Energy Efficient Routing in Wireless Sensor Networks using the SCH-LEACH Clustering method

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Abstract*—Wireless sensor networks consist of small battery powered devices with limited energy resources. One of the major issues in wireless sensor network is developing an energy-efficient routing protocol. Energy efficiency is the key parameter which improves the life span of the network. In this paper, we propose a novel clustering routing protocol called Selective Cluster Head based Low-Energy Adaptive Clustering Hierarchy (SCH-LEACH). This cluster-based routing protocol method will distribute the cluster heads evenly over the network and reduce energy dissipation. The performance of this novel approach is then compared to clustering-based schemes such as Low-Energy Adaptive Clustering Hierarchy (LEACH) and Static Clustering Protocol. Simulation results show that SCH-LEACH reduces overall energy consumption and improves network lifetime over its comparatives.*

Keywords— Energy Efficient, LEACH protocol, Routing, Static Clustering Protocol

I. INTRODUCTION

Wireless Sensor networks (WSN) can contain hundreds or thousands of sensing nodes. Sensors are powered by battery, which is impossible to get recharged after deployment. But sensor networks are designed to last. It is desirable to make these nodes as cheap and energy-efficient as possible. Many routing protocols have been proposed for wireless sensor networks. The main goal of the routing protocols in wireless sensor networks is to find ways for improvement of energy efficiency and reliable transmission of sensed data to the sink. During the creation of network topology, the process of setting up routes in WSNs is usually influenced by energy considerations. Because the power attenuation of a wireless link is proportional to square or even higher order of the distance between the sender and the receiver, multi-hop routing is assumed to use less energy than direct communication.

Based on the network structure adopted, routing protocols for WSNs can be classified into flat network routing, hierarchical network routing and location-based network routing. In flat network routing, all nodes have the same functionality and they work together to perform sensing and routing tasks. Hierarchical network routing divides the network into clusters to achieve energy-efficient, scalability and one of the famous hierarchical network routing protocol is Low-Energy Adaptive Clustering Hierarchy (LEACH) [1]. In location-based network routing, location information of nodes is used to compute the routing path. This information can be obtained from global positioning system devices attached to each sensor node. Many research projects and papers have shown that the hierarchical network routing and specially the clustering mechanisms make significant improvement in WSNs in reducing energy consumption and overhead.

In this paper, we propose a new clustering routing protocol called Selective Cluster Head based Low-Energy Adaptive Clustering Hierarchy (SCH-LEACH). This cluster-based routing protocol method will distribute the cluster heads evenly over the network and reduce energy dissipation. Our scheme tries to evenly distribute cluster heads over the whole network and avoid creating redundant cluster heads within a small range so that it can increase the network lifetime.

The rest of the paper is organized as follows: In section 2, we review some conventional cluster-based routing protocols. In section 3, we propose a new distribution scheme of cluster heads. Section 4 deals network model, Section 5 contains evaluation indicators, Section 6 simulations and comparisons. Finally, we conclude the paper in section 7.

II. RELATED WORKS

The main goal of cluster-based routing protocol is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a cluster and by performing data aggregation and fusion in other to decrease the number of transmitted messages to sink and transmission distance of sensor nodes.

Cluster-based routing protocol is classified into distributed and centralized clustering algorithms depending on the manner of selecting the cluster heads. In the distributed clustering algorithm, every sensor node deployed in the sensing field independently determines its role (whether it acts as a cluster head or not) based on the probabilistic value and/or residual energy. In centralized clustering algorithms, by contrast, sink node takes the leading role in selecting the cluster heads. Sink node knows geographical position, residual energy and neighbour information of all sensor nodes. Based on this information, sink node selects cluster heads and broadcasts sensing field in order to organize clusters.

