HCTE: Hierarchical Clustering based routing algorithm with applying the Two cluster heads in each cluster for Energy balancing in WSN

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***Abstract*—In wireless sensor networks, the energy constraint is one of the most important restrictions. With considering this issue, the energy balancing is essential for prolonging the network lifetime. Hence this problem has been considered as a main challenge in the research of scientific communities. In the recent papers many clustering based routing algorithms have been proposed to prolong the network lifetime in wireless sensor networks. But many of them not consider the energy balancing among nodes. In this work we propose the new clustering based routing protocol namely HCTE that cluster head selection mechanism in it is done in two separate stages. So there will be two cluster head in a cluster. The routing algorithm used in proposed protocol is multi hop. Simulation Results show that the HCTE prolongs the network lifetime about 35% compared to the LEACH.**

Keywords-wireless sensor network; multi hop routing; clustering; energy balancing

I. INTRODUCTION

Wireless sensor networks are containing of the thousands or more sensors that are widely distributed in the environment. Distribution of the sensors in the environment can be done manually or randomly. These networks have many applications such as environmental monitoring, healthcare, military operations, target tracking and etc. Due to the power constraint, energy balancing and maximizing network lifetime have been important challenge in wireless sensor networks. For this reason, use of data aggregation which limits redundant transmission between sensors is essential. One of the techniques that use the data aggregation to reduce energy consumption in WSNs is called clustering based routing algorithm [1-4]. In [5-10] there are protocols that use the clustering technique in the network.

LEACH is one of the most famous clustering based routing protocols in WSN [6]. Cluster head selection among sensor nodes is done randomly and also data transmitting between cluster heads and base station is done directly in the LEACH. Although this specification of LEACH avoids energy hole problem but causes the energy of cluster heads that are far from the base station be discharge faster than others.

HEED [9] is another well-known clustering based routing algorithms in WSN. Cluster head selection algorithm is based on a relationship between remaining energy and reference energy in HEED.

In this paper we propose the HCTE protocol that is a combination of new cluster head selection and routing algorithms. The cluster head selection algorithm in HCTE is done in two separate stages. In addition, data transmitting between cluster heads and base station is multi hop in proposed protocol.

The rest of the paper organized as follows: in section 2, we describe the related works. Section 3 explores the proposed algorithm with detailed. Section 4 explain the simulation parameters and result analysis. Final section is containing of conclusion.

II. RELATED WORKS

As mentioned above in previous papers have suggested many protocols for clustering. In this section we explain the some celebrated clustering protocols.

MCBT [11] proposes a distributed algorithm to create a stable backbone by selecting the nodes with higher energy or degree as the cluster heads. LNCA [12] introduces a novel clustering algorithm which uses the similarity of sensed data as an important factor in cluster formation. In [13], a cluster-based routing protocol for wireless sensor networks with non-uniform node distribution is proposed, which includes an energy-aware clustering algorithm EADC and a cluster-based routing algorithm. EADC uses competition range to construct clusters of even sizes. In [14], the authors propose a mobility-based clustering (MBC) protocol for wireless sensor networks with mobile nodes. In this clustering protocol, a sensor node elects itself as a cluster-head based on its residual energy and mobility. A non-cluster-head node aims at its link stability with a cluster head during clustering according to the estimated connection time. HEED [9] periodically selects cluster-heads. In this protocol, cluster-head selection is primarily based on the residual energy of each node. HEED also consider intra-cluster "communication cost" as a secondary clustering parameter.

Clustering algorithm in HEED is done in three phases that is described in more. In first phase, each of nodes identifies its neighbors in cluster range and then computes the required energy for communication with them and also calculates the primary cluster head selection probability by (1).

$$CH_{prob} = C_{prob} * (E_r / E_m). \quad (1)$$

Where C_{prob} *is the* initial percentage of cluster-heads among all n nodes, E_r is the estimated current residual energy in the node and E_m is a reference maximum energy.

In the second phase each of nodes sends an advertisement message to the other nodes of its cluster and also receives the same message from other candidates. This advertisement message is containing of the obtained values from the first phase. Each of these candidates cancels candidacy if its cost is more than the other candidates.

In the last phase, non-cluster head nodes attempt to select a cluster head and join to it.

LEACH is containing of four phase that are the advertisement, cluster formation, scheduler creation and data transmission. In first phase, nodes compete with each other for election as cluster head, so that all nodes produce a random number between 0 and 1, then produced number be compared with threshold value which is achieved from (2). If produced number is smaller than T(n), then the node is selected as a cluster head.

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

In this formula, p is percent of cluster heads per all nodes, r is current round and G is set of nodes that are not selected as cluster head in 1/p of last rounds. As can be inference, cluster heads election in LEACH is random operation.

In the second phase, nodes join to their near cluster head and forms the clusters. In the next phase, cluster heads create the scheduler such as TDMA. In the last phase, all nodes transmit the data to their cluster heads based on the created scheduler and cluster heads also aggregate the data before directly sending to the base station. This action will cause unbalanced energy consumption among the cluster heads and therefore lifetime of some nodes is much less than the lifetime of entire network.

III. PROPOSED PROTOCOL

As mentioned above, HCTE is the clustering based routing algorithm that has two cluster heads namely initial and second cluster heads in each cluster and is based on multi-hop transmitting mechanism in the data routing from the cluster heads to sink. Each of these cluster heads has separate tasks in the cluster.

First, we explain the definition and assumptions used in HCTE. Then we will describe the HCTE protocol.

A. Definition

A cluster head is a high level one if its distance to sink is less than the distance of sender cluster head to sink

B. Assumptions

- All nodes are randomly distributed.
- Nodes are static or pseudo static.
- The initial energy is the same for all nodes.
- Nodes are aware of the location (by GPS or other positioning algorithms).
- Nodes are able to control their energy consumption.
- Cluster heads are aware from their remaining energy and also from the remained energy of their high level cluster heads.

C. Energy Consumption Model

In HCTE, energy model is obtained from [6] that use both of the open space (energy dissipation d^2) and multi path (energy dissipation d^4) channels by taking amount the distance between the transmitter and receiver. So energy consumption for transmitting a packet of l bits in distance d is given by (3).

$$E_{Tx}(l,d)=\begin{cases} lE_{elec}+l\varepsilon_{fs}d^2 & , d\le d_0\\ lE_{elec}+l\varepsilon_{mp}d^4 & , d> d_0\end{cases} \quad (3)$$

In here d_0 is the distance threshold value which is obtained by (4), E_{elec} is required energy for activating the electronic circuits. ε_{fs} and ε_{mp} are required energy for amplification of transmitted signals to transmit a one bit in open space and multi path models, respectively.

$$d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}. \quad (4)$$

Energy consumption to receive a packet of l bits is calculated by (5).

$$E_{Rx}(l)=lE_{elec}. \quad (5)$$

D. HCTE Protocol

HCTE like other clustering based routing algorithms has several phases to configure the network in cluster form and to send the data to sink. For this reason, HCTE has five phases that are initial cluster head announcement, cluster formation, second cluster head announcement, schedule creation and data transmission.

1) Initiall Cluster Head Announcement

The initial cluster head announcement phase which is the initial cluster head selection phase is almost like a cluster head selection algorithm in HEED but the difference is that in the beginning all nodes calculates the probability of initial cluster head selection by (6) and then follows from the operations in the HEED.

$$C\_V_{ICH} = \alpha(\frac{E_r}{E_i}) + \beta(\frac{N_{non}}{N_{on}}) + \lambda(\frac{\sum E_{i\_non} - \sum E_{r\_non}}{\sum E_{i\_non}}) \quad (6)$$

Here, E_r is remaining energy of sensor node and E_m is the initial energy of sensor. N_{non} of a node is the number of neighboring ordinary nodes which is in its transmission radio range and N_{on} is the number of all ordinary nodes in the network. $E_{r\text{-}non}$ is remaining energy of neighboring ordinary node and $E_{i\text{-}non}$ is its initial energy. Parameters α, β and λ determine the weight of each ratio so that sum of them is 1.

In fact, the node is selected as a initial cluster head that in addition to having the high level of residual energy, the number of nodes in its neighborhood was more and the average residual energy of its neighboring nodes is low.

Initial cluster heads are used for cluster formation, data gathering from cluster members and sending the data after gathering to second cluster heads in the clusters.

2) Cluster Formation

In cluster formation phase, each of the nodes tries to find the best cluster head and then joins to it. For this reason, the all nodes calculate the confidence value of initial cluster heads that are on their radio transmission range by (7). Then they join to the initial cluster head that its confidence value is greater than other.

$$M\_V_{ICH} = \frac{E_N + E_{ICH}}{(D_{N\_ICH})^2} \quad (7)$$

In here E_{ICH} is remaining energy of initial cluster head and E_N is remaining energy of node. D_{N_ICH} is the distance between desired node and the initial cluster head.

