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# Experimental Design and Analysis of LEACH Protocol and Improved Algorithm

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***Abstract***

Many sensor nodes need to be randomly distributed in the area to be detected to collect information during application of wireless sensor network. Effective transmission of the information to observers is a key problem to be solved by routing protocols and an important factor determining the performance of wireless sensor network. From different points of view, different types of routing protocols are present. In order to help students understand and design routing protocols, the experiment is presented during teaching in this study. First, the principles of the LEACH protocol and the improved algorithm were analyzed. Second, the program of the LEACH protocol was implemented under the environment of MATLAB R2014a, which was run to analyze the operation of LEACH protocol, and the relationship between live nodes in network and run round number was summarized. Finally, LEACH protocol and improved algorithm were compared by experimental design and analysis. By relevant experiments, students can understand and apply the principle of LEACH protocol and relevant routing technology, and further understand the role of routing protocol, resulting in enhanced interest in learning.

***Keywords:****LEACH protocol， Wireless sensor network， Routing protocol*

## 1. INTRODUCTION

Wireless sensor network (WSN) is a key component of the perception layer of the IoT [1,2]. A self-organized and multi-hop network system has been developed by many low-cost microscopic sensor nodes connected by wireless communication in the monitoring area. This system is employed to detect, collect and process information of the sensing objects in the network-covered area, before sending it to the observer [3,4,5]. Fixed network support is not required for WSN, and it has been applied in commercial fields such as military reconnaissance, environmental monitoring and medical monitoring [6,7,8,9,10]. Therefore, the network engineering specialty of our college started to offer the course of sensor network technology from the network grade 14. During teaching of this course, considering the important influence of routing technology on the performance of WSN [11,12,13], we focused on the classical plane routing protocol and the cluster routing protocol. As the LEACH (low energy adaptive clustering hierarchy) protocol is a classical clustering routing protocol, LEACH protocol experiment was designed based on MATLAB and theory teaching was combined with experiments, resulting in good teaching effectiveness.

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This study mainly discussed the key knowledge of LEACH protocol. First, the principle and design process of LEACH protocol were analyzed, and LEACH protocol experiment based on MATLAB was implemented. By analyzing the program code and observing the results, students can thoroughly understand the routing technology and methods involved in LEACH protocol.

## 2.RESEARCH METHOD

### 2.1 Related work

#### 2.1.1 LEACH protocol principle

LEACH protocol is a classical clustering routing protocol proposed in WSN[14,15,16].Its topology is shown in Figure 1.The network consists of multiple clusters and each of them includes a cluster head node(CHN)(Black node in Figure 1)and multiple ordinary nodes(White node in Figure 1).LEACH protocol works periodically and each cycle has two stages:the establishment stage of cluster and the stable data transmission stage.Since CHNs consume more energy,LEACH protocol adopts the method of periodic election so that each node has the opportunity to be selected as a cluster head in different periods.In this way,the nodes in the network bear a certain amount of s(EC)and the network life time was extended as much as possible.

