Energy Efficient Clustering in Heterogeneous Wireless Sensor Networks

[1]Yogita Thareja, [1]Sakshi Khullar

Assistant Professor, Dept. of Information Technology, Vivekananda Institute of professional studies, Pitampura, Delhi.

Abstract:- In this paper, a performance evaluation of heterogeneous Wireless Sensor Networks using Energy-Efficient Clustering is presented. Energy- Efficient clustering are algorithms designed for heterogeneous WSN under consideration so these protocols do not work efficiently under homogenous scenarios because these algorithms are unable to treat nodes differently in terms of their energy. Here, we evaluate the performance of DEEC clustering algorithms based on stability period, network lifetime, and throughput for different levels of heterogeneous wireless sensor networks. Energy Efficient Clustering performs well under three-level heterogeneous WSNs containing high energy level differences between normal, advanced, and supernodes in terms of the stability period. Simulation results show that the number of alive nodes varies as the network evolves and the first node dies around 1900 round. Result also shows that in Energy Efficient Clustering in Heterogeneous Wireless Sensor Networks unstable region starts very later as compared to other protocols.

Index Terms: Energy-efficient clustering (EEF), cluster heads (CHs), Wireless Sensor Networks (WSN), a base station (BS).

I. INTRODUCTION

In many critical applications, WSNs are very useful such as military surveillance [1], environmental [2], traffic [3], temperature [4], pressure [5], vibration monitoring [6], and disaster areas [1]-[6]. All the nodes have to send their data towards BS often called a sink. Usually, nodes in WSN are power constrained due to limited battery, it is also not possible to recharge or replace the battery of already deployed nodes and nodes might be placed where they cannot be accessed. Nodes may be present far away from BS so direct communication is not feasible due to limited battery as direct communication requires high energy. Clustering is the key technique for decreasing battery consumption in which members of the cluster select a Cluster Head.

Wireless Sensor Networks [1] (WSN) have gained worldwide attention in recent years due to the advances made in wireless communication, information technologies, and the electronics field. The development of low-cost, low-power, multifunctional sensors has received increasing attention from various industries. Sensor nodes or motes in WSNs are small-sized and are capable of sensing, gathering, and processing data while communicating with other connected nodes in the network, via radio frequency (RF) channel.

Wireless sensor networks [2] are one of the categories belonging to ad-hoc networks. Sensor networks are also composed of nodes. Here actually the node has a specific name that is “Sensor” because these nodes are equipped with smart sensors. A sensor node is a device that converts a sensed characteristic like temperature, vibrations, or pressure into a form recognized by the users. Wireless sensor network nodes are less mobile than ad-hoc networks. So mobility in the case of ad-hoc is more. In wireless sensor network data are requested depending upon a certain physical quantity. A sensor consists of a transducer, an embedded processor, a small memory unit, and a wireless transceiver and all these devices run on the power supplied by an attached battery.

Clustering can be done in two types of networks i.e homogenous and heterogeneous networks. Nodes having the same energy level are called homogenous network and nodes having different energy levels called heterogeneous networks. Low-Energy Adaptive Clustering Hierarchy (LEACH) [7], Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [8], Hybrid Energy-Efficient Distributed clustering (HEED) [9]-[11].

In this paper, the performance evaluation of heterogeneous Wireless Sensor Networks using Energy-Efficient Clustering is presented. Energy- Efficient clustering are algorithms designed for heterogeneous WSN under consideration so these protocols do not work efficiently under homogenous scenarios because these algorithms are unable to treat nodes differently in terms of their energy. Here, we evaluate the performance of Energy Efficient Clustering algorithms based on stability period, network lifetime, and throughput for a different levels of heterogeneous wireless sensor networks. Energy Efficient Clustering performs well under three-level heterogeneous WSNs containing high energy level differences between normal, advanced, and supernodes in terms of the stability period.

The outline of this paper is as follows. In Section II, we provide a brief introduction to the wireless sensor network. A basic component of the sensor node is described in Section III. In Section IV energy-efficient clustering for a heterogeneous model is described. Section V analyzes the performance of heterogeneous Wireless Sensor Networks using Energy-Efficient Clustering and is presented. Finally, Section VII presents the conclusions.