A. *Static Clustering Protocol*

In this protocol, the sensor nodes from the entire network are divided into several clusters, cluster-head nodes

communicate with the local base station, then the local base station feed data to the entire network of base stations, and terminal user can access useful information. The distance between the local base stations and the cluster node was very close, therefore greatly reducing the energy consumption of these nodes send their information to local base station. In view of this, static clustering protocol seems to be a more efficient communication protocol [2]. However, in the entire network life cycle, these clusters and cluster-head nodes are fixed, and the local base station is assumed as a high-energy nodes situation. In most cases, the local base station is an energy constrained node. The entire network may die soon because of excessive using about local base station node.

B. *LEACH Protocol*

Low-Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular distributed cluster-based routing protocols in wireless sensor networks. LEACH randomly selects a few nodes as cluster heads and rotates this role to balance the energy dissipation of the sensor nodes in the networks. The cluster head nodes fuse and aggregate data arriving from nodes that belong to the respective cluster. And cluster heads send an aggregated data to the sink in order to reduce the amount of data and transmission of the duplicated data. Data collection is centralized to sink and performed periodically [3].

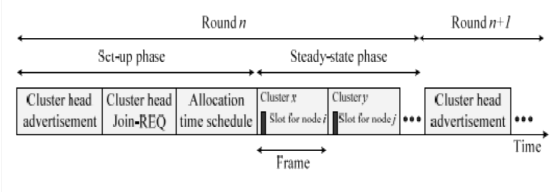

Fig 1. Timeline of LEACH Protocol

The operation of LEACH is generally separated into two phases, the set-up phase and the steady-state phase, as shown in Fig. 1. In the set-up phase, cluster heads are selected and clusters are organized. In the steady-state phase, the actual data transmissions to the sink take place. After the steady-state phase, the next round begins.

During the set-up phase, when clusters are being created, each node decides whether or not to become a cluster head for the current round. This decision is based on a predetermined fraction of nodes and the threshold T(n). The threshold is given by

$$T(n) = \frac{p}{1-p*(r \bmod \frac{1}{p})} \qquad \text{for n } \varepsilon \text{ G} \qquad (1)$$

where p is the predetermined percentage of cluster heads (e.g., p = 0.05), 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 round within 1/p rounds. After 1/p rounds, all nodes are once again eligible to become cluster heads.

In LEACH, the optimal number of cluster heads is estimated to be about 5% of the total number of nodes [4]. Each node that has elected itself a cluster head for the current round broadcasts an advertisement message to the rest of the nodes in the network. All the non cluster head nodes, after receiving this advertisement message, decide on the cluster to which they will belong for this round. This decision is based on the received signal strength of the advertisement messages. After cluster head receives all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster head creates a TDMA schedule and assigns each node a time slot when it can transmit.

C. *LEACH-C Protocol*

LEACH-centralized (LEACH-C) is similar to LEACH in operation except cluster formation [5]. In LEACH-C, the cluster head selection is carried out at Base Station. During the setup phase, Base Station receives from other nodes information about their current locations and remaining energy levels. Base Station uses the remaining energy level to determine the candidate set for cluster head node. The average node energy is computed and the node has remaining energy falling below this value will be removed from the candidate set. Using the candidate set, Base Station finds clusters using the simulated annealing algorithm. This algorithm attempts to minimize the total energy that non-cluster head nodes use to transmit their data to cluster head nodes by minimizing the total sum of squared distance between nodes and their cluster head nodes. Once the cluster head nodes are determined, Base Station broadcast to all nodes the information including cluster head nodes, clusters member node and transmission schedule for each cluster. Nodes use this information to determine its TDMA slot for data transmission.

D. *Disadvantages of LEACH methods*

Despite the obvious advantages in using LEACH protocol for cluster organization, few features are still not supported. LEACH assumes a homogeneous distribution of sensor nodes in the given area. This scenario is not very realistic [6]. Let us consider a scenario in which most of the sensor nodes are grouped together around one or two cluster-heads. As being shown in Fig. 2, cluster-heads A and B have more nodes close to them than the other cluster-heads. LEACH's cluster formation algorithm will end up by assigning more cluster member nodes to both A and B. This could make cluster head nodes A and B quickly running out of energy [7].