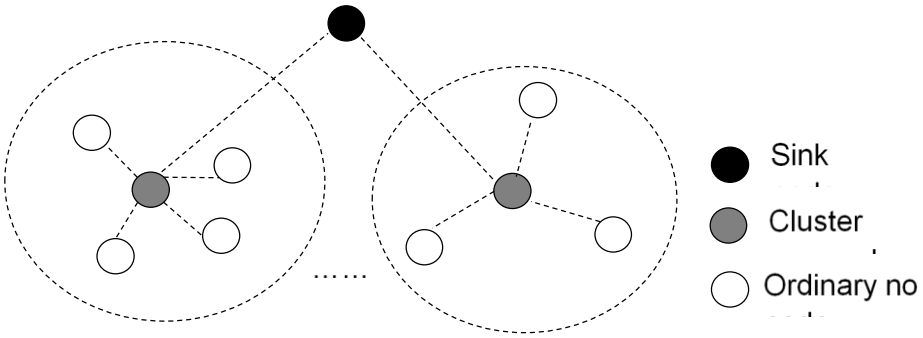


**Figure.1** LEACH protocol topology

**(1)Cluster establishment stage**

CHNs are generated by dynamic random selection,and cluster heads(CHs)serve as the core part in development of clusters.In other words,each node generates a random number in[0,1]:if the number<T(n),the node was elected as the CH;if a node serves as CH in the previous cycle,its threshold T(n)will be set to 0 in this cycle so that the random number of nodes must be greater than T(n)and it cannot be chosen as CH again.For the nodes with unselected CH,the threshold T(n),the probability of the random number less than T(n)and the probability of selection increase as the quantity of sensor nodes with unselected CH decreases.The expression of T(n)is shown in equation(1).

$$T(n)=\begin{cases}\frac{p}{1-p(r\ mod\frac{1}{p})}, n\in G\\ 0, others\end{cases} \quad (1)$$

where p is the percentage of CHs in all nodes,r is the total quantity of elected rounds,r mod(1/P)represents the quantity of selected CHNs in the current round,and G is the set of unselected CHNs.

When a node is selected as a CHN,it will broadcast messages to inform other nodes to become new CHs.Upon receiving the message,a non-cluster head node calculates the distances to all CHNs and selects the nearest CH to join,and sends a message to invite the CH to join.Upon receiving the invitation,the CHNs will send TDMA timing message according to the number of nodes in the cluster to inform all nodes in the cluster about the time slot of data transmission.Meanwhile,the CH can generate the CDMA code,which is used to prevent signal interference by clusters nearby.In this way,the cluster was established.

**(2)Data transmission stage**

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Upon receiving the TDMA message,the node will send data in its own time slot according to the message.After a period of data collection,the CHN will collect data of nodes in the cluster,and the data will then be fused through the algorithm,and eventually the results will be sent directly to the sink node.

### 2.1.2 Energy consumption(EC)model of LEACH network

The EC model was employed to calculate the EC of each node.If the distance between nodes was set as D,the EC by transmission of k-bit information can be calculated by:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^2 \quad (2)$$

The EC by receiving k-bit information can be calculated by:

$$E_{Rx}(k) = E_{Rx-elec}(k) = E_{elec} * k \quad (3)$$

where $E_{elec}$ represents the EC by the transmitting circuit and the receiving circuit,and $\varepsilon_{amp}$ represents the amplification factor of the RF amplifier.

### 2.2 Improved algorithm

In LEACH protocol,the node selected as CH accounts for data receiving,fusion and forwarding of all nodes in the cluster,so the EC of CH is significantly larger than EC of non-cluster head one.After running for some time,the energy of each node is not uniform.If the low energy node is selected as CH,the CHN may die soon after running,which greatly affects the survival duration of the network.Therefore,it is necessary to increase the limit condition of low-energy nodes becoming CHNs,in order to prevent the low-energy nodes from dying soon after becoming CH and affecting the lifetime of the network.This algorithm improves the threshold T(n)by introducing a CH selection influence value of Q,and indicates that nodes with high residual energy tend to be selected CHs.The improved expression of T(n)equation is shown in equation(4):

$$\mathbf{T(n)} = \begin{cases} \frac{p*Q}{1-p(r \bmod \frac{1}{p})}, n \in G \\ 0, others \end{cases} \quad (4)$$

Where the expression of Q is shown in equation(5):

$$\mathbf{Q} = \sqrt{\frac{E_C(r)+0.5}{E_o(r)+0.5}} \quad (5)$$

where r refers to the round number,$E_C(r)$refers to the residual energy of nodes after r rounds, $E_o(r)$ refers to the initial energy of the node.When the influence value of Q is introduced,the value of T(n) is proportional to$E_C(r)$.High energy nodes have a high probability of being selected,which effectively improves the negative effect of fast failure of low energy nodes when they become CHNs.

