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HCEE: Hierarchical Clustered Energy Efficient Protocol for Heterogeneous Wireless Sensor Networks

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Abstract: *A wireless sensor network with a large number of tiny sensor nodes can be used as an effective tool for gathering data in various situations. One of the major issues in is wireless sensor network developing energy–efficient routing protocol which has a significant impact on the overall lifetime of the sensor network. In this paper, we study the impact of heterogeneity of nodes in terms of their energy in wireless sensor networks that are hierarchically clustered. We have assumed that some fraction of the sensor nodes is equipped with the additional energy resources. We also assumed that the sensor nodes are uniformly distributed and are static, the coordinates of the sink and the dimensions of the sensor field are known .Adapting this approach, we have proposed a hierarchical clustered energy efficient (HCEE) protocol for prolonging network lifetime and stability which is crucial for many applications. So, this protocol enhances the system lifetime and stability over the LEACH protocol.*

Keywords: *wireless sensor networks, clustering, lifetime, heterogeneous*

1. INTRODUCTION

Advances in wireless communication made it possible to develop wireless sensor networks consisting of small devices, which collect information by cooperating with each other. These small sensing devices are called nodes and consist of CPU, memory, battery energy and transceiver. The size of each sensor node varies with applications. For example, in some military or surveillance applications it might be microscopically small. Its cost depends on its parameters like memory size, processing speed and battery [1].

In this paper, we have considered clustered sensor networks because clustering allows for scalability of routing. LEACH uses the paradigm of data fusion to reduce the amount of data transmitted between sensor nodes and the base station. It selects a small number of cluster heads (CHs) by a random scheme which collects and fuses data from sensor nodes and transmits the result to the base station or sink. LEACH uses randomization to rotate the CHs and achieves a factor of 8 improvement compared to the direct approach before the first node dies [2].

The rest of the paper organized as follows, after the introduction in 1, Section 2 dealt with related work. Section 3 is proposed model. Section 4 presents simulation results. Finally, section 5 concludes the paper.

2. RELATED WORK

The cluster-based routing protocols are investigated in several research studies. In [5] authors show that 2-tier architecture is more energy efficient when hierarchical clusters are deployed at specific locations. In [3] author described a multi-level hierarchical clustering algorithm, where the parameters for minimum energy consumption are obtained using stochastic geometry.

In [4] author described a directed diffusion protocol where query (task) is disseminated into the network using hop-by-hop communication. When the query is traversed, the gradients (interests) are established for the result return path. Finally, the result is routed using the path based on gradients and interests. In [6], a variation of directed diffusion, use rumor routing to flood events and route queries; this approach is suitable for a large number of queries and a fewer events.

The first work that questioned the behavior of clustering protocols in the presence of heterogeneity in clustered wireless sensor networks was [7]. In [8], author presented a cost-based comparative study of homogeneous and heterogeneous clustered wireless sensor networks.

3. HCEE: PROPOSED MODEL

Consider the heterogeneous cluster-based wireless sensor network with hundreds sensor nodes dispersed in a field. Base station or sink, an observer, is located in the centre of the field remotely. First, we have described a few terms that are used in defining our protocol. A clusterhead is a sensor node that transmits an aggregated sensor data to the distant base station. Non-cluster heads are sensor nodes that transmit the collected data to their cluster head. The cluster heads act as local control centers to coordinate the data transmissions in their cluster.

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Figure 1 missing please check

The cluster head must be awake to receive all the data from the nodes in the cluster. Once the cluster head receives all the data, it performs data aggregation to enhance the common signal and reduce the uncorrelated noise among the signals. In our analysis, we assume perfect correlation such that all individual signals can be combined into a single representative signal. The resultant data are sent from the cluster head to the base station. Since the BS may be far away and the data messages are large, this is a high-energy transmission.

In this section we describe our model of a wireless sensor network with nodes heterogeneous in their initial amount of energy. In this model, we propose using three types of nodes with different energy. We assume *m* be the fraction of the total number of nodes *n*, which are equipped with α and β times, more energy than the other nodes. We refer these nodes as advanced and super nodes, and (1-2m) .*n* as normal nodes.

