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New Heterogeneous Clustering Protocol for Prolonging Wireless Sensor Networks Lifetime

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Abstract

Clustering in wireless sensor networks is one of the crucial methods for increasing of network lifetime. The network characteristics of existing classical clustering protocols for wireless sensor network are homogeneous. Clustering protocols fail to maintain the stability of the system, especially when nodes are heterogeneous. We have seen that the behavior of Heterogeneous-Hierarchical Energy Aware Routing Protocol (H-HEARP) becomes very unstable once the first node dies, especially in the presence of node heterogeneity. In this paper we assume a new clustering protocol whose network characteristics is heterogeneous for prolonging of network lifetime. The computer simulation results demonstrate that the proposed clustering algorithm outperforms than other clustering algorithms in terms of the time interval before the death of the first node (we refer to as stability period). The simulation results also show the high performance of the proposed clustering algorithm for higher values of extra energy brought by more powerful nodes.

Keywords: Heterogeneity, Lifetime, Clustering, Wireless Sensor Networks.

1. Introduction

A Wireless Sensor Networks (WSNs) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants[1][2]. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. They are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation and traffic control [1],[3].

Because these sensors have a low battery lifetime, they announced one-using, to this case, their lifetime was expired when their energy finished. So energy is scarce source for wireless sensor networks. We must manage accurate in right use of energy for increasing sensor lifetime [4]. In wireless sensor networks all of sensed data must send to base station that called sink. Sending data to sink can accomplish both event-driven or periodically.

In hierarchy network like Low-energy Adaptive Clustering Hierarchy (LEACH) [5] that network divided to separate clusters that create from member nodes were selected for clusters and high energy nodes as a Cluster Head (CH).Sending data to sink is by this node. Random choosing of cluster heads in LEACH algorithm basis is probability in some part of network haven't cluster head and other parts have cluster head with amount of density is high. Choosing of cluster heads in this algorithm done randomly and it is probability low energy nodes was selected as cluster head. Thus fault has a high probability. This problem was solved by Stable Election Protocol (SEP) [6].Again Heterogeneous Hierarchical Energy Aware Routing Protocol (H-HEARP) [7] is designed to extend the system lifetime, reduce energy consumption and latency.

Proposed protocol that produced in this paper has two advantages in comparison with LEACH, SEP, and H-HEARP algorithm. Firstly, in proposed method, which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes and the additional energy factor between advanced and normal nodes. Secondly, proposed method attempts to maintain the constraint of well balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes. It has been found in our simulation that the proposed method always prolongs the stability period compared to others current clustering protocols (LEACH, SEP, H-HEARP).

The rest of this paper is organized as follows. Section 2 LEACH protocol is produced. Section 3 consists of SEP protocol. Section 4 describes H-HEARP and, in Section 5 we provide novel protocol. In section 6, simulation results were presented and finally in part 7, conclusion will be discussed.

2. LEACH Protocol

LEACH protocol is hierarchical routing algorithm that can organize nodes into clusters collections. Each cluster controlled by cluster head. Cluster head has several duties. First one is gathering data from member cluster and accumulates them. Second one is directly sending

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accumulation data to sink. Used model in LEACH shows in Figure 1. Third one is scheduling based of Time-Division Multiple Access (TDMA). In that, each node in cluster related to it's time slot could send collection data [8].

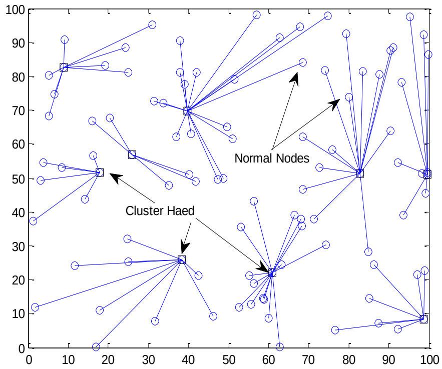


Fig. 1. Snapshot of cluster foundation in LEACH for 100 nodes.

Cluster head announce time slot by uses of distribution property to all members of cluster. Main operations of LEACH are classify in two separate phase. First phase or initialization phase has two process; clustering and cluster head determining. Second phase mean steady-state, that this phase concentrate to gathering, accumulation and transmit data to sink.

First phase as a compared with second one less overhead impose to protocol. In initialization phase, at first in choose of cluster head step, randomly allocate number between zero and one for each node and then compared with cluster head threshold. A node is chosen for cluster head if its number is less than threshold. The threshold value is calculated based on an equation that incorporates the desired percentage to become a CH, the current round, and the set of nodes that have not been selected as a CH in the last ($1/p$) rounds, denoted G. It is given by

$$T(s) = \frac{p}{1 - p(r \bmod (1/p))} \tag{1}$$

and $n \in G$

where G is the set of nodes that are involved in the CH election

3. H-HEARP Protocol

H-HEARP is a hierarchical energy-efficient routing protocol. H-HEARP is based on both LEACH and PEGASIS [9] protocols. In H-HEARP, network establishment begins with the formation of clusters. Several clusters are formed with one cluster head (CH) in each cluster. Each cluster contains several nodes called member nodes, after the clusters are formed; a chain is established among all the CHs using a greedy algorithm. A CH is chosen as leader node form this chain for sending data to the BS. The operation of H-HEARP is broken up into rounds, where each round begins with a set-up phase, followed by data transmission phase.

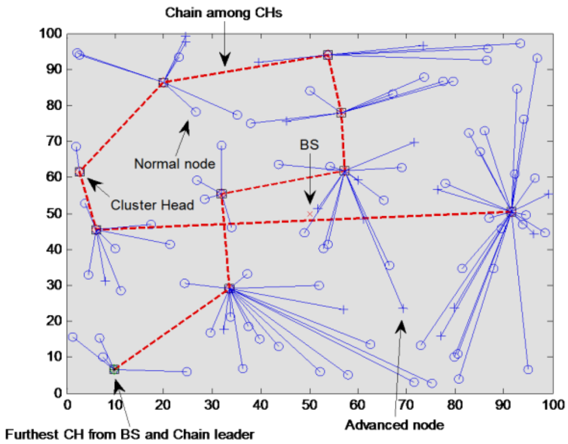


Fig. 2. Snapshot of cluster foundation in H-HEARP for 100 nodes

During the set-up phase, at the beginning of cluster formation, H-HEARP makes use of the same algorithm as LAECH, where each sensor chooses a number between 0 and 1. If the number is less than a threshold $T(s)$ (Equation (1)), the node broadcast itself as a CH. It has been found from simulation results that H-HEARP is better than LEACH, in terms of energy consumption. Again in terms of latency, H-HEARP performs better than LEACH as well as PEGASIS. H-HEARP saves energy because only one node transmits data directly to the base station. Figure 2 shows a snapshot of cluster-head foundation as well as nodes deployment in H-HEARP for 100 nodes.

4. SEP Protocol

SEP protocol was improved of LEACH protocol. Main aim of it was used heterogeneous sensor in wireless sensor networks. This protocol have operation like LEACH but with this difference that, in SEP protocol sensors have two different level of energy. Therefore sensors are not homogeneous. In this protocol with suppose of some sensors have high energy therefore probability of these sensors as cluster head will increased. But in SEP and LEACH, cluster heads aren't choose base of energy level and their position. This is main problem of these methods, so their operations are static. Figure 3 shows a snapshot of cluster-head foundation as well as normal nodes, advanced nodes deployment in SEP for 100 nodes.

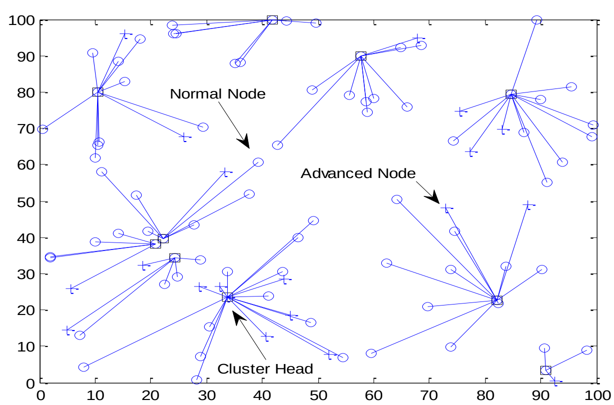


Fig. 3. Snapshot of cluster foundation in SEP for 100 nodes.

5. The Proposed Protocol

In LEACH, SEP, and H-HEARP Protocol, because of accidentally choosing cluster head, in some part of network don't have cluster head and the other parts have cluster head with high density is probability. The proposed protocol is an extension of H-HEARP. H-HEARP is made with the formation of clusters. Several clusters are formed in the network followed by a cluster head in each cluster. Several nodes called member node are belonged in each cluster. A chain is established among all the cluster heads using a greedy algorithm. A node is chosen as leader node from this chain for sending data to the BS (base station).Like H-HEARP the operation of the proposed protocol is broken up into rounds, where each round begins with a set-up phase, followed by a data transmission phase. The set-up phase and the data transmission phase of the proposed protocol are same as the H-HEARP.

Actually, the proposed protocol is designed to improve the stable region of H-HEARP, based on the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (a) as used in SEP. Here "stable region" is the time interval from the start of network operation until the death of the first sensor node. Stable region is crucial for many applications where it is necessary to collect information over a long time from the possible coverage of sensing fields to make an effective decision from the collected information thereby improve the performance of the network.

In order to prolong the stable region, the proposed algorithm attempts to select advanced nodes have to become cluster heads more often than that of normal nodes, which is equivalent to a fairness constraint on energy consumption. Note that the new heterogeneous setting (with advanced and normal nodes) does not affect on the spatial density of the network. As a result, the a priori setting of p_{opt} does not change where p_{opt} is an optimal percentage of nodes that has to become cluster head in each round assuming uniform distribution of nodes in space. Although, the total energy of the system will be changed.

Suppose that E_0 is the initial energy of each normal sensor. The energy of each advanced node is then $E_o \times (1 + a \cdot m)$. The total (initial) energy of the new heterogeneous setting is equal to $(n \cdot E_o) \times (1 + a \cdot m)$.

If the same threshold is applied in H-HEARP like LEACH for both normal and advanced nodes with the difference that each normal node $\in G$ becomes a cluster head once every $(1/P_{opt})\times(1+\alpha m)$ round per epoch and each advanced node $\in G$ becomes a cluster head $1+\alpha$ times every $(1/P_{opt})\times(1+\alpha m)$ rounds per epoch, then there is no guarantee that the number of cluster heads per round per epoch will be $n \times P_{opt}$ .The reason is that there is a significant number case where this number cannot be maintained per round per epoch with probability 1.A worst-case scenario could be the following. Suppose that every normal node becomes a cluster head once within the first $(1/P_{opt})\times(1-m)$ rounds of the epoch. In order to maintain the well distributed energy consumption constraint, all the remaining nodes denoted as advanced nodes, have to become cluster heads with probability 1 for the next $(1/P_{opt})\times m \times (1+\alpha)$ rounds of the epoch. But the threshold $T(s)$ is increasing with the number of rounds within each epoch and becomes equal to 1 only in the last round (when all the remaining nodes become cluster heads with probability 1.). So the above constraint of $n \times P_{opt}$ cluster heads in each round is violated. Like SEP, we introduce new protocol where the extra energy of advanced nodes is forced to be expended within sub epochs of the original epoch. Our approach is to assign a weight to the optimal probability P_{opt}. This weight must be equal to the initial energy of each node divided by the initial energy of the normal node. Let us define as P_{nrm} the weighted election probability for normal nodes, and P_{adv} the weighted election probability for the advanced nodes.

In the heterogeneous scenario the average number of cluster heads per round per epoch is equal to $n \times (1+\alpha m) \times P_{nrm}$ (because each virtual node has the initial energy of a normal node.) The weighed probabilities for normal and advanced nodes are, respectively

$$P_{nrm} = P_{opt}/(1+\alpha m) \tag{2}$$

and

$$P_{nrm} = P_{opt} \times (1+\alpha)/(1+\alpha m) \tag{3}$$

In Equation 1, Like SEP we replace the p by the weighted probabilities to obtain the threshold that is used to elect the cluster head in each round. We define as $T(s_{nrm})$ the threshold for normal nodes, and $T(s_{adv})$ the threshold for advanced nodes. Thus, for normal nodes, we have:

$$T(s_{nrm}) = \frac{p_{nrm}}{1 - p_{nrm} \cdot \left(r . \bmod \frac{1}{p_{nrm}} \right)}, \tag{4}$$

if $s_{nrm} \in G'$ otherwise $T(s_{nrm}) = 0$

where r is the current round, G' is the set of normal nodes that have not become cluster heads within the last $1/p_{nrm}$ rounds of the epochs, and $T(s_{nrm})$ is the threshold applied to a population of $n \times (1-m)$ (normal) nodes. These guarantees that each normal node will become a cluster head exactly once every $1/p_{opt} \times (1 + \mathrm{a} \times m)$ rounds per epoch. Therefore, that the average number of cluster heads that are normal nodes per rounds per epoch is equal to $n \times (1-m) \times p_{nrm}$.