## 3.RESULTS AND DISCUSSION

### 3.1 Experimental Design of LEACH protocol

The design flow of LEACH protocol is shown in Figure 2.Establish a network composed of wireless sensor nodes and sink nodes,initializedata,set the maximum round number,select CHs according to the principle of LEACH protocol,form clusters with common nodes,and forward the data collected by nodes in each cluster to sink nodes.

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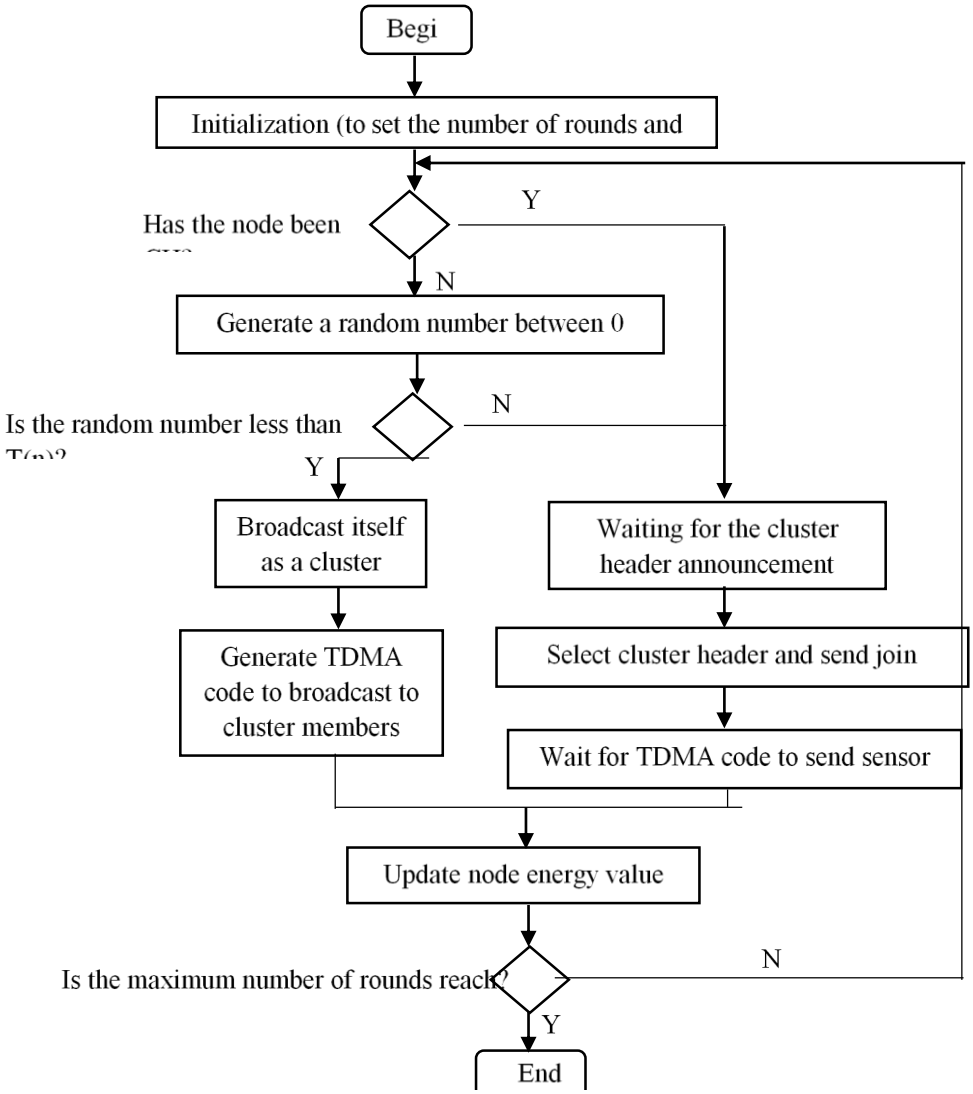


**Figure.2** Design flow chart of LEACH Protocol

### 3.2 Experimental analysis of LEACH protocol

According to the above design in section 3.1,LEACH protocol simulation implementation and experimental analysis write a program in MATLAB R2014a environment,set a 100×100 area,and set a sink node in the center(represented by the symbol"×").100 sensor nodes were included in this area,the initial energy of each node was set to be 0.5,and the percentage of CHs in all nodes p was set to be 0.1.Set the energy loss and free space energy loss of sending and receiving a binary bit information to be represented by *ERX*,*ETX* and *Efs*,the energy required for power amplification to be represented by Emp,and the maximum number of running rounds *rmax* to be set to 1500.The CHN is represented by"+",and the dead node is represented by red dot.According to the above set values,at the beginning of the program operation,the node distribution is shown in Figure 3.

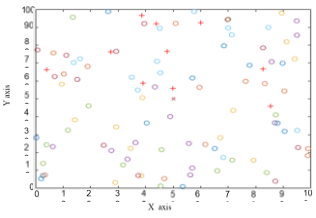

**Figure.3** LEACH protocol node distribution and CH election

In Figure 3,a 100×100 wireless sensor network area is generated.The center position is the sink node and 100 sensor nodes are distributed randomly near this node.During cluster building,10 CHNs are

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selected.After 1,500 rounds of operation,the final operation results are shown in Figure 4.As observed,the red node is the dead node,and the number of surviving nodes is 10,including 4 CHNs.The quantity of dead nodes is included in the dead variable,and the overall quantity of n-dead nodes is the quantity of surviving nodes.The quantity of survival nodes as the Y axis and the quantity of running rounds are taken as the Xaxis.The relationship between survival nodes and running rounds is shown in Figure 5.As observed,the first dead node appears when running round is 1,049,and more and more nodes are dead as the round number increases.The quantity of surviving nodes is approximately linearly decreasing with the number of rounds.

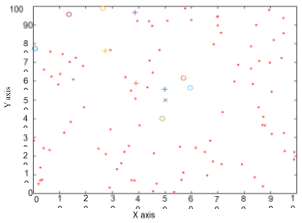


**Figure.4** LEACH protocol operation results

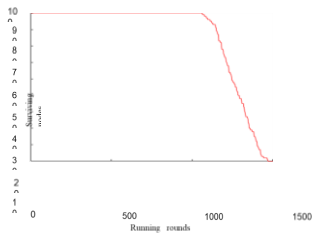


**Figure.5** Relationship between surviving nodes and running rounds

Through the above analysis,we can see that LEACH protocol can optimize the energy load of the entire network,and it is ensured that no node will die due to exhaustion of energy in the early stage.Its disadvantages are also obvious,because the generation of CHs is random and local aggregations of CHs cannot be avoided,while some areas do not have CHs,which is not conducive to energy saving of the network.

### 3.3 LEACH protocol vs.improvedalgorithm

In the section,the experiment is designed to compare LEACH and improved algorithm,and we set the LEACH protocol as leachs1 and the improved algorithm as leachs2.Similar initial values are still taken.The difference is that the maximum number of rounds*rmax* is set to 3,000.The relationship between the quantity of dead nodes and the quantity of rounds is shown in Figure 6.As observed,the X axis reflects the quantity of nodes running rounds and the Y axis reflects the quantity of dead nodes.The first death node in leachs1 protocol appeared earlier than leachs2,and all nodes died earlier than leachs2.Both protocols increase the number of death nodes gradually after the first death node appears,and their increasing rate is approximately the same.Through the comparison,we can see that survival time of the leachs2 protocol node is longer,and the network survival time is extended.

