HEED algorithms. In the end, we drew the conclusion that the proposed algorithm lowers the energy consumption and increases network survival time.

There are following drawbacks in the algorithm proposed in this paper and the next research plan is as follows:

1) In cluster_head selection stage, that different gradients have different chances to become cluster_head nodes can be considered. When we control the possibility for a node to be a cluster_headby the value of gradient, energy consumption is leveled among nodes with longer network survival time; as nodes are closer to the base station, it is more likely that they become heads.

2) Next step in this paper is to conduct simulative experiments closer to the real network scale. In different network scales, we study the relationship between the parameter and network scale.

REFERENCES

1. M. Sharma, K. Sharma, (2012). An Energy Efficient Extended LEACH.*2012 International Conference on Communication System and Network Technologies, Rajkot, India*, 377-382.
2. S. Ning, J. Yoon-su, L. Sang-ho. (2013). Energy Efficient Mechanism Using Flexible Medium Access Control Protocol for Hybrid Wireless Sensor Networks. *Central South University Press and Springer-Verlag. Berlin, Heridelberg*, 2165-2174.
3. Shang Fengjun. (2011). Communication protocol for wireless sensor networks. *Beijing: Publishing House of Electronics Industry*,1-30.
4. Sun Limin, Li Jianzhong. (2010). Wireless sensor networks. *Beijing: Tsinghua University Press*, 4-21.
5. Q. X. Xiong, C. H. Chen. (2014). A Novel Application Semantics Based Routing Algorithm in Wireless Sensor Networks. *2014 Fourth International Conference Communication Systems and Network Technologies, Bhopal, India*, 143-146.
6. S. Tyagi, N. Kumar. (2013). A Systematic Review on Clustering and Routing Techniques Based Upon Leach Protocol for Wireless Sensor Networks. *Journal of Network and Computer Applications*,36(2), 623-645.
7. He Yongqiang, GuChunying, Wang Junpeng. (2015). Flow divided-based uniform clustering for WSN routing algorithm.*Application Research of Computers*, 32(10), 3075-3077.
8. Hu Yanhua, Zhang Jianjun. (2009). Improved algorithm of cluster_head multi-hops based on LEACH. *Computer Engineering and Applications*, 45(34), 107-109.
9. Li Yan, Zhang Xihuang, Li Yanzhong. (2007). Algorithm of cluster_head multi-hops based on LEACH. *Computer Engineering and Design*, 28(17), 4158-4160.
10. O. Younis, S. Fahmy. Heed: a Hybrid. (2004). Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks. *IEEE Transactions On Mobile Computing*, 3(4), 366-379.
11. Lang Lili. (2013). Design and Implementation of Dijkstra Shortest Path Clustering Wireless Network Based on nRF24L01. *Bei Jing: Northeastern University*,37-41.
12. J. B. Liang, J. X. Wang. (2010). An Efficient Algorithm for Constructing Maximum Lifetime Tree for Data Gathering Without Aggregation in Wireless Sensor Networks. *Proceedings IEEE INFOCOM, San Diego, America*., 1-5.
13. S. Ning, C. Young-bok, L Sang-ho. (2011). A Distributed Energy Efficient and Reliable Routing Protocol for Wireless Sensor Networks. *Proceeding of the 14th IEEE International Conference on Computational Science and Engineering, Dalian, Liaoning.*, 273-278.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication