Energy-Based Region Clustering Routing Protocol in WSNs

Shuang Zhang
School of Computer Science and Technology
China University of Mining and Technology, CUMT
Xuzhou, China
cumt_zs@163.com

Qianping Wang
School of Computer Science and Technology
China University of Mining and Technology, CUMT
Xuzhou, China
qpwang@cumt.edu.cn

***Abstract*—Considering that the uneven distribution of the cluster heads and the high frequency of the cluster heads elcetion in LEACH, a new routing protocol in wireless senseor network, which is called energy-based region clustering routing protocol, EBRC, was proposed. In EBRC, firstly according to the signal strength the nodes received, it divided the network into some monitoring regions. When electing the cluster heads in these regions, besides the threshold referred to in LEACH, the residual energy and average comsumption energy of the cluster heads were considered comprehensively. Simulation results showed that EBRC outperforms LEACH, in terms of the lifetime of the network and the data Base Station received.**

Keywords-region clustering; signal strength;threshold; energy; LEACH

I. INTRODUCTION

Wireless sensor networks (WSNs) are composed of a large number of low-power sensor nodes with limited energy, which were randomly deployed in the monitored area, and self-organized into a network. Energy consumption which is one of the major factors which are directly the lifetime of the network has been focused on by more and more researchers. Generally, energy consumption is addressed in the five cases following[1]: (1) the effective scheduling of the states, to change between the stats of sleep and active, (2) the effective control of transmission power to ensure the optimum between energy comsumption and the connectivity, (3) data compression to reduce the amount of the uselessly transmission data, (4) the effective channel access and packet retransmission on the Data Link Layer, and (5) energy-efficient routing, clustering and data aggregation. Clustering routing is utilized to perform energy-efficient routing in WSNs. LEACH designed as a low-power adaptive clustering routing protocol is the first clustering routing protocol in WSNs. And the following emerging clustering protocols(LEACH-C, PEGASIS, etc.) were almost developed form LEACH, so was the proposed protocol(EBRC).

In EBRC, according to the signal strength the nodes received, it divided the network into some monitoring regions. Then when electing the cluster heads (CH), not only the threshold involved in LEACH was considered, but also the residual energy and the average comsumption energy of the CHs were considered.

The remainder of this paper is organized as follow: Section 2 gives some related works and previous. Section 3 proposes the system model. Section 4 discusses the proposed algorithm in detail. Section 5 shows EBRC effectiveness via simulation and compares it to LEACH. Finally, conclusion is given in Section 6.

II. RELATED WORK

Heinzelman et al. introduced [2] a hierarchical clustering algorithm for wireless sensor networks, called Low Energy Adaptive Clustering Hierarchy (LEACH), one of the first distributed clustering routing protocol proposed for WSNs. LEACH randomly elects a few nodes an CHs and rotates this role to balance the energy comsumption of the sensor nodes in the networks. LEACH is completely distributed and requires no global knowledge of the network, and energy-efficient. However, LEACH doesn’t guarantee good CHs distribution. Furthermore, the idea of periodic election brings extra energy comsumption.

LEACH-C [3], an enhancement over the LEACH, uses a centralized clustering algorithm. Each node sends information about its current location and residual energy to the Base Station (BS). BS finds clusters using the simulated annealing algorithm to solve the NP-hard problem of finding k optimal clusters. This algorithm attempts to minimize the amount of energy for the ordinary nodes to transmit their data to the cluster head. Once the cluster heads and associated clusters are found, BS broadcasts a message that obtains the cluster head ID for each node.

PEGSIS [4], proposed by Lindsey et al., makes a communication chain using a greedy algorithm. Each node only communicates with two close neighbors along the communication chain. Only a single designated node gathers data from other nodes and transmits the aggregated data to the sink node.

EEUC [5], proposed by Li et al., is an energy－efficient unequal clustering protocol. It divides the nodes into clusters of unequal size. The clusters closer to the base station have smaller sizes than those farther away from BS. Thus cluster heads closer to the base station can preserve energy for the inter-cluster data forwarding. However, the re-election of the CHs in every round results in the extra energy comsumption.