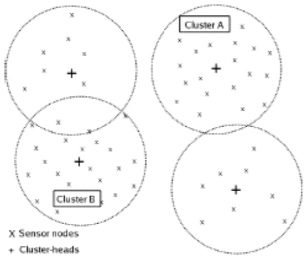

Fig 2. A Sensor Network

In addition, LEACH does not really support movement of nodes. If a node moves away from its cluster-head, it will have to spend more power in communicating with the current cluster-head. It is really worse if a cluster-head move away from its cluster member nodes. The nodes cannot change its cluster head even if it has another cluster head node closer to itself.

In this paper, we describe additional features to LEACH to solve the issues mentioned above. In the next section, we will

present about the algorithm and operations of the proposed protocol called SCH-LEACH.

III. SCH-LEACH PROTOCOL

In sensor networks, the nodes serving as cluster heads are over-loaded with the long range transmissions to the remote nodes or sink as well as due to the extra processing necessary for data process. In static clustering protocol, the cluster-head nodes are fixed and static. In LEACH, we choose cluster-head nodes randomly [8]. Nodes are unfortunately to be chosen if the energy is not enough. So, we can choose the nodes variable by effective methods but not only by randomly. In this paper, Selective Cluster head based weighted clustering algorithm was used to choose cluster-head nodes based on LEACH protocol.

The weight value formula for node v as follows:

$$W_v=w_1|d_v - \$+w_2(\sum_{u\in N(v)} dist(v,u))+w_3T(v) +w_4(E_o-E_{residual}(v)) \quad (2)$$

In this formula, $w_1 \sim w_4$ are the weight factors, N(v) is the adjacent nodes of node v, $E_{residual}(v)$ is node v residual energy, energy E_o is the initial value of each node, T (v) is the time which a node v has been the cluster-head (from the system started working hours). Needs to be pointed out is that the node is static, so in the calculation of the weights do not consider mobile node speed.

The different parameters can be adjusted on the network life cycle, so we can change the value of weights in the formula in order to have a better result [9]. This makes the choice of the cluster-head nodes is not considered one of the factors (i.e, residual energy, transmission consumption, adjacent nodes, the time nodes have play the cluster-head), a number of factors can be estimated taking into account the circumstances balanced so as to extend the network life time.

The Cluster organisation is shown in the Fig.3 given below:

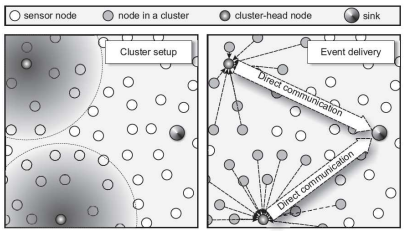

Fig 3. Cluster organisation in SCH-LEACH

IV. NETWORK MODEL AND PARAMETER SETTINGS

In our proposal we have considered the following network model:

- All the nodes are capable of communicating directly with the Base Station (BS).
- The BS is located far from the sensor network and fixed.
- All nodes are homogeneous, energy constrained and immobile.

Initial energy E_o is 4J in this paper. Sensor nodes are densely deployed therefore might generate huge redundant data. Similar data from multiple nodes can be combined or fused together in order to reduce the required number of transmission to the BS. To reduce the number of communication is the most focused issue for a sensor networks because it requires more than 100,000 times [10].