In LEACH there is an optimal percentage p_{opt} of nodes that has to become cluster heads in each round assuming uniform distribution of nodes in space [3], [8]. If the nodes are homogeneous, which means that all the nodes in the field have the same initial energy, the LEACH protocol guarantees that everyone of them will become a cluster head exactly once every $1/p_{opt}$ rounds. Throughout this paper we refer to this number of rounds, $1/p_{opt}$ as *epoch* of the clustered sensor network. Initially each node can become a cluster head with a probability p_{opt}. On average, $p_{opt}\,.n$ nodes must become cluster heads per round per epoch. Nodes that are elected to be cluster heads in the current round can no longer become cluster heads in the same epoch. The non-elected nodes belong to the set *G* and in order to maintain a steady number of cluster heads per round, the probability of nodes ε *G* to become a cluster head increases after each round in the same epoch. The decision is made at the beginning of each round by each node *s* ε *G* independently choosing a random number in [0, 1]. If the random number is less than a threshold *T(s)* then the node becomes a cluster head in the current round. The threshold is set as:

$$T(s) = \begin{cases} \dfrac{p_{opt}}{1 - p_{opt}.(r \bmod \dfrac{1}{p_{op}t})} \; ifs \in G \\ 0 \text{ otherwise} \end{cases} \tag{1}$$

where *r* is the current round number. The election probability of nodes *s* ε *G* to become cluster heads increases in each round in the same epoch and becomes equal to 1in the last round of the epoch. Note that by round we define a time interval where all cluster members have to transmit to their cluster head once. We show in this paper how the election process of cluster heads should be adapted appropriately to deal with heterogeneous nodes, which means that not all the nodes in the field have the same initial energy.

3.1 Optimal Clustering

According to the radio energy model described previously, in [6] the optimum number of clusters k_{opt} for a cluster-based network that uses LEACH communication protocol, and contains *N* sensor nodes distributed uniformly in an region has been calculated as:

$$k_{opt} = \sqrt{\frac{N}{2\pi}}\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}\frac{M}{d_{BS}^2} \tag{2}$$

where d_{BS} is the distance from the cluster head node to the BS. Substituting minimum and maximum values of d_{BS}, the upper bound and lower bound of the desired number of clusters can be obtained.

3.2 HCEE Architecture

In this section, we describe HCEE, which improves the lifetime of the network by using the characteristic parameters of heterogeneity, namely the few advanced nodes and super nodes of α and β times more energy factor than the normal nodes. In order to prolong the lifetime of the network. Intuitively, super nodes and advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constant on energy consumption. The new heterogeneous setting has no effect on the spatial density of the network so the setting of $p_{opt,}$ does not change. On the other hand, the total energy of the network changes. Let assume that E_0 is the initial energy of each normal node. The energy of each super node is then E_0 (1+α) and each advanced node is then E_0 (1+β). The total initial energy of the new heterogeneous network setting is equal to:

Initial Energy of normal nodes (*En*) = $n.(1–2\,m).E_0$.
Initial Energy of advanced nodes (*Ea*) = $n\,.\,m.\,E_0.(1+\alpha)$
Initial Energy of super nodes (*Es*) = $n\,.\,m.\,E_0.(1+\beta)$
Net Energy of the network (*Et*) = $n.E_0.(1+m.\,(\alpha + \beta))$

The net energy of the system is increased by a factor of (1+*m.* (α + β). The first improvement to the existing LEACH is to increase the epoch of the sensor network in proportion to the energy increment in view of the stability of the network system. The new epoch must be changed accordingly as the energy of the system is increased. The stability of the network is increased as the probability of each super node and each advanced node increases than the normal nodes. If at the end of each epoch the number of times that an advanced and super sensor node has become a cluster head is not equal to the factor (1+α) and (1+β) then the energy is not well distributed and the net number of cluster heads per round per epoch will be less than $p_{opt}\times n$. This problem can be minimized to a problem of optimal threshold *T*(*s*) setting in (equation 1), with the constraint that each node has to become a cluster head as many times as its initial energy divided by the energy of a normal sensor node.

If the same threshold is set for super, advanced and normal nodes with the difference that each normal node ε *G* becomes a cluster head once every $(1 + m.\,(\alpha + \beta))/p_{opt}$ rounds per epoch, each super node ε G becomes a cluster head $(1+\beta)$ and each advanced node ε G becomes a cluster head $(1+\alpha)$ times every $(1 + m.\ (\alpha+\ \beta))/p_{opt}$ rounds per epoch, then there is no guarantee that the number of cluster heads per round per epoch will be $p_{opt} \times n$. So the constraint of $p_{opt} \times n$ cluster heads per round is violated.

4. SIMULATION RESULTS

In this section, we have evaluated the performance of the HCEE protocol. We have considered first order radio model simulation to LEACH and the simulation parameters for our model are mentioned in the Table 1. To validate the performance of HCEE, we simulate a heterogeneous clustered wireless sensor network in a field with dimensions 100m × 100m. The total number of sensor nodes $n = 100$. The super, advanced and normal nodes randomly distributed over the field. This means that the horizontal and vertical coordinates of each sensor are randomly selected between 0 and maximum value of the dimension. The sink or base station is in the centre and so, the maximum distance of any node from the base station is approximately 70m .The size of the message that nodes send to their cluster heads as well as the size of the (aggregate) message that a cluster head sends to the sink is set to 4000 bits.

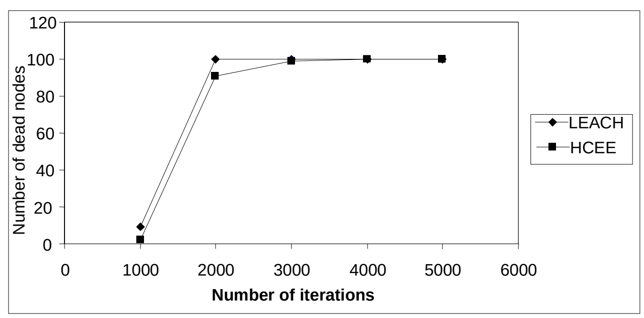
Table 1
Transmission Parameters Value

Description	*Symbol*	*Value*
Number of nodes in the system	n	100
Energy consumed by the amplifier to transmit at a short distance	ε_{fs}	10pJ/bit/m^2
Energy consumed by the amplifier to transmit at a longer distance	ε_{mp}	0.0013pJ/bit/m^4
Energy consumed in the electronics circuit to transmit or receive the signal	E_{elec}	50nJ/bit
Data aggregation energy	E_{DA}	5nJ/bit/report

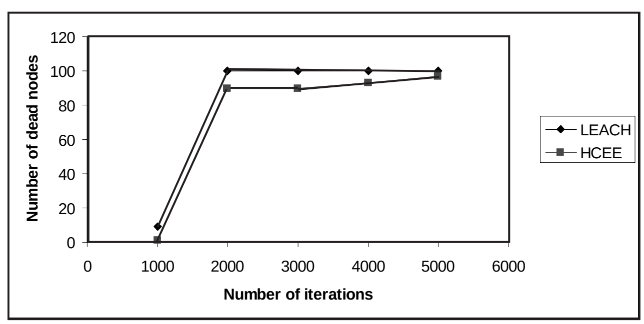
We simulate the LEACH and HCEE protocol, in the presence of different heterogeneity parameters with initial energy of nodes in the sensor network. The results of HCEE and LEACH simulations are shown in Fig. 1 and Fig. 2.

In Fig. 1, a detailed view of the behavior of LEACH and HCEE is illustrated, for different heterogeneity parameters. Figs. 2(a)-(b), shows the number of dead nodes for the different scenarios. The number of nodes die in LEACH is more than HCEE for the same number of iterations. Moreover, the normal nodes die very fast and as a result the sensing field becomes sparse very fast. On the other hand, advanced nodes die in a very slow fashion. When a significant number of normal nodes and advanced nodes are dead the average number of cluster heads per round per epoch is less than one. This means that in most of the rounds there is no cluster head, so the remaining nodes can not report their values to the sink. Figs. 3(a)-(b), indicates that the

Figure 1 Missing

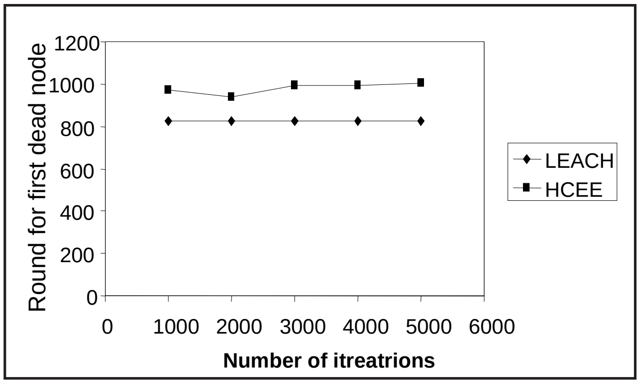


(a)

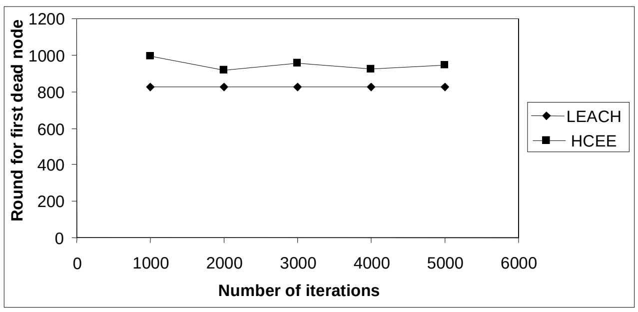


(b)

Figure 2: Number of Dead Nodes using (a) LEACH ($m = 0$, $\alpha = 0$, $\beta = 0$) and HCEE ($m = 0.1$, $\alpha = 1$, $\beta = 0$ (b) LEACH ($m = 0$, $\alpha = 0$, $\beta = 0$) and HCEE ($m = 0.1$, $\alpha = 1$, $\beta = 1$)



(a)



(b)

Figure 3: Round for Death of First Node using (a) LEACH (m = 0, α = 0, β = 0) and HCEE (m = 0.1, α = 1, β = 0) (b) LEACH (m =0, α = 0, β = 0) and HCEE (m = 0.1, α = 1, β = 1)

lifetime and stability of the system is extended by the heterogeneity for the different scenarios. This shows with HCEE, as the first node dies after a higher number of rounds compared to the LEACH. Furthermore, HCEE successfully extends the stability and lifetime of the network over LEACH.

5. CONCLUSIONS

The wireless sensor networks have been envisioned to help in numerous monitoring applications. Energy efficient routing is paramount to extend the lifetime of the system. In this paper, we proposed a heterogeneous clustered energy efficient protocol. The energy efficiency and ease of deployment make HCEE a desirable and robust protocol for wireless sensor networks. Simulations results show that HCEE has a better performance than LEACH. For future work, HCEE to deal with clustered sensor networks with more than two levels of hierarchy and more than three types of nodes.

REFERENCES

[1] Römer, Kay, F. Mattern, The Design Space of Wireless Sensor Networks, *IEEE Wireless Communications*, (Dec. 2004).

[2] Q. Xue, A.Ganz, Maximizing Sensor Network Lifetime: Analysis and Design Guides, in Proceedings of MILCOM, October 2004.

[3] S. Bandyopadhyay, E. J. Coyle, An Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Networks. In *Proceedings of the IEEE Conference on Computer Communications* (INFOCOM), (2003).

[4] C. Intanagonwiwat, R. Govindan, D. Estrin, Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks, In *Proceedings of the 6th Annual I nternational Conference on Mobile Computing and Networking*, (August 2000), 56–67.

[5] J. Pan, L. Cai, Y. T. Hou, Y. Shi, S. X. Shen, Optimal base-station Locations in Two-tiered Wireless Sensor Networks. *IEEE Transactions on Mobile Computing (TMC)*, (2005), 458–473.

[6] D. Braginsky, D. Estrin, Rumor Routing Algorthim for Sensor Networks, In *Proceedings of the 1st ACM International Workshop on Wireless Sensor Networks and Applications*, New York, NY, USA, (2002), 22–31.

[7] W. R. Heinzelman, Application-Specific Protocol Architectures for Wireless Networks, Ph.D. Thesis, Massachusetts Institute of Technology, (2000).

[8] W. R. Heinzelman, A. P. Chandrakasan, H. Balakrishnan, Energy Efficient Communication Protocol for Wireless Microsensor Networks, in *Proceedings of the 33rd Hawaii International Conference on System Sciences* (HICSS-33), (January 2000).