Similarly, for advanced nodes, we have:

$$T_{s_{adv}} = \frac{p_{adv}}{1 - p_{adv} \cdot \left(r . \bmod \frac{1}{p_{adv}} \right)}, \tag{5}$$

if $s_{adv} \in G''$ otherwise $T(s_{adv}) = 0$

where G'' is the set of advanced nodes that have not become cluster heads within the last $1/p_{adv}$ rounds of the epoch, and $T(s_{adv})$ is the threshold applied to a population of nXm (advanced) nodes. Each advanced node will become a cluster head exactly once every $(1/P_{opt})\times((1+\alpha m)/(1+\alpha))$ rounds, similar to SEP. We define this period as sub-epoch. It is clear that each epoch has $1+\alpha$ sub-epochs. Therefore, each advanced node becomes a cluster head exactly $1+a$ times within a heterogeneous epoch. The average number of cluster heads that are advanced nodes per round per heterogeneous epoch and sub-epoch is equal to $n\times m\times p_{adv}$.

Thus the average total number of cluster heads per round per heterogeneous epoch is equal to:

$$n\times(1-m)\times p_{nrm}+n\times m\times p_{adv}=n\times p_{opt} \qquad (6)$$

which is the desired number of clusters per round per epoch

6. Simulation Scenario

In this paper, the random distributed 100-nodes are considered in the network shown in Figure 2. The network size is 100×100 meter. Cartesian coordinates are used to locate the sensors. Both the normal and advanced nodes, are randomly (uniformly) distributed over the field. This means that the horizontal and vertical coordinates of each sensor are randomly selected between 0 and the maximum value of the dimension. The base station is located at the center (x=50, y=50). So, the maximum distance of any node from the sink is approximately 70m [6].

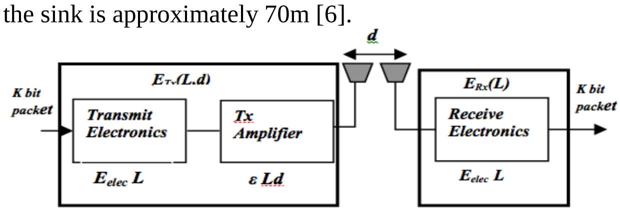


Fig. 4. Radio Energy Dissipation Model.

We have used the energy dissipation model illustrated in [10] as shown in Figure 4.The initial energy of a normal node is set E_0 =0.1 Joules. Although this value is arbitrary for the purpose of this study and it does not affect the behavior of our proposed protocol. The size of the transmitted message from nodes cluster heads and the size of the aggregated message from chain leader sends to the BS are set to 4000 bits [10]. The energy required for data aggregation is $5nj/bit/signal$, data processing time per node is taken as 5-10 millisecond [9].The radio speed is considered as 1 Mbps [10]. The network parameters are summarized in Table 1.

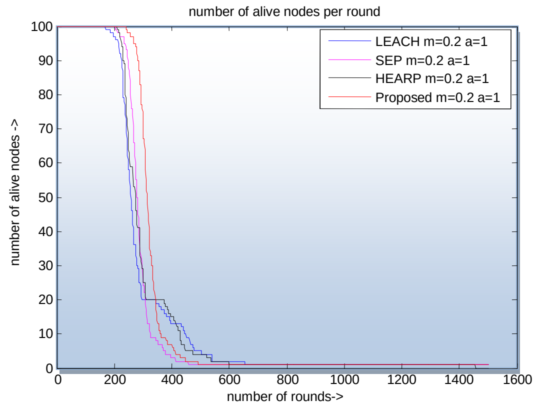
Table 1. Network parameters used in the simulation.