With considering this function, a node will join to the initial cluster head that in addition to having high levels of residual energy, it is also close to desired node.

If the node not able to found the cluster head on its radio transmission range, same as LEACH it join to the its near initial cluster head.

3) Second Cluster Head Announcement

In second cluster head announcement phase which is the second cluster head selection phase, all nodes within the clusters compete with each other on their confidence value which is obtained by (8). The node within a cluster is selected as a second cluster head that its confidence value is greater than other nodes at the same cluster.

$$C\_V_{SCH} = \alpha(\frac{E_r}{E_i}) + \beta(\frac{D_m - D_{SCH\_BS}}{D_m}). \quad (8)$$

Here, D_m is the maximum distance in network and D_{SCH_BS} is the distance between desired node and sink.

In short, the node is selected as a second cluster head that has high level residual energy and also it has the minimum distance to sink.

Second cluster heads are used for data forwarding to the sink. These cluster heads forward the received data from their initial cluster heads and also from their low level second cluster heads to their high level second cluster heads or directly to the sink.

Fig. 1 shows an example of a network with initial and second cluster heads in the clusters.

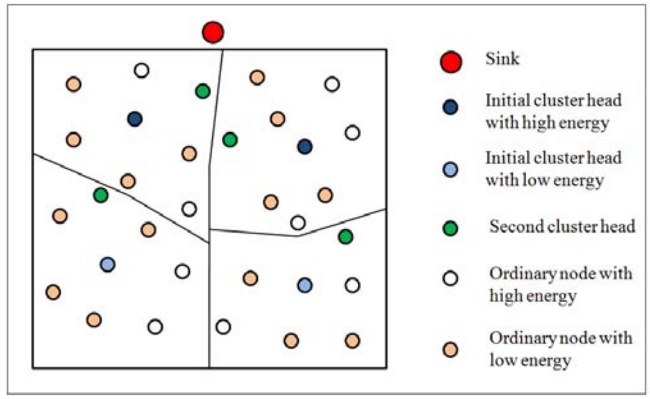


Figure 1. A network with initial and second cluster heads in the clusters

4) Schedule Creation

Schedule creation phase in HCTE is the same as LEACH.

5) Data Transmission

The other difference between LEACH and HCTE is in data transmission from cluster heads to the sink. This operation is done directly in the LEACH, but in the HCTE it is multi hop. The proposed protocol considers the distance between initial cluster heads and base station in multi hop and hence can solve the unbalanced energy consumption problem.

In data transmitting phase, in order to data sending to base station, the second cluster head must choose the best high level second cluster head with considering the several parameters such as remaining energy and distance to sink in the form of (9). This function is a cost function in the high level second cluster head selection. Hence, the second cluster head is selected among the high level second cluster heads that has the lowest cost. Fig. 2 illustrates these operations.

$$C\_F_{HCH} = \frac{(D_{CH\_HCH})^2}{E_{CH}} + \frac{(D_{HCH\_BS})^2}{E_{HCH}} \quad (8)$$

Here, E_{CH} is remaining energy of source second cluster head and E_{HCH} is the remaining energy of high level second cluster head. D_{CH_HCH} is the distance between source second cluster head and the high level second cluster head and D_{HCH_BS} is the distance between high level second cluster head and sink.

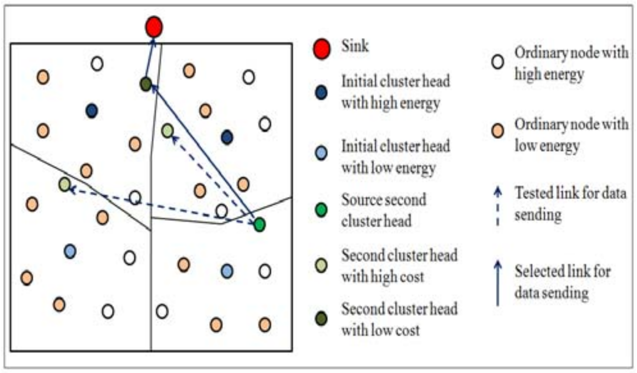
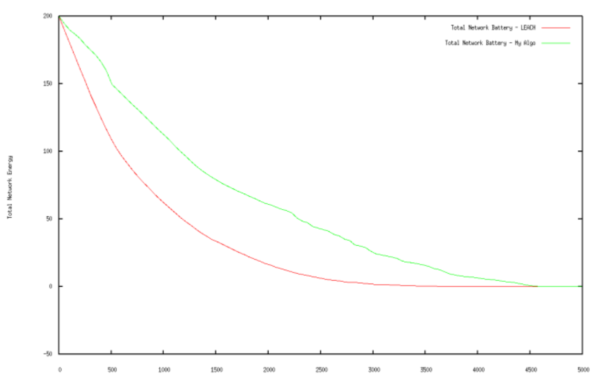