We consider a 100-node network with randomly distributed nodes in a (100×100) meter area. The BS is located at (x=0, y=0). The length of each signal is 4000 bits and the energy required for data aggregation is 5nJ/bit/signal. The radio spends $E_{Tx\text{-}elec}=E_{Rx\text{-}elec}=E_{elec}=5nJ/bit$ energy to run receiver and transmitter electronics. Therefore the transmission cost to transfer a bit message to a distance d is given by the equation:

$$E_{Tx}(a,d)= aE_{elec}+aE_{fs}d^2,\ d<do$$

$$E_{Tx}(a,d)= aE_{elec}+aE_{mp}d^4,\ d<do \quad (3)$$

Where $E_{fs}=10pJ/b/m^2$ and $E_{mp}= 0.0013pJ/b/m^4$ are required amplifier energy for free space. The threshold distance do can be given by equation (4)

$$do=\sqrt{\frac{Efs}{Emp}} \quad (4)$$

Similarly, the receiving cost can be given by equation:

$$E_{Rx}(a)= aE_{elec} \quad (5)$$

As previously described, cluster heads need to be evenly distributed over the whole network for saving energy. In our scheme, we try to avoid redundant creation of cluster heads in a small area.

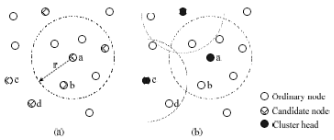

Fig 4. Basic Concept

The sensor nodes are randomly deployed and some of them are initially selected as candidate nodes using Eq.1. The nodes that have not been selected as cluster heads for the last 20 rounds are chosen to become candidate nodes [11].. Nodes receiving this advertisement message are ruled out the qualification of candidate node. In Fig. 4 (a), node a, b, c, and d are elected for candidate nodes among the sensor nodes. First, node a broadcasts an advertisement message within the range r. Node b receiving the advertisement message from node a is ruled out the qualification of candidate nodes. After that, node d is also ruled out the qualification by the same process. As a result, node a and c are actually selected for cluster heads as shown in Fig. 4 (b). Fig. 5 shows state transition diagram of each sensor node.

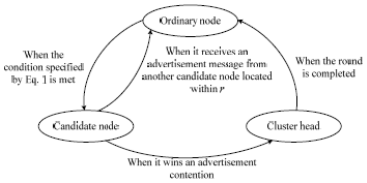

Fig 5. State Transition diagram of each sensor node

V. EVALUATION INDICATORS

The Evaluation indicators in WSN are as follows:

1. Energy consumption: In the wireless sensor networks, the nodes of energy resources are very limited, which directly impacts on the life cycle and network quality of the information. Therefore, this article will mainly compare three protocols in the relationship between the total energy consumption and the time.
2. Data accuracy: The more date BS received, the higher the data accuracy is. If BS received many data, the data can describe the environment more accuracy.
3. Life time: At present there are many definitions about the life time of the network: The first one is defined as the first node died in network; second is defined as the last node died in network, and some other definitions. We can use the relationship between the total alive nodes in network and the time as a comparison.

In order to compare the state clustering protocol, LEACH protocol, and SCH-LEACH three protocols performances, in this paper, we will collect simulation data regularly when simulating by NS. In a certain time intervals, the following three data will be collected:

1. Total energy consumption of nodes in the entire network;
2. Total date which BS has received yet;
3. Total alive nodes in the entire network.

VI. SIMULATIONS AND COMPARISONS

In this paper, simulations are given for the protocol proposed with NS, and the results compared with that of static clustering protocol, LEACH protocol, and SCH-LEACH protocol. Fig.6 is the total energy consumption of entire network nodes about static clustering, LEACH, and SCH–LEACH. Since time of 45, the cluster-head nodes were all dead when using static clustering protocols, and the network stopped working, so the total energy consumption of network after 50 has remained at the level about 60J. Compare the LEACH and SCH-LEACH protocols, before 430, total energy consumption about these two protocols are almost unanimously, but after 430, there is a change in the two protocols about total energy consumption, the total energy consumption of SCH-LEACH is less than the total energy consumption of LEACH protocol. So, SCH-LEACH which can save more energy is better than static clustering protocol and LEACH protocol.