III. SYSTEM MODEL

A. Netwoek Model

In this paper, we make the following assumptions [6]:

- N sensor nodes are deployed in M*M square area. And the nodes are homogeneous.
- All sensor nodes have various transmission power levels, and each node can change the power dynamically.
- The BS is considered a powerful node having enhanced communication capabilities with no energy constraints, and all the nodes could receive from the BS.
- The nodes can computer the residual energy and average comsumption energy.
- All sensor nodes aren't equipped with GPS, so they aren't aware of the positions of themselves.
- Links are symmetric, i.e., two nodes can communicate using the same transmission power.

B. Energy Model

We use the similar radio model described in [7]. The amount of energy consumed for transmission E_{TX}, of an l-bit message over a distance d is given by,

$$E_{TX}(l,d)=\begin{cases} l*E_{elc}+l*\varepsilon_{fs}*d^2 & d\le d_0 \\ l*E_{elc}+l*\varepsilon_{mp}*d^4 & d>d_0 \end{cases} \quad (1)$$

The energy expended in receiving an l-bit message is given by

$$E_{Rx}(l)=E_{Rx-elec}(l)=lE_{elec} \quad (2)$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ε_{fs} and ε_{mp} depend on the transmitter amplifier model we use, and d the distance between the sender and the receiver. When $d>d_0$, power loss factors for free space is adopted; and when $d<d_0$, multipath fading is adopted.

IV. ENERGY-BASED REGION CLUSTERING ROUTING PROTOCLC

In this paper, due to the uneven distribution of the cluster hedas and the high frequency of the cluster heads elcetion in LEACH, energy-based region clustering routing protocol, EBRC, was proposed. In EBRC, according to the message about the divided regions, the network would be divided into several smaller regions. Then in these regions, the CHs are elected respectively. Furthermore, when electing the CHs, the residual energy of the new CH and the average comsumption energy of all the cluster heads had been elected. Finally, the data is sent from the CHs to the BS through the multi-hop.

A. Region Divion

In EBRC, considering to the distribution of the CHs, the network was firstly divided into several regions[8], as shown in Fig. 1. In advance the optimum number τ of the divided regions was determined based on the size of the network and the transmission range of the node. The BS sent a message to the network, and when all the nodes received the message, they would transmit their received signal strength to the BS. The received signal strength of each node was arranged from high to low, and was divided into several parts, in which the sums of the received signal strength were approximately equal. So the network was divided into τ regions. Then BS sent the message with maximum signal strength and lowest signal strength of every regions to the network.. According to that message, the nodes determined which region to belong to, and indicated in their own information tables.

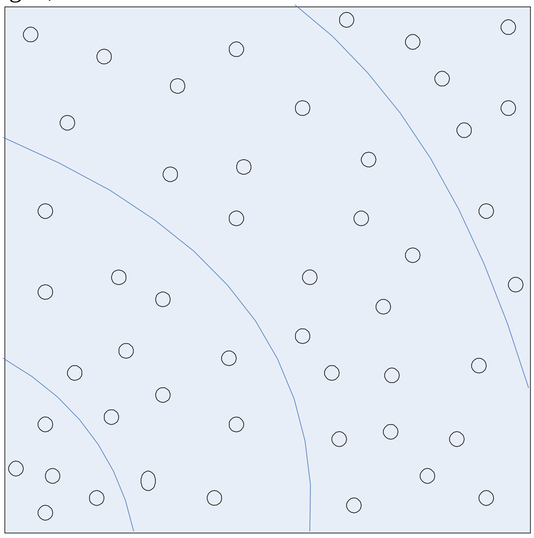

Figure 1. Divided regions in WSNs

B. Election of the Cluster Heads

As LEACH in the first round of the election phase, all sensor nodes elected a cluster head using a threshold $T(n)$ in (4). Each node generated a random number between 0 and 1. If the generated number was less than the threshold $T(n)$, the node became a cluster head.

$$T(n)=\begin{cases} \dfrac{p}{1-p\left[r \bmod (\frac{1}{p})\right]} & n\in G \\ 0 & Otherwise \end{cases} \quad (4)$$

Where p is the ration of a cluster head, r is the current round, and G is a set of nodes that were not a cluster head in $\frac{1}{p}$ rounds. Then the first elected cluster heads broadcasted the ADV message in their region respectively.

The non-CH nodes receiving the ADV message decided to join to one of the clusters for the current round. This decision is based on the strength of the received signal strength from the CH.

To elect the CHs in the following rounds, the residual energy E_{re} and average comsumption energy E_{av} of the CHs indicated in their information table were introduced. Firstly, a judgment that whether the residual energy E_{re} of the CH is bigger than the average comsumption E_{av} is made. If $E_{re} > E_{av}$, the re-election of the CHs in current round was not needed; otherwise, the re-election of the CHs was carried out. As a result, the high frequency of the CHs elcetion was avoided. The process of the election was show in Fig. 2.

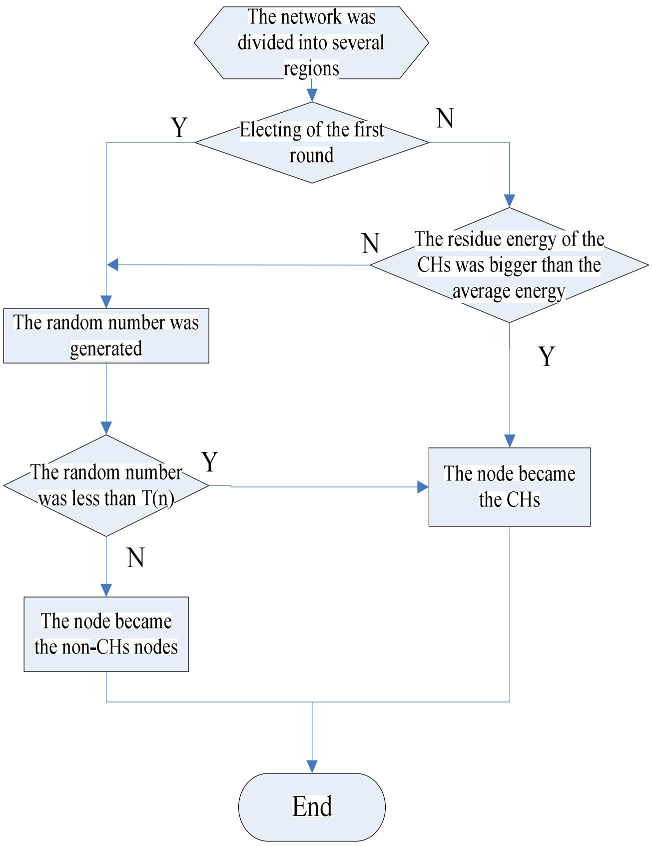

Figure 2. Process of th cluster heads election

C. Data Transmission

EBRC used time-division multiple access protocol (TDMA) in intra cluster, which allowed the nodes to enter a sleep mode when they are not transmitting data to the cluster head. Meanwhile, in intra cluster, the non-CHs nodes sent their data to their cluster heads by one hop.

As known, the task of the CHs is aggregation data non-CHs nodes collected and transmission data to the BS. In this paper, the combination of multi-hop and single-hop for the CHs was considered. As shown in Fig.1,the CHs close to the BS in the first region communicated with the BS through the single-hop, that is, the CHs in other further regions adopted the multi-hop communication. According to comparing the residual energy of all the CHs in the (i-1) region, CHs in i region selected a CH from the (i-1) region as the next hop. The process is as follows:

Step 1: The elected CHs transmitted their residual energy in the region they belonged to in every round. In the same region the CH compared residual energy with other CHs. Go to Step 2.

Step 2: The CH with the highest residual energy in the i region transmitted the message to the (i+1) region. The CHs in the （i+1） region computed appreciatively the distance to the CH with the highest residual energy in the ith region, and saved its information table. Go to Step 3.

