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Heterogeneity Analysis and Threshold Tuning for HEC Technique

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ABSTRACT

Energy heterogeneous wireless sensor network consists of sensor nodes having dissimilar initial energy. Clustering is the key technology to extend the network lifetime through efficient resource utilization. Heterogeneity-aware Energy-efficient Clustering (HEC) technique introduced the concept of network lifecycle phases to effectively utilize the energy heterogeneity. The network lifetime is divided into three phases- initial, active and dying out. The effective utilization of additional energy of advanced nodes is done through autonomous cluster head selection process for each lifecycle phase rather than single selection process for the complete lifetime. This paper deals with analysis of HEC technique for total network energy, heterogeneity parameters and phase shift thresholds. The aim is to get the optimal value of heterogeneity parameters having maximum stability period per unit energy. Further, the phase shift threshold is fine tuned that was initially fixed through random observations.

Keywords

Heterogeneity; lifecycle phases; fine tuning; energy

1. INTRODUCTION

Wireless sensor networks [1] are energy-limited networks. Their lifetime depends upon the batteries attached at the time of deployment. It is quite difficult to recharge these energy-limited nodes or replace their batteries. So, efficient utilization of energy is the only alternative to prolong the network lifetime [2]. This paper deals with analysis of Heterogeneity-aware Energy-efficient Clustering (HEC) technique for total network energy, heterogeneity parameters and phase shift threshold. The aim is to get the optimal value of heterogeneity parameters having maximum stability period per unit energy. The phase shift threshold is fine tuned to further improve the stability period of the network.

1.1. Heterogeneity-aware Energy-efficient Clustering (HEC) Technique

Energy efficient clustering techniques [3],[4],[5],[6] are suggested by various researchers from time to time. As clustering divides the network into clusters, researchers aims to improve the cluster formation, cluster head selection, multi-level clustering etc. Heterogeneity-aware Energy-efficient Clustering (HEC) technique [7] is a breakthrough in this direction. Rather than improving the clustering, we analyzed the lifecycle of wireless sensor network and divided it into three phases - initial, active and dying out. Selection of cluster head nodes is done based on these three network lifecycle phases: only advanced nodes are allowed to become cluster heads in the initial phase; in the second active phase all nodes are allowed to participate in cluster head selection process with equal probability, and in the last dying out phase, clustering is relaxed by allowing direct transmission. Simulation-based performance analysis shows that HEC achieves longer stable region, improved throughput, and better energy dissipation owing to judicious consumption of additional energy of advanced nodes.

Energy heterogeneity is achieved through parameters m and α, where m is fraction of advanced nodes and α is the additional energy factor between advanced and normal nodes. The total energy of network depends upon the heterogeneity parameters. The total energy of the network $E_{t,}$ is represented as:

$$E_{t,} = T_n(1 + \alpha . m). E_0 \quad (1)$$

where T_n is the total number of nodes and E_0 is the initial energy of normal nodes.

The total energy of network ($E_{t,}$) increases with increase in fraction of advanced nodes and/or the additional energy factor between advanced and normal nodes. So, it is desirable to understand the relationship between heterogeneity parameters and stability period of network.

This paper deals with analysis of HEC technique for total network energy, heterogeneity parameters and phase shift threshold. The aim is to get the optimal value of heterogeneity parameters having maximum stability period per unit energy.

Further, two thresholds are used to decide the time when the technique will move from phase 1 to phase 2, and from phase 2 to phase 3. Threshold 1 is used to decide the phase shift from phase 1 to phase 2 whose optimization results in increased stability period for the HEC technique. The fine tuning of the threshold 1 is considered to get optimal results.

2. Heterogeneity Analysis of HEC

The ultimate goal of this paper is to prolong the stability period of energy heterogeneous wireless sensor network through optimization of HEC technique. Following are the major contributions of this paper:

• To understand the relationship between the total energy of network and stability period

• To analyze the relationship of heterogeneity parameters (m and α) and stability period

• To fix the heterogeneity parameters and fine-tuning of threshold 1 for phase shifting from phase 1 to phase 2

2.1. Simulation Parameters Used

A wireless sensor network having field size of 100m × 100m is considered for simulations. The nodes are deployed uniformly randomly over the field with sink at the center. HEC technique is used for cluster head selection and communication. Simulation is run for different values of heterogeneity parameters (m and α), network lifetime and threshold 1. Simulation parameters considered are given below:

Table 1. Simulation Parameters

Simulation Parameters	Values
No. of Nodes	100
Field Size	100m*100m
Additional Energy Factor between Advanced and Normal Nodes	1, 2, 3, 4, 5
Fraction of advanced nodes (m)	0.1, 0.2, 0.3, 0.4, 0.5
Threshold 1	0.25, 0.3, 0.35, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75
No. of Iterations	10

2.2. Relationship between the total energy of network and Stability period

The total energy of network ($E_{t,}$) increases with increase in no. of advanced nodes and/or increase in additional energy of advanced nodes. Stability period results are calculated by varying the heterogeneity parameters m and α. The results are ordered in terms of total energy of total energy of network while selecting results with maximum stability period if more than one entry for the same total energy of the network. The results (Fig.1) show the impact of increased total energy of network on the stability period of the network.

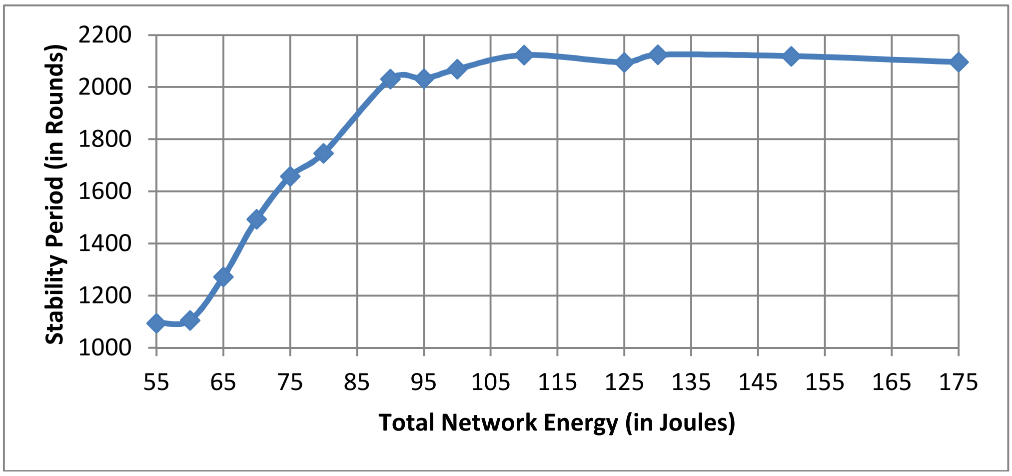

Fig 1: Total Network Energy vs Stability Period

Results indicate that heterogeneity improves the stability period initially, but, for higher values of total energy of network (due to higher values of m and α) the improvement is either negligible or negative. The stability period is 1106, 1494, 1747, 2013, 2069, 2123, 2095, 2119 and 2096 for total network energy of 60, 70, 80, 90, 100, 110, 125, 150, 175 joules respectively. So, there is a need to fix the heterogeneity parameters to get optimal results from clustering techniques.

2.3. Relationship between heterogeneity parameters (m and α) and Stability period

To further investigate the impact of individual values of m and α, results are evaluated for all possible combinations of m and α. As every unit of energy is important, the results are analyzed based upon the no. of rounds (stability period) per joule of energy drawn (Fig. 2).

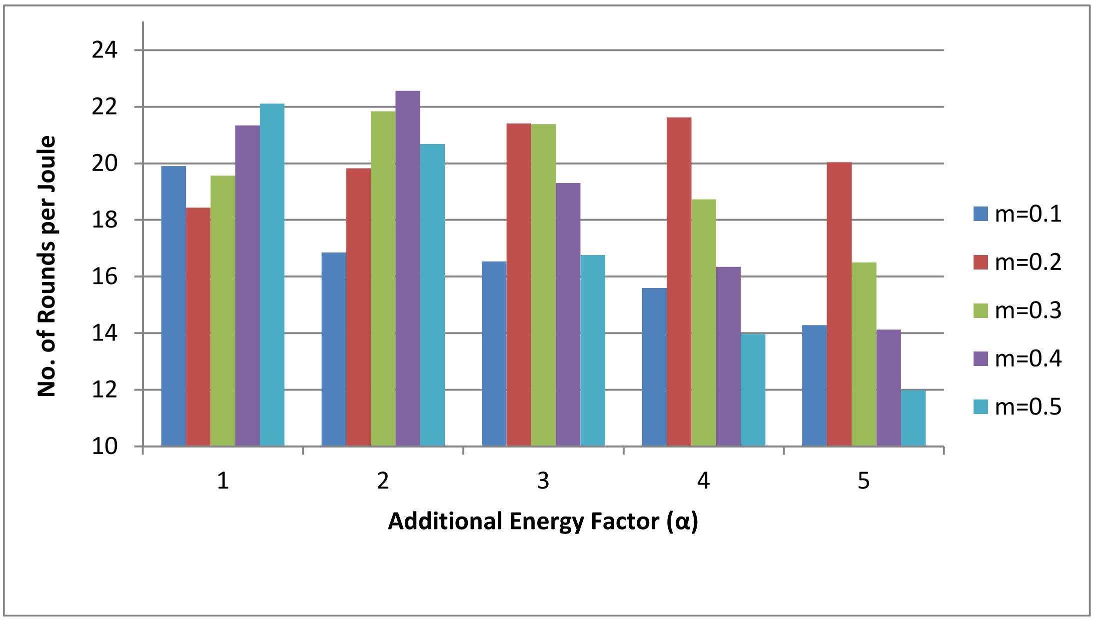

Fig 2: Heterogeneity Parameters vs Stability Period

It can be observed that maximum no. of cycles per joule are attained at m=0.4, α=2 (40% advanced nodes having 2 times additional energy). It provides stability period of 2031 for total network energy of 90 joules giving 22.57 rounds per joule of energy.

An important outcome here is the analysis of impact of individual values of m and α. As the total energy of the network is same for scenarios having m=0.4, α=2 and m=0.2, α=4 the stability period attained is 2031 and 1946 rounds respectively. Similar is the case with all possible combinations of m and α. It clearly indicates that higher values of m give better stability period than higher values of α for the same total energy network. So, it is better to have more number of advanced nodes with lesser additional energy than lesser number of advanced nodes having higher additional energy.

2.4. Fixation of heterogeneity parameters and fine tuning of threshold for phase

To fine tune the threshold (threshold 1) the heterogeneity parameters are required to be fixed in advance. So the heterogeneity parameters m and α are fixed to the values m=0.4, α=2 having the maximum no. of cycles per joule of energy.

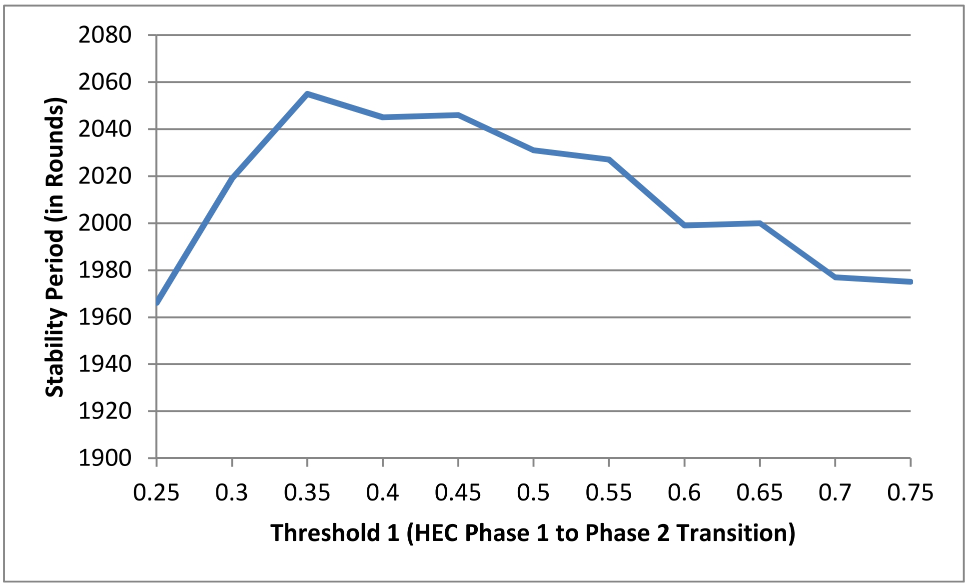

Fig 3: Threshold 1 vs Stability Period.

Results are evaluated for the stability period varying the value of threshold 1 from 0.25 to 0.75 (Fig. 3). Results show the maximum value of stability period for the threshold 1 = 0.35, so it may be considered as optimal value of threshold.

3. Conclusions

Heterogeneity-aware Energy-efficient Clustering (HEC) technique has been evaluated for various heterogeneity parameters and fine tuning of thresholds to further improve the stability period. Simulation results indicate that the increase in heterogeneity parameters increases the overall energy of network that contributes to increased stability period. Detailed analysis of stability period for different amount of initial energy reveals that increase in total network energy improves upon the stability period for some maximum value after which the improvements are either negligible or negative. Results point out the need of having more number of advanced nodes with lesser additional energy as compared to lesser number of advanced nodes having higher additional energy for the network having same total energy. Further, the heterogeneity parameters having maximum number of rounds per unit energy are fixed for fine tuning the threshold 1. The initial value of threshold 1 is changed to a new value that improves the stability period significantly.

While extensive simulations are performed to analyze the heterogeneity parameters and fine tune the threshold, there remains a scope of empirical or statistical models to get optimal results from the proposed technique.

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