II. WIRELESS SENSOR NETWORKS (WSN)

Wireless Sensor Networks (WSNs) are ad-hoc networks, consisting of spatially distributed devices (motes) using sensor nodes to cooperatively monitor physical or environmental conditions at different locations. Devices in a WSN are resource-constrained; they have low processing speed, storage capacity, and communication bandwidth. In most settings, the network must operate for long periods, but the nodes are battery-powered, so the available energy resources limit their overall operation. To minimize energy consumption, most of the device components, including the radio, should be switched off most of the time [4]. Another important characteristic is that sensor nodes have significant processing capability in the ensemble, but not individually. Nodes have to organize themselves, ad- ministering and managing the network altogether, and it is much harder than controlling individual devices. Furthermore, changes in the physical environment where a network is deployed make also nodes experience wide variations in connectivity and it influences the networking protocols [5].

III. SENSOR NODES

Four basic components can be found in all sensor nodes. These components are a power unit, a processing unit, a sensing unit, and a transceiver. Some sensor nodes also contain optional components such as a location-finding system, a mobilizer, or a power generator. Fig. 1 shows the basic components of a sensor node [2].

The power unit is very important in a sensor node. It is responsible for providing all of the other units with energy so that the node can perform its functions. A power generator or power scavenging unit can support the power unit. Solar cells could be used as power scavenging units.

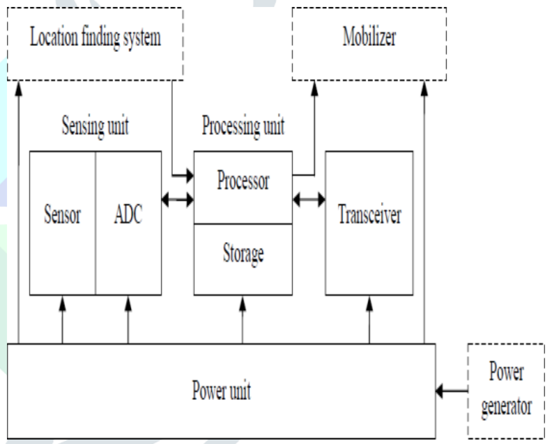

Fig. 1 Basic Components of a Sensor Node

The processing unit consists of a processor and some storage or memory. This unit is responsible for managing the tasks of the sensor unit. The sensing unit generally consists of a sensor and an analog-to-digital converter (ADC). The ADC converts the analog data from the sensor to digital data that can be processed by the processor. The transceiver connects the sensor node to the network. The transceiver can use either radio frequency (RF) or optical communications, such as infrared, to wirelessly connect to the network [5].

IV. ENERGY-EFFICIENT CLUSTERING (EEC)

Energy-Efficient clustering is designed to deal with nodes of heterogeneous WSNs. For CH selection, Energy-Efficient clustering uses the initial and residual energy levels of nodes. Let n_i denote the number of rounds to be a CH for node s_i. p_{opt} N is the optimum number of CHs in our network during each round. CH selection criteria in Energy-Efficient clustering are based on the energy level of nodes. As in a homogenous network, when nodes have the same amount of energy during each epoch then choosing $p_i = p_{opt}$ assures that $p_{opt}N$ CHs during each round. In WSNs, nodes with high energy are more probable to become CH than nodes with low energy but the net value of CHs during each round is equal to $p_{opt}N$. p_i is the probability for each node s_i to become CH, so, the node with high energy has a larger value of p_i as compared to the p_{opt}. E(r) denotes the average energy of the network during round r which can be given as in [19]

$$E(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \tag{1}$$

The probability for CH selection in DEEC is given as

$$p_i = p_{opt}[1 - \frac{\bar{E}(r) - E_i(r)}{\bar{E}(r)}] = p_{opt}\frac{E_i(r)}{\bar{E}(r)} \tag{2}$$

In Energy-Efficient clustering, the average total number of CH during each round is given as

$$\sum_{i=1}^{N} p_i = \sum_{i=1}^{N} p_{opt}\frac{E_i(r)}{\bar{E}(r)} = p_{opt}\sum_{i=1}^{N}\frac{E_i(r)}{\bar{E}(r)} = Np_{opt} \tag{3}$$

pi is the probability of each node becoming CH in a round where G is the set of nodes eligible to become CH at round r. If the node becomes CH in recent rounds then it belongs to G. During each round each node chooses a random number between 0 and

1. If the number is less than the threshold as defined below, it is eligible to become a CH or else not.

$$T(s_i) = \begin{cases} \frac{p_i}{1 - p_i(r \bmod \frac{1}{p_i})} & if\ s_i \epsilon G \\ 0 & otherwise \end{cases} \tag{4}$$

As p_{opt} is the reference value of average probability p_i. In homogenous networks, all nodes have the same initial energy so they use p_{opt} to be the reference energy for probability p_i. However, in heterogeneous networks, the value of p_{opt} is different according to the initial energy of the node. In a two-level heterogeneous network, the value of p_{opt} is given by

$$p_{adv} = \frac{p_{opt}}{1+am}, p_{nrm} = \frac{p_{opt}(1+a)}{(1+am)} \tag{5}$$

Then use the above p_{adv} and p_{nrm} instead of p_{opt} in equation (2) for a two-level heterogeneous network as

$$p_i = \begin{cases} \frac{p_{opt}E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ normal\ node \\ \frac{p_{opt}(1+a)E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ the\ advanced\ node \end{cases} \tag{6}$$

The above model can also be extended to a multi-level heterogeneous network given below as

$$p_{multi} = \frac{p_{opt}N(1+a_i)}{(N + \sum_{i=1}^{N} a_i)} \tag{7}$$

Above p_{multi} in equation (2) instead of p_{opt} to get p_i for heterogeneous node p_i for the multilevel heterogeneous network is given by

$$p_i = \frac{p_{opt}N(1+a)E_i(r)}{(N + \sum_{i=1}^{N} a_i)\bar{E}(r)} \tag{8}$$

In DEEC we estimate the average energy E(r) of the network for any round r as

$$E(r) = \frac{1}{N}E_{total}(1 - \frac{r}{R}) \tag{9}$$

R denotes total rounds of network lifetime and is estimated as follows:

$$R = \frac{E_{total}}{E_{round}} \tag{10}$$

E_{total} is the total energy of the network whereas E_{round} is energy expenditure during each round.

V. SIMULATION RESULTS

In this section, the energy-efficient clustering in heterogeneous wireless sensor networks is presented. Here, the performance of energy-efficient clustering algorithms is based on control parameters such as stability period, network lifetime, and throughput for a different levels of heterogeneous wireless sensor networks. Simulation is presented using Matlab. We simulate different clustering protocols in heterogeneous WSN using MATLAB and for simulations, we use 100 nodes randomly placed in a field of dimension 100m×100m. For simplicity, we consider all nodes are either fixed or micro-mobile and ignore energy loss due to signal collision and interference between signals of different nodes that are due to dynamic random channel conditions.

Performance parameters used for the evaluation of clustering protocols for heterogeneous WSNs are a lifetime of heterogeneous WSNs, several nodes alive during rounds, and data packets sent to BS.

- ***Lifetime*** is a parameter that shows that node of each type has not yet consumed all of its energy.
- ***The number of nodes alive*** is a parameter that describes the number of alive nodes during each round.
- ***Data packets sent to the BS*** are the measure that how many packets are received by BS for each round.

Table: 1 Control parameters

Parameters	Values
Network field (Size)	100m * 100m
Initial Energy of normal node (E_o)	0.5 J
P_{opt}	0.1 J
E_{fs}	10nJ/bit/m2
Number of nodes	100
message size	4000 bit
EDA	5nJ/bit/ signal
E_{elec}	50 nJ/bit
Transmit amplifier (E_{amp})	0.0013 pJ/bit/m4
Threshold distance (d_o)	70m

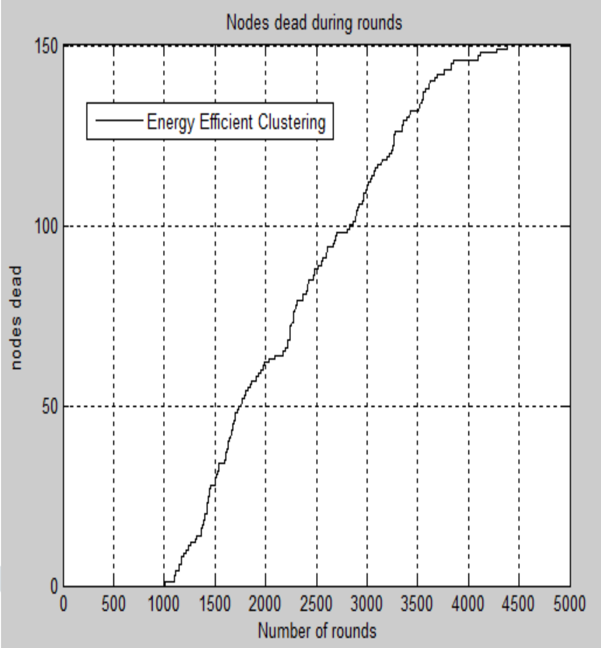

Fig. 2 Dead Nodes during 5000 rounds and 100 nodes