Step 3: The non-CHs nodes collected the data and sent data the CH in intra cluster. The CH aggregated the data , and sent data to the CH with the highest residual energy in next region based on the distance saved in the its information table.

V. SIMULATION AND ANALYSISUSING

A. Related Parameters

To illustrate the performance of the proposed algorithm, the simulations are performed in NS2, and analyze the performance of EBRC against LEACH in terms of network lifetime and the amount of the received data by the BS. The simulation parameters are given in Table.1.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Network Size	500m*500m
Number of Region	5
BS Location	（50，175）m
Number of Node	200
Initial Energy	2J
E_{elec}	$50nJ/bit$
ε_{fs}	$10pJ/bit/m^2$
ε_{mp}	$0.0013pJ/bit/m^4$
Number of CHs	6
Data Pcket Size	500Bytes
Packet Headers Size	25Bytes

B. Simulation Result

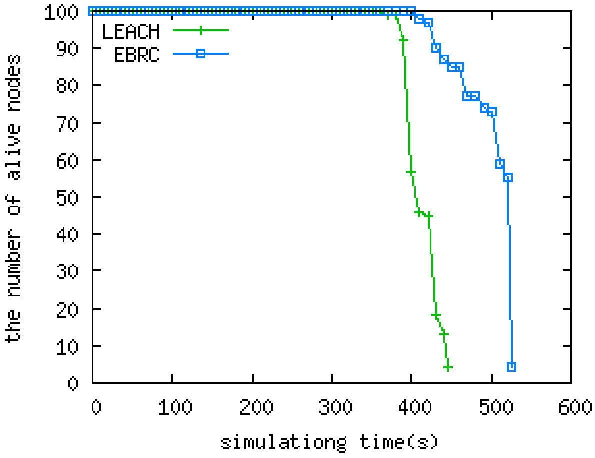

Figure 3. The number of the alive node in WSNs

Fig.3 shows the number of the alive nodes in the network. In LEACH, the first dead node was appeared at 370 second, and the number of the alive nodes was not more than 10 at 445second; In EBRC, the fist dead node is appeared at 410 second, and at 526 second the number not more than 10.This shows that EBRC performs better than LEACH in prolonging the networking lifetime.

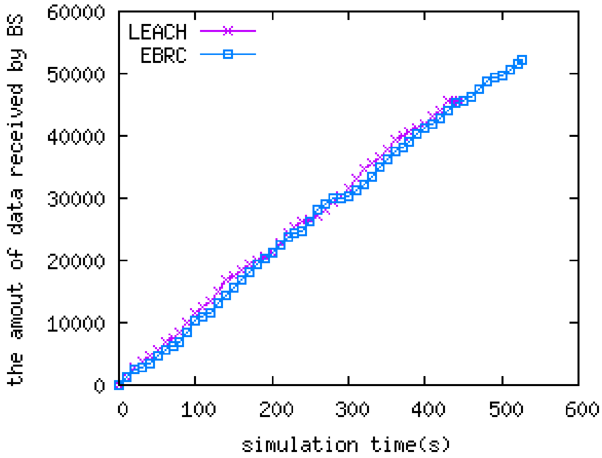

Figure 4. The amount of data receicved by the BS in WSNs

Fig.4 shows that the amount of data received by the BS. In LEACH, because of the number of the alive node not more than 10 and the residue energy are getting less, BS would not receive the data at almost 445 second. However, in EBRC the BS could receive more data than LEACH.

VI. CONCLUSION

In this paper, a new energy-based region clustering routing protocol, EBRC was introduced. In EBRC, according to the size of the network, the transmission range of the nodes and the signal strength received by BS, the network was divided into several regions. When electing the cluster heads respectively in every region, besides the threshold referred to in LEACH, the residual energy and average comsumption energy of the cluster heads was considered comprehensively. In the data transmission phase, the combination of multi-hop and single-hop communication was adopted. Simulation results showed that compared with LEACH, EBRC could improve the lifetime of the network and the amount of the data received by BS.

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