Parameters	Value
The network size	100x100 meter
Location of the sink	(50,50)
Number of nodes	100
The initial energy of nodes	0.1 joule
Data packet length	4000 *bit*
Transmitter/Receiver Electronics (E_{elec})	50 nj/bit
Aggregation energy, E_{DA}	5 nj/bit
Transmit amplifier, $\in_{fs}$, if $d_{toBS}\le d_0$	10pj/bit/m^2 pj/bit/m^2
Transmit amplifier, $\in_{mp}$, if $d_{toBS}\ge d_0$	0.0013 pj/bit/m^2

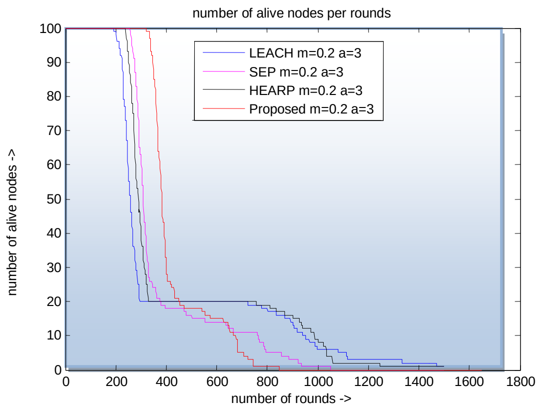
7. Simulation Result

In this section we compare the performance of our proposed protocol with (1) LEACH and H-HEARP in the same heterogeneous setting, and (2) SEP where the limitation of LEACH is overcome under its heterogeneous settings. For all considered protocol, the length of stable region is obtained from individual simulation runs (i.e. starting from different random number seeds) which is appealing stable for the same value of m and a.

Figure 5(a) shows the simulated results for the condition of m=0.2 and α=1. It is obvious that the stable region does not moderately change in SEP and H-HEARP than that of LEACH. However, the unstable region of the figure is remarkable; it is shows that H-HEARP and SEP are more and less than LEACH, respectively. It can be noted the interesting feature of this figure in the stable region for our proposed protocol which is extended in comparison with LEACH (by 7 %), SEP (3.5%), and HEARP (by 3%). Moreover, the unstable region of our proposed protocol is shorter than that of LEACH, H-HEARP, while that of slightly larger than that of SEP.



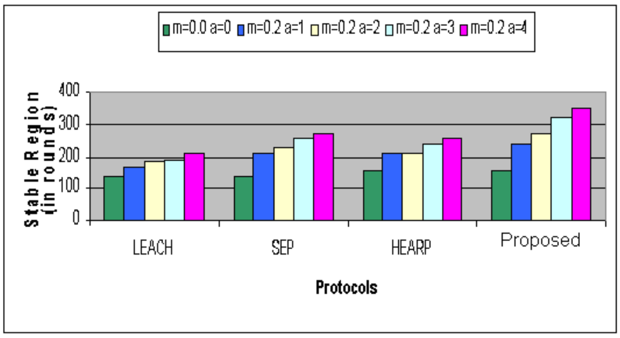
(a)



(b)

Fig. 5. Comparison among LEACH, SEP, H-HEARP, and the proposed protocol in the presence of heterogeneity: (a) m=0.2 and α=1, and (b) m=0.2 and α=3.

Figure 5(b) shows results for the case of m=0.2 and α=3. The stable region is increased significantly by 13% (LEACH), 6% (SEP), 8% (HEARP). Proposed protocol shows better performance (stable region) by increasing only the value of α. The unstable region of the proposed protocol is shorter than that of LEACH, H-HEARP, and SEP. This is because under the proposed protocol, the advanced nodes follow the death process of nodes, as the weighted probability of electing cluster heads causes the energy of each node to be consumed in proportion to the node's initial energy. Figure 6 summarized improvement in stable region of proposed algorithm over LEACH, SEP, and H-HEARP, respectively. It can be pointed out that the stable region strongly depends on heterogeneity parameters.



Fig, 6. Length of Stable region in rounds for different values of heterogeneity.

7. Conclusion and Future works

The goodness of a micro-sensor network depends on the properties followed by prolonging the stability period, reduce the unstable region and utilize the maximum energy. The performances of our proposed protocol are analyzed and compare the results with LEACH, SEP. and H-HEARP in terms of stable region. Finally after simulating we conclude that proposed protocol can increase network lifetime and observation of the first dead sensor in network can be delayed in comparison with other considered protocols.

In future paper we will increase network lifetime and fault-tolerance with putting high power sensors as a gateway between cluster head and sink.

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