TELKOMNIKA, Vol. 11, No. 10, October 2013, pp. 5980 ~ 5985
ISSN: 2302-4046

Research on an Improved Wireless Sensor Networks Clustering Protocol

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Abstract

Energy consumption of clustering routing protocol is one of the exigent problems needs to solve in wireless sensor networks. Aiming at the uneven energy consumption and unreasonable cluster heads selection in LEACH protocol, a new clustering routing protocol is proposed in this paper including number of cluster heads, cluster head choosing algorithm and network topology. Finally we give some analysis and comparison between the improved protocol and other two protocols, and the results show that the improved protocol can increase node energy-efficiency and prolong network survival lifetime.

Keywords: *Wireless sensor networks- LEACH protocol- Cluster heads*

1. Introduction

As a new technology, wireless sensor network (WSN) is recognized as the fourth industry revolution of IT technology and the developing direction of the next-generation computer network. It changes the interaction method between people and environment, and becomes the indispensable part of our life [1] [2]. WNS is applied in the adverse environment which can't be monitored, and shows large application values in the area of military, environment, biology, medical care, space exploration and business, and it has the advantage of high accuracy, good fault tolerance, large monitor area and the character of energy constrain.

WSN is constrained by the strict and harsh energy and bandwidth, and the sensor nodes work in the adverse environment, its energy is provided by micro battery and can hardly be charged or replaced. Sensor nodes need to collect the data and finish the data transmission, so how to design a clustering routing protocol in wireless sensor networks and decrease the energy consumption becomes the key problem need to be solved in wireless sensor networks application. The main energy consumption of nodes include three parts-processor unit, sensor unit and wireless transmission unit, which cost the main energy.

2. Transmission Unit of Wireless Sensor Newtorks

The design of wireless sensor networks routing protocol is related with energy consumption of transmission. Figure 1 is the common transmission consumption model.

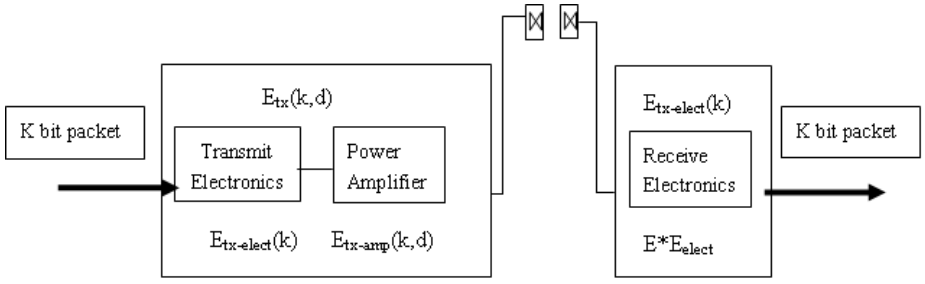

Figure 1. Model of transmission consumption

Received March 7, 2013; Revised July 9, 2013; Accepted July 20, 2013

In this model, it considers the energy consumption of transmitting, receiving and amplifying of signals. And the signal-amplifier makes sure that the signal can be received by another node.
So, when sending K bit packet with distance d, the energy consumption is as formula 1.

$$E_{tx}(k,d) = E_{tx-elect}(k) + E_{tx-amp}(k,d) \quad (1)$$

In this formula, Etx-elect is the energy consumption of sending K bit packet, and Etx-amp is the energy consumption of amplifier.

3. Basic Research

Because the main energy consumption in wireless sensor nodes is transmitting, thus in designing a energy-efficient clustering routing protocol, reducing the energy consumption of nodes become the key problem need to be solved.

3.1. Leach Protocol

In order to decrease the energy consumption, some research puts forward the concept of cluster network topology, which divides the whole monitor area into clusters, and each cluster has one cluster head node and some sensor nodes. The lower cluster heads are the sensor nodes of some higher cluster, and the highest cluster heads communication with sink node. The LEACH [3] protocol which is put forward by Heinzelman W is the first clustering routing protocol, and its basic thinking is equiprobably selecting the head nodes in a random cyclic, so the energy of whole network can be assigned to each sensor node averagely, and therefore reduce the energy consumption and prolong the network survival lifetime.

3.1.1. Working Process of Leach

LEACH introduces the concept of " round ", and each round includes the initial stage and persistent working stage.

a. Initial Stage

First, the wireless sensor networks nodes randomly generate a number between 0 and 1, and then compare the number with the defined threshold number, if it greater than the threshold number, the node become the cluster head. The formula of threshold number is as

$$T(n) = \begin{cases} \dfrac{p}{1 - p * [r * \bmod(1/p)]} & n \in G \\ 0 \end{cases} \quad (2)$$

In this formula, p the is percentage of expected head nodes, r is the round number, mod(1/P) means the selected head number in each round, and G is the non-head nodes sets in the last 1/p rounds.

Second, after the head selecting, each cluster head broadcasts its state to other nodes, and informs other sensor nodes join into its cluster. When each non-head node receives some broadcast message, it selects the right head node depending on the distance and then transmits its state to cluster head.

Finally, cluster heads arrange the TDMA time slots according to the number of nodes, and then send the result to sensor nodes which belong to cluster head.

b. Persistent Stage

In the persistent stage, each non-cluster node of LEACH transmits data to cluster head in its own time slot, and goes to sleeping in other time slots to save the energy. Then the cluster head transmint the data to sink node after data fusion, and then one round is over.

3.1.2. Disadvantage of Leach

LEACH adopts the random way to select the cluster head, which avoids the node energy cost excessively. But it still has some disadvantage.

1) The random way of selecting cluster head makes each node possibly become the cluster head, but it also makes the possibility that low-energy nodes become the cluster heads. If the cluster head exhaust its energy, it will become a blind node and finally makes the network to die.

2) In transmission stage, LEACH algorithm adopts one hop routing, and each sensor node directly transmits data to sink node. But according to energy consumption model above, the energy consumption is larger if the distance is longer, so each node will have uneven rest energy in this network with rapid running of LEACH.

3.2. Existing Routing Protocol

Aiming at the LEACH disadvantage, HEED [4] took node rest energy and inter cluster communication cost into account, and realized the even energy cluster in the process after several iteration. EECS [5] combined the random selecting mechanism and local competition mechanism to select the cluster heads. The literatures [6] [7] put the rest energy into cluster head selecting algorithm, in which, literature [7] put forward the uneven energy cluster head competition algorithm, and increased the probability of cluster heads then the node had more rest energy. Though above algorithms improved the energy efficiency, there still have some problems to solve.

4. Improved Clustering Routing Protocol in Wirelsess Sensor Network

From the communication perspective, we present a imporved clustering routing protocol in wireless sensor network based on LEACH. The improvements include numbers of cluster heads, cluster head selecting algorithm, network topoloy and so on. The imporved clustering routing protocol includes three parts, they are application environment model, cluster process and communication.

4.1. Application Environment Model

Application environment includes thress models, they are network model, transmission model and time line model showed in Figure 2.

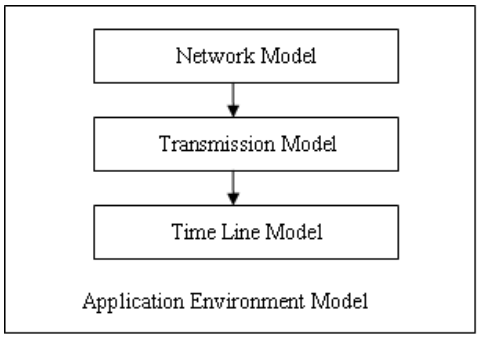

Figure 2. Application environment model

Wireless sensor networks is widely used in many kinds of environment, so we deploy n nodes into a rectangle area randomly. The sink node is in the center area, and all sensor nodes have the same initial energy and can't move. Every node has the ability to send data to sink node and has the ability to transmit and fuse data.

In transmission model, we adopt the model of transmission consumption in chapter 2. And in time line model, we adopt the round including cluster head selecting, cluster process and communication. Because of the energy consumption of cluster head selecting in each round, we use double round instead of every round clustering. That is to say, after initialization, in the odd

rounds, we select the cluster head nodes, secondary cluster head nodes, finish cluster process and communication. And in the even rounds, there left only communication.

4.2. Cluster Process

Cluster process includes three stages showed in Figure 3, they are number of cluster heads, cluster head selecting and cluster process.

4.2.1. Number of Cluster Heads

In clustering routing algorithm, the number of cluster heads has large influence on its performance, and reasonable number will even the network energy consumption and improve the performance, so in this paper, we adopt the number of cluster heads algorithm in literature [8].

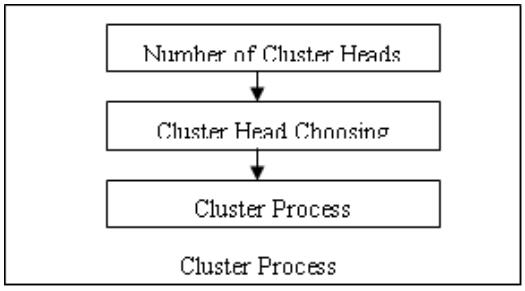

Figure 3. Cluster process

4.2.2. Cluster Head Choosing

In traditional LEACH, it is supposed that the energy consumption of each node is even, so the probability of to be the cluster head is the same. But in real environment, the distance between sensor nodes to sink node are not the same, and the rest energy of each node will be different after several rounds. So in our algorithm, we take rest energy and average rest energy of each node as the important factor of selecting the cluster head, and make sure that the highest energy node becomes the cluster head node, and the secondary highest energy node become the secondary cluster head node. The formula is 3.

$$T(n)=\begin{cases}\dfrac{p}{1-p*[r*\bmod(1/p)]}*\dfrac{E_{rest}(r)-E_{used}(r)}{E_{average}(r)-E_{used}(r)} & n\in G\\ 0\end{cases} \quad (3)$$

In this formula, Erest(r) is the rest energy, Eused(r) is the used energy and Eaverage(r) is the average rest energy when the node in the r-1 round.