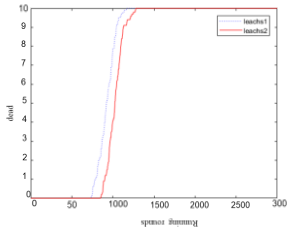


**Figure.6** Comparison chart of dead node changing with running rounds

The relationship between the EC and the number of rounds is shown in Figure 7,the X axis reflects the number of nodes running rounds and the Y axis reflects the EC.If EC of leachs2>EC of leachs1,it continues to run 110 rounds after leachs1 runs out of energy.

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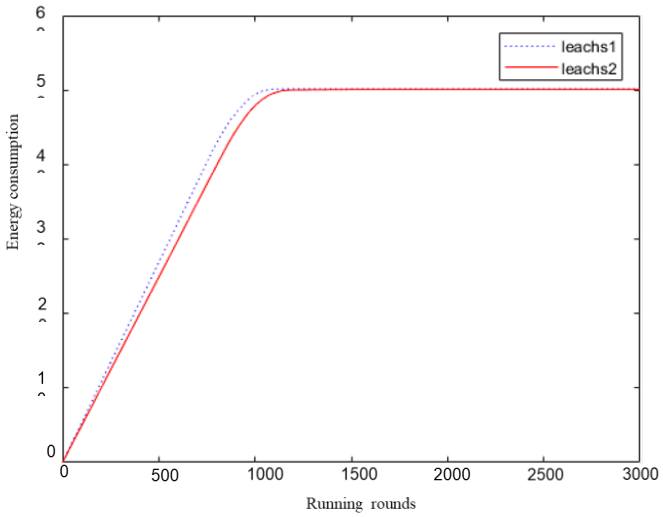


**Figure.7** Comparison of EC

As shown in Figure 8,the X axis reflects the number of running rounds of the node and the Y axis reflects the data transmission volume.As can be seen that the amount of data transmitted by leachs2 is much larger than leachs1.The transmission volume of leachs1 is 9698bit,while the data transmission volume of leachs2 is 21958bit.The total efficiency of data transmission is increased by 126%.

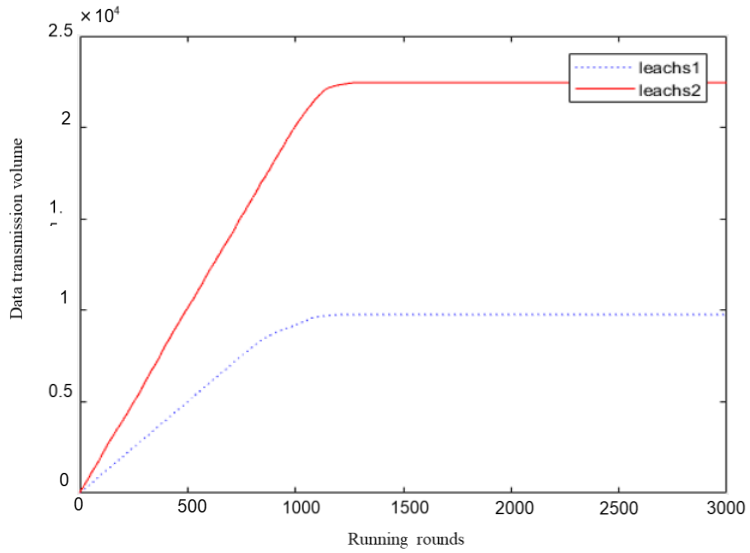


**Figure.8** Comparison data transmission volume

## 4.CONCLUSIONS

With the continuous progress of wireless communication technology and microprocessor technology,wireless sensor network develops rapidly and is widely used.However,WSNs are often deployed outdoors,which inevitably encounter nodes failure.Good routing protocol can effectively improve performance of WSNs.Therefore,this paper designs the experiment in the process of routing protocol teaching,analyzes the principle and design of the typical LEACH protocol and improved

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algorithm,and uses MATLAB R2014a to carry out code implementation and protocol operation.By observing the results concreting the abstract theory,this paper enables students to deeply understand the technical principles related to routing protocol and deeply grasp the application methods of routing protocol,laying a foundation for the subsequent knowledge learning of the course.

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