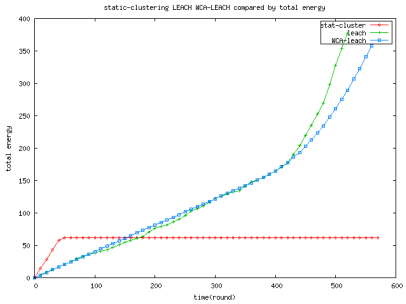

Fig 6. Total Energy Consumption

In order to compare the accuracy of the entire network about the three protocols, the paper compares the total date packages have been received by the base station, as shown in Fig.7. Comparing with the three curves, the date received by BS is least when using static clustering protocol, followed by using LEACH protocol, the most by using SCH-LEACH. In static clustering, BS received data packets to maximize overall when in 50, but after the time, it has been maintained. It is clear that BS received data least when using static clustering protocol. This is because the cluster-head nodes are fixed, so they are overloaded. These fixed cluster-head nodes consume energy faster, once they died, the cluster-head nodes will not be able to send data to the BS, so BS will no longer receive data.

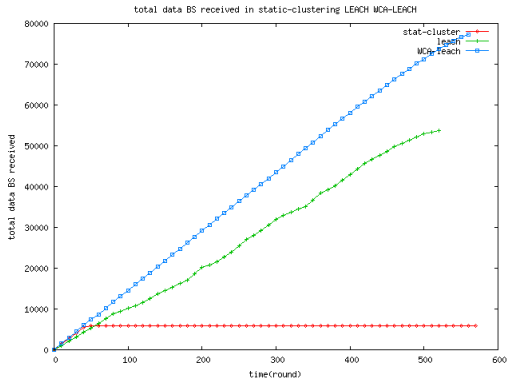

Fig 7. Total date BS has Received

Since the election of cluster by LEACH is randomly, it works not stability. SCH-LEACH can work longer time than LEACH. Fig.7. shows the total data received by BS is the largest number when using SCH-LEACH, which is much higher than the static clustering, and higher 20% than LEACH. So SCH-LEACH is the best protocol.

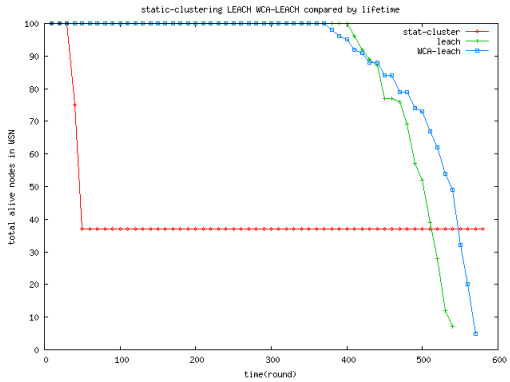

Fig 8. Total alive nodes in network

Energy is the most important issue in WSN, and the most important standard for measuring WSN is network life time. Figure.3.shows, although in SCH-LEACH, the first node died earlier than LEACH, but the last node died later 10% than LEACH. In static clustering protocol, 37 nodes are still alive until last, this is because the network died when all cluster-head nodes died, but the normal nodes were still alive. Therefore, the network life time is shortest by using static clustering, LEACH extend the network life time than static clustering. If we use the last node death to define the life time, SCH-LEACH is better than LEACH. This shows that the use

of weighted clustering algorithm based LEACH can improve energy efficiency and prolong the life of the network. in the entire network.

VII. CONCLUSION

This paper proposed a method based on elective Cluster Head based Low-Energy Adaptive Clustering Hierarchy (SCH-LEACH) routing protocol. By the simulations, we infer that SCH-LEACH has the higher date received by BS, and the lower energy consumption. Finally, we compare the life time of the three, SCH-LEACH is the best one, too. Therefore, the simulation analysis weighted clustering algorithm based LEACH is energy efficient wireless sensor network routing protocol, and it can extend the network lifetime. So we conclude that this SCH-LEACH method outperforms the static clustering protocol and all other LEACH methods.

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