4.2.3. Cluster Process

After the cluster head is selected, cluster heads broadcast a message to tell all sensor nodes that it's a cluster head in odd round. Other nodes decide which head to choose according to the signal of received cluster heads and transmit the rest energy to the cluster head, and then the cluster head give the time slot to each node according to the energy, and the secondary cluster head has the first time slot. In even round, the secondary cluster head become the cluster head and other nodes begin to transmit the data to new cluster head.

4.3. Data Communication

4.3.1. Communication in Interior of Cluster

According to some research, the energy cost in active sate is more than in sleeping state, so we combine sleeping stratagem with TDMA stratagem. That is to say, each node has its own time slot. It wakes up and transmits the data only in its time slot and goes into sleeping

state and closes down its radio and stops listening the network when it is in other turn. In this paper, we adopt the size of time slots in literature[8] which is equal the max transmitting time of max size data packet.

4.3.2. Communication between Cluster Head and Sink

Every nodes share the same broadcast channel in the communication between cluster head and sink, so signal from two clusters near by may be interrupted by each other. To solve the problem, we adopt CDMA and distribute a unique code for each cluster. When a node is selected as a cluster head, it choose a code in the spectrum randomly, and then broadcasting this code to all member node in this cluster. Later, all nodes use this code to transmit message in this cluster. Cluster head filter out the message which doesn't use this code. So it avoids the interruption.

When cluster head sending data to the sink, the energy consumption aren't the same because of their different distances to the sink. To proportion the energy consumption, we combine one hop with multi-hops topology instead of one hop according to the distance between sink and cluster head.

5. Simulation

5.1. Simulation Environment

The monitor area is a rectangle of 100m×100m as in Figure 4, and node number is 100 in this wireless sensor network. The sink lies in the center of the area, all node locations are known and the radius of sensor node is 25m. The initial energy is 0.02J, the data packet is 4000bit, E_{elect}=5nJ/bit and $\mathcal{E}_{fs}$ =10nJ/bit/m2.

5.2. Simulation Result

In this part, we compare the improved clustering protocol with LEACH and DD. From Figure 5, we can see that the round number of first node dead time in DD is about 110, the round number of first node dead time in LEACH is 150, and the round number of first node dead time in improved clustering protocol is 260. When the percent of dead nodes is over 70%, the network can not work well. From Figure 5, we can see that round number of 70% node dead time in DD and in LEACH is about 500, but in our improved protocol, the number is about 600. When the initial energy changed, the result of simulation is the same as in the initial energy is 0.02J.

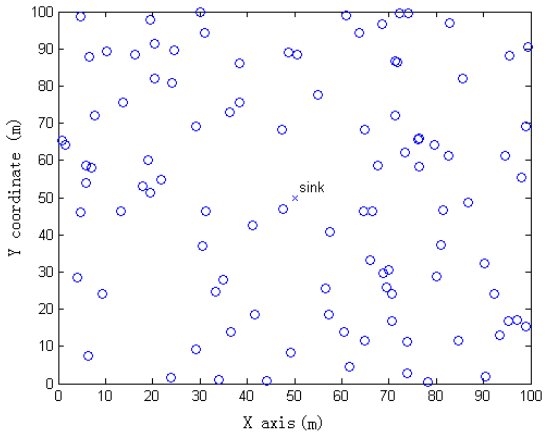

Figure 4. Network model

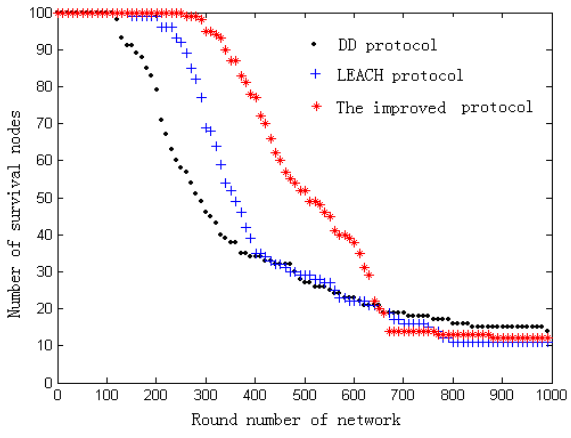

Figure 5. Round number of survival nodes

6. Conclusion

Aiming at the disadvantage of LEACH, this paper presents a improved clustering routing protocol in wireless sensor networks including number of cluster heads, cluster head

selecting and network topology. Finally we do some analysis and comparison between the improved protocol and other two protocols, and the results show that the improved protocol can increase the node energy-efficiency and prolong the network survival lifetime

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