Figure 2. Illustration of data transmitting operations

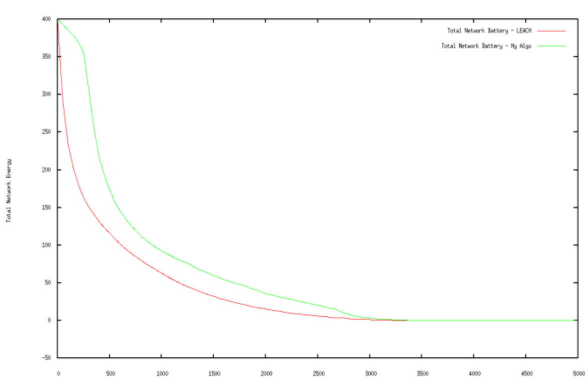
IV. Simulation and Result Analysis

HCTE and LEACH are simulated with GCC and the simulation repeated for many times with different simulation areas and number of nodes to achieve the reliable results about proposed algorithm. Simulation parameters are presented in Table I and obtained results are shown below.

Fig. 3 (a) and 3 (b) shows the residual energy of whole network per round for LEACH and HCTE in the network with the different nodes. As it can be seen, obtained values for HCTE is better than LEACH.



(a) Residual energy of whole network per round with default parameters

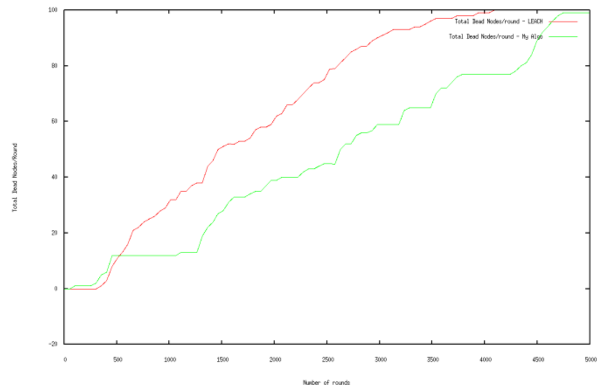


(b) Residual energy of whole network per round with 200 nodes

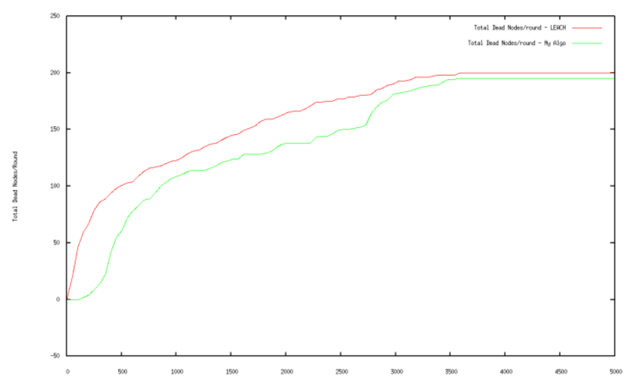
Figure 3. Residual energy of whole network per round with the different nodes in network

Fig. 4 (a) and 4 (b) shows the number of dead nodes per round in LEACH and HCTE in the network with the different nodes.

As it can be seen, proposed protocol has a performance better than LEACH protocol so that in HCTE, the times of first node dies (FND) and half nodes alive (HNA) and last node dies (LND) are optimized about 8%, 72% and 24%, respectively compared to the LEACH.



(a) Number of dead nodes per round with default parameters



(b) Number of dead nodes per round with 200 nodes

Figure 4. Number of dead nodes per round with the different nodes in network

V. Conclusion

This work proposes a new clustering based routing protocol namely HCTE for wireless sensor networks that has two cluster heads namely initial and second cluster heads in each cluster and is based on multi-hop transmitting mechanism in the data routing from the cluster heads to sink. Each of the cluster heads has separate tasks in the cluster. The routing algorithm used in proposed protocol is multi hop so that can balance the energy consumption among nodes. Simulation results show that the HCTE prolongs the network lifetime about 35% in comparison to the LEACH.

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