Energy Efficient Cluster Routing Protocol for Heterogeneous Wireless Sensor Networks

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Abstract. In this paper, a new routing protocol for heterogeneous networks with improved clustering strategies has been developed. Energy Efficient Stable Election Protocol(EE-SEP) is proposed which has the impact on network lifetime, network stability and cluster heads formation in every round. Simulation results show that the proposed algorithm outperformed SEP and Low Energy Adaptive Clustering Hierarchy (LEACH) in all the factors considered when two different topologies with advanced nodes and their energies taken into consideration.

Keywords: routing protocols, network stability, network lifetime, energy efficient Cluster Heads (CHs), heterogeneous environment.

1 Introduction

A wireless sensor network (WSN) consists of a set of autonomous devices called sensor nodes, equipped with short-range wireless interfaces and hardware for monitoring environmental parameters, such as humidity, pressure, and temperature [1]. Sensor nodes are also equipped with a small microprocessor, and they are usually powered by batteries. Sensors use other nodes as relays to send messages to other sensors or data sinks, which are not within their coverage area [2].

This paper shows impact of heterogeneity in terms of node energy. It is assumed that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network called heterogeneous sensor networks. These nodes will be equipped with more energy than the nodes that are already in use which creates heterogeneity in terms of node energy. The stable election protocol (SEP) weights the CH election probabilities according to the initial energy of a node relative to that of the other nodes in the network. SEP is proved to be more resilient than LEACH in consuming the extra energy of the advanced nodes [3].

The main goal of this work is the formulation of a newly proposed clustering threshold applied for the advanced nodes and normal nodes, so that they can have a significant impact on the overall performance when compared to SEP with network lifetime, network stability and formation of more energetic CHs in every round.

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2 The Energy Efficient Stable Election Protocol (EE-SEP)

In EE-SEP, a node elected as CH with a probability p can be attained for each nonCH node by choosing the CH with the least communication energy [4]. A node becomes a CH for the current rotation round if the number is less than the threshold $Th\ (n_i)$ which is proposed as:

$$Th(n_i) = \begin{cases} \frac{p}{(1-p)\left\lfloor rem\left\{(r-1)\left(\frac{1}{p}\right)\right\}\right\rfloor} & if\ n_i \in G \\ 0 & otherwise \end{cases} \quad (1)$$

where p is the desired percentage of the CH nodes in the sensor population, r is the current round number, and G is the set of nodes that have not been CHs in the last $1/p$ rounds.

If the fraction of advanced nodes is m and the additional energy [3] factor between advanced and normal nodes is α, then

$$p_{inrml} = \frac{p}{(1+\alpha m)} \quad , \quad p_{iadncd} = \frac{p(1+\alpha)}{(1+\alpha m)} \quad (2)$$

Hence, in SEP, the threshold in (1) is replaced by that of the normal sensors, $Th\ (n_{inrml})$, and the same for advanced nodes $Th\ (n_{iadncd})$ is as follows:

$$Th(n_{inrml}) = \begin{cases} \frac{p_{inrml}}{(1-p_{inrml})\left\lfloor rem\left\{(r-1)\left(\frac{1}{p_{inrml}}\right)\right\}\right\rfloor} & if\ n_{inrml} \in G' \\ 0 & otherwise \end{cases} \quad (3)$$

$$Th(n_{iadncd}) = \begin{cases} \frac{p_{iadncd}}{(1-p_{iadncd})\left\lfloor rem\left\{(r-1)\left(\frac{1}{p_{iadncd}}\right)\right\}\right\rfloor} & if\ n_{iadncd} \in G'' \\ 0 & otherwise \end{cases} \quad (4)$$

where r is the current round, G' is the set of normal nodes that have not become CHs within the last $1/p_{inrml}$ rounds of the epoch, and $Th\ (n_{inrml})$ is the new threshold applied to a population of $n\ (1 - m)$ normal nodes. This guarantees that each normal node will become a CH exactly once every $1/p$ x $(1 + \alpha\ m)$ rounds per epoch, and that the average number of cluster heads that are normal nodes per round per epoch is equal to $n\ (1 - m)\ p_{inrml}$. Similarly, G'' is the set of advanced nodes that have not become CHs within the last $1/p_{adncd}$ rounds of the epoch, and new $Th\ (n_{iadncd})$ is the threshold applied to a population of n x m advanced nodes. This guarantees that each advanced node will become a CH exactly once every $(1/p)(1 + \alpha\ m)/\ (1 + \alpha)$ rounds.

