Jianguo SHAN[1], Lei DONG[1], Xiaozhong LIAO[1], Liwei SHAO[1] , Zhigang GAO[1], Yang GAO[2]

Beijing Institute of Technology (1), Shenyang Institute of Engineering (2)

Research on Improved LEACH Protocol of Wireless Sensor Networks

Abstract. *This investigation was performed to see if the improved LEACH protocol operates more effectively than the traditional LEACH protocol. The improved protocol adds energy factor and distance factor to the threshold T(n). The multi-hop routing algorithm of cluster head is introduced too, it based on the hop count and the remaining energy. MATLAB was used to simulate. The simulation data suggests that the death rate of nodes of the improved protocol was lower than the traditional one. It is concluded that the improved LEACH protocol can balance network load and extend the life-cycle of network.*

Streszczenie *Zbadano efektywność pracy udoskonalonego, w stosunku do tradycyjnego, protokołu hierarchicznego klastrowania LEACH. Udoskonalenie protokołu polega na wprowadzeniu współczynników energii i odległości węzłów oraz wykorzystaniu ich przy obliczaniu wartości progowej T(n). Zastosowano również wielo-przeskokowy algorytm klastrowania węzła głównego. Algorytm działa na zasadzie liczenia przeskoków i zachowania energii. Do symulacji wykorzystano program MATLAB. Wyniki symulacji wykazują, że tempo uszkodzeń węzłów przy zastosowaniu udoskonalonego protokołu jest mniejsze niż przypadku tradycyjnego. Podsumowując, udoskonalony protokół LEACH może zrównoważyć obciążenie i wydłużyć okres życia sieci.* ***Badania udoskonalonego protokołu LEACH bezprzewodowych sieci czujnikowych***

Keywords: Energy; LEACH; improved LEACH; Wireless Sensor Networks..

Introduction

Wireless sensor networks (WSNs) [1,2] are composed of a large number of radio-equipped sensor devices that autonomously form networks through which sensor data is transported. The sensor networks can be used in Military situation, Disaster management, Habitat observing, Medical and health care, Industrial fields, Home networks, Spotting chemical, Biological, radiological, Nuclear, and Explosive material etc[3].

Most sensor nodes use batteries for power supply in wireless sensor networks. So battery power is a significant resource for sensor devices. The sensor nodes can be installed in an extensive geographical space to observe physical phenomenon with adequate precision and dependability. Once installed, the minor sensor nodes are usually unapproachable to the operator. Therefore, conservation of energy and energy efficient routing must be taken into account to realize a dynamic and adaptive networking concept for wireless sensor networks. Thus, how to design an energy efficient routing protocol that decreases the energy consumption of data transmissions and prolongs network lifetime is an important issue.

W.R.Heinzelman [4], introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Cluster Hierarchy – based protocol (LEACH). Paper[5] and paper[6] introduce LEACH protocol in detail. LEACH protocol is a grade routing protocol. It can extend the network life-cycle but it also has shortcomings. In this paper, according to the every node‘s remaining energy and its location, a new improved multi-hop LEACH protocol is introduced. We conducted this study to determine whether the improved LEACH protocol could be better than the traditional one.

LEACH protocol

The core idea of LEACH protocol is to divide the whole wireless sensor networks into several clusters. The cluster head node is randomly selected, the opportunity of each node to be selected as cluster head is equal, and energy consumption of whole network is averaged. Therefore, LEACH can prolong network life-cycle. LEACH algorithm is cyclical; it provides a conception of round. LEACH protocol runs with many rounds. Each round contains two states: cluster setup state and steady state. In cluster setup state, it forms cluster in self-adaptive mode; in steady state, it transfers data. The time of second state is usually longer than the time of first state for saving the protocol payload. The selection of cluster head depends on decision made 0 and 1. If the number is less than a threshold, the node becomes a cluster head for the current round. The threshold is set as[7]:

$$T(n)=\begin{cases}\dfrac{p}{1-p*(r*\bmod 1/p)} & if\ \ n\in G\\ 0 & else\end{cases} \tag{1}$$

Where P is the desired percentage of cluster heads (e.g. is 4% or 5%), r is the current round, and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

Using this threshold, each node will be a cluster head at some point within 1/p rounds. Nodes that have been cluster heads cannot become cluster heads for a second time for 1/p -1 rounds. After that, each node has a 1/p probability of becoming a cluster head in every round. At the end of every round, every normal node that is not a cluster head select the nearest cluster head and joins that cluster to transmit data. The cluster heads combine and compress the data and forward it to the base station, therefore it extends the life span of major nodes.

In this algorithm, the energy consumption will allocate approximately uniformly among all nodes and the non-head nodes are turning off as much as possible. LEACH assumes that all nodes are in range of wireless transmission of the base station which is not the case in many sensor deployments. 5% of the total nodes play as cluster heads in every round. Time Division Multiple Access (TDMA) is deployed for better management and scheduling.

The problems in the traditional LEACH protocol are:

1) The cluster head node is randomly selected in LEACH protocol. There are some shortcomings, due to the probability of each node to be selected as cluster head is same. After several rounds, the node with more remaining energy and the node with less remaining energy have same probability to be selected as cluster head. If the node which has less energy is selected as cluster head, it will run out energy and die quickly, so that network's robustness will be affected and network lifetime will be short.

2) The traditional LEACH Protocol divides clusters randomly, also leads to uneven distribution of clusters easily. Eventually the divided clusters may not be the best. For instance, some clusters have more nodes than others, some clusters have fewer nodes. Some cluster heads in the relatively central of clusters, some clusters heads may be in

the edge of clusters far away from members. These phenomena can cause increase in energy consumption and impact on the overall performance of the network.

3) In steady state, cluster head send data to sink data directly, but this did not take into account the distribution of cluster heads is not uniform. Cluster head which farther from the sink communicate with the sink directly must spend a lot of energy. It will crash soon because it runs out of energy. Especially accompanied by the expansion of the scale of the network, these effects are more noticeable and affect the network life seriously.

Improved LEACH protocol

1、The improved threshold

In order to solve the drawbacks of the LEACH Protocol, we introduce the energy impact factor ($1 - \frac{E_{ce}}{E_n}$) and the distance impact factor ($1 - \frac{d_n}{R_c}$).

DEFINITION 1:E_{ce} is the remaining energy of cluster.

DEFINITION 2:E_n is the remaining energy of the node n within the cluster.

E_{ce} can be expressed as:

(2) $$E_{ce} = \min(E_n)$$

Where E_{ce} is the minimum value of the remaining energy of every node in the cluster.

The flow chart of E_{ce} 's formation is shown in figure 1.

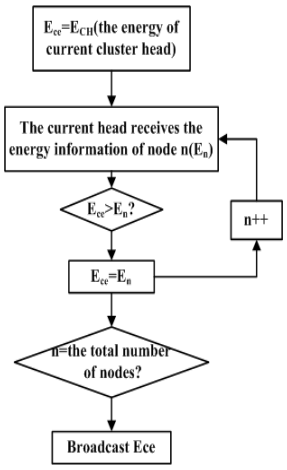

Fig.1. Flow chart of E_{ce}'s formation

DEFINITION 3: Contains all nodes within the cluster with a minimum radius of the circle is shown in figure 2. R_c is the radius of this circle.

DEFINITION 4: d_n is the distance between node n and the centre of this circle.

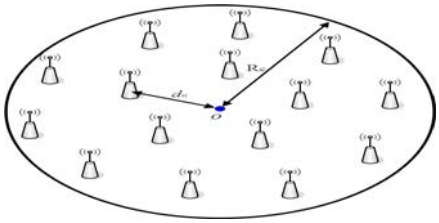

Fig.2. R_c and d_n

The improved LEACH protocol formula as follow:

(3) $$T(n) = \begin{cases} \frac{p}{1 - p*(r*\bmod 1/p)} * [(1 - \frac{E_{ce}}{E_n}) + \frac{E_{ce}}{E_n}(1 - \frac{d_n}{R_c})] & if\ n \in G \\ 0 & else \end{cases}$$

The above formula can be written as:

(4) $$T(n) = \begin{cases} \frac{p}{1 - p*(r*\bmod 1/p)} * (1 - \frac{d_n}{E_n} * \frac{E_{ce}}{R_c}) & if\ n \in G \\ 0 & else \end{cases}$$

Where $\frac{d_n}{E_n}$ becomes one of the important factors to affect the probability of normal node to become a cluster head.

Only more recent from the centre of the circle and more remaining energy be lest, the node will become cluster head in the High-Probability. In this way, we can average the energy consumption of all nodes in the cluster.

In the following, the algorithm of Obtaining E_{ce} is.

```
Function GETECE(S)
1       Ece = S(1).E;
2       for i=1:1:n
3          if ((S(i).E)<Ece)
4             Ece = S(i).E;
5          end
6       end
7       if (Ece==Eo )
8             Ece=0;
9       End
10    End
```

2.Multi-hop routing of cluster head

In order to solve the problem 3, we introduce a multi-hop routing protocol. This is based on energy and hops. Cluster head which far from the sink node can send a message to the sink node through multi-hop. Near the sink node, cluster head can send a message to the sink node directly.

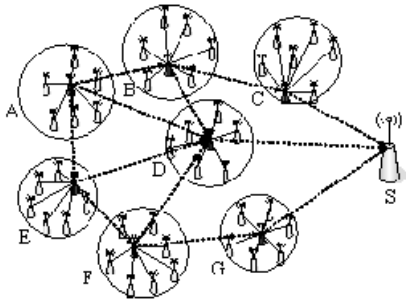

Fig.3. The architecture of network

For instance, we have 8 clusters (A,B,C,D,E,F,G) and a sink node (S) in figure 3.Now, we want to send message from A to S. There are 6 paths. Which patch is the best one? A new path selection policy is given below.

(5) $$N(i) = a * E_{p(i)} + b / H_i$$

Where a and b is weight values. $E_p(i)$ is the minimum energy of the cluster headers of path i. Hi is the number of hops of path i.

Select the maximum value of $N(i)$ as the best transmission path.

(6) $$E_{p(i)} = \min(E_{ce}(i))$$

Where $E_{ce}(i)$ is the E_{ce} of path i .

The remaining energy E_{ce} of every cluster is given in the following Table 1.

Table.1. The remaining energy of clusters

Cluster number	A	B	C	D	E	F	G	S
E_{ce}	0.6	0.8	0.6	0.7	0.9	0.7	0.5	1

The following routing Table 2 is obtained according to the routing request above. According to the formula (4), calculate value of $N(i)$, set a=0.6, b=0.4

Table.2. The routing table of cluster heads

Path number	path	$E_p(i)$	H_i	$N(i)$
1	A-D-S	0.5	2	0.50
2	A-B-C-S	0.7	3	0.55
3	A-B-D-S	0.5	3	0.43
4	A-E-D-S	0.5	3	0.43
5	A-E-F-D-S	0.7	4	0.52
6	A-E-F-G-S	0.5	4	0.40

After comprised the value $N(i)$ of the six paths, we can see that the path 2 is the best route; path 1,3,4,5 and path 6 are the alternative routes.

Simulation analysis

1.The simulation design

MATLAB was used to simulate different routing protocols and verify the advantage of improved LEACH protocol. Parameters of network model are: there is a network with 100 randomly nodes with initial energy of 0.5 Joule, they are deployed in area about 100m*100m, the sink node is located at (50,175) m. In figure 4 is the distribution of sensor nodes random.

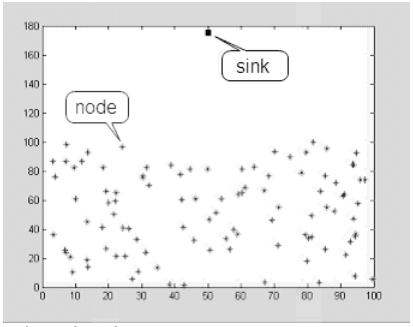

Fig.4. Distribution of nodes

2.The result of simulation

In the following two pictures figure 5 and figure 6, the red line indicates the number of the active nodes in the traditional LEACH protocol. The blue line indicates the number of the active nodes in the improved LEACH protocol. In figure 5, randomly nodes with initial energy of 0.5 J. Horizontal coordinates expresses the simulation time (seconds). Vertical coordinates expresses the active node numbers left. The simulation result obviously shows that, when the active nodes of the LEACH protocol retain 40%, the active nodes of the improved LEACH protocol just start to decrease. In figure 6, randomly nodes with initial energy of 1 J. The simulation result obviously shows that, the improved LEACH protocol has a more pronounced effect. The time of the active node to become less is longer than the traditional one. The life-cycle of the network is about to be extended by nearly half.

Therefore, the improved LEACH protocol can average energy consumption and effectively prolong the network lifetime. The reason is flowing. On the one hand, the improved LEACH protocol takes the energy factor into consideration. The threshold is different from each node. The node with more remaining energy has more opportunities to become a cluster head. On the other hand, every cluster head has more than one routes to send the data to the sink, cluster head can select the optimal path to transmit information and reduce the loss of energy of cluster head. We can see the improved LEACH protocol can average energy consumption of every node and dispersed the network flow. Comparing figure 5 with figure 6, nodes have different initial energy levels instead of uniform initial energy level, but the effect caused by the improved LEACH protocol is same. The life-cycle of the network is extended both.

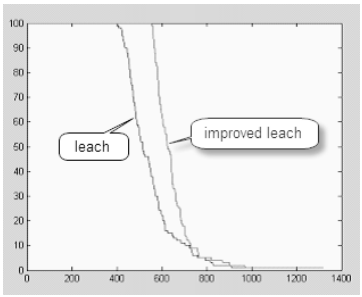

Fig.5. Result of simulation (initial energy of 0.5J)

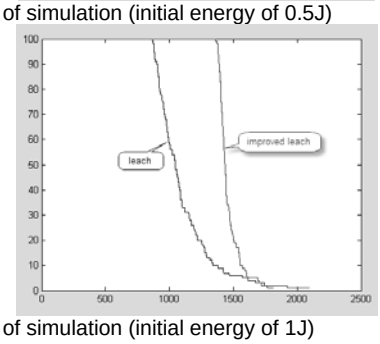

Fig.6. Result of simulation (initial energy of 1J)

Conclusion

In this paper, the improved LEACH protocol acts as a remedy to the shortcomings of traditional LEACH protocol. It can solve the issue of the probability of each node to be selected as cluster head is same. The issue of some clusters heads may be in the edge of clusters far away from members cause increase in energy consumption is solved too.This paper also proposes a multi path route algorithm based on energy-hops . The simulation result indicates: the improved LEACH protocol can neatly average energy consumption of network, achieve the balance of network's flow and extend the life-cycle of network.

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***Authors**: Jianguo Shan,* School of Automation, Beijing Institute of Technology, *Address: 5 South Zhongguancun Street,Haidian District, Beijing 100081, P. R. China,*
E-mail:mymanlian@126.com.