According to the radio energy dissipation model illustrated in literature [5, 6], the total energy dissipated in the network is equal to:

$$E_{total} = B\left\{2n_i E_{elec} + n_i E_{DA} + \varepsilon_{fs}\left(K d_{toBS}^2 + n_i d_{toCH}^2\right)\right\} \quad (5)$$

The average distance from a cluster head to the sink is given [6] by

$$d_{toBS} = 0.765\frac{M}{2} \quad (6)$$

The optimal probability of a node to become a cluster head, *p*, can be given [6] by

$$p = \frac{K_{opt}}{n_i} \quad (7)$$

$$K_{opt} = \sqrt{\frac{n_i}{2\pi}} \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \sqrt{\frac{M}{d_{toBS}^2}} \quad (8)$$

The optimal construction of clusters which is equivalent to the setting of the optimal probability for a node to become a cluster head is very important.

3 Simulation Results and Analysis

A clustered wireless sensor network is simulated in a field with dimensions 100m × 100m. The nodes, both normal and advanced, are randomly distributed over the field. The radio characteristics used in the simulations are taken from [7] where BS is assumed at the center of the network. Here *p*=0.05, where *p* is the probability to become cluster head per every round. All the routing protocols (LEACH, SEP and EE-SEP) are implemented in MATLAB.

As shown in Fig. 1, the network lifetime has been compared among LEACH, SEP and EE-SEP with m=0.1 and α=1respectively. From the simulations it is found that all nodes die at the 4000 rounds in EE-SEP, which is much better compared to LEACH and SEP. The results indicate that the algorithm has more than 45% extension of network life compared with SEP. The SEP and LEACH network lifetimes are 2150 and 1350 respectively.

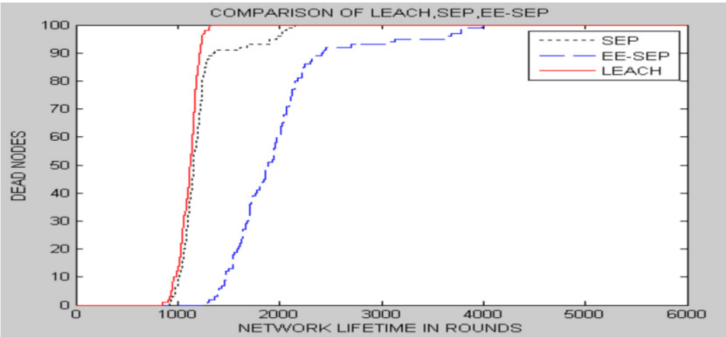

Fig. 1. Network lifetime comparison of LEACH, SEP and EE-SEP with m=0.1 and α=1

The Fig. 2 gives the network lifetime comparison for above algorithms with m=0.2 and α=1. In this approach also, the proposed algorithm outperforms the SEP and LEACH with 10% more heterogeneity applied to the nodes. Similarly the network lifetime of EE-SEP has 55% more than SEP where their lifetime observed as 4800 and 2250 rounds respectively with the increase of advanced nodes to 10% compared to Fig. 1.

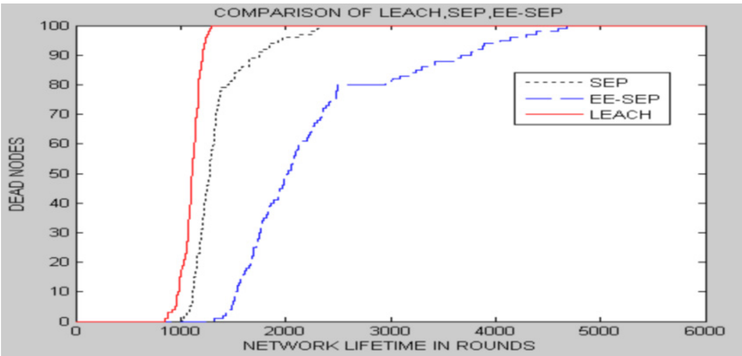

Fig. 2. Network lifetime comparison of LEACH, SEP and EE-SEP with m=0.2 and α=1

The network stability from first round to death of first node (FND) has been compared among the three algorithms. EE-SEP has outperformed the other two in all the graphs taken in consideration with two different topologies. This indicates formation of more energy efficient CHs with the newly proposed algorithm.

4 Conclusion

EE-SEP routing protocol has been proposed. Simulations have indicated that it outperformed SEP and LEACH algorithms with the new clustering threshold applied to the advanced nodes and normal nodes with two different topologies. The proposed algorithm has more network stability, network lifetime and energy efficient CHs selection in every round than the other two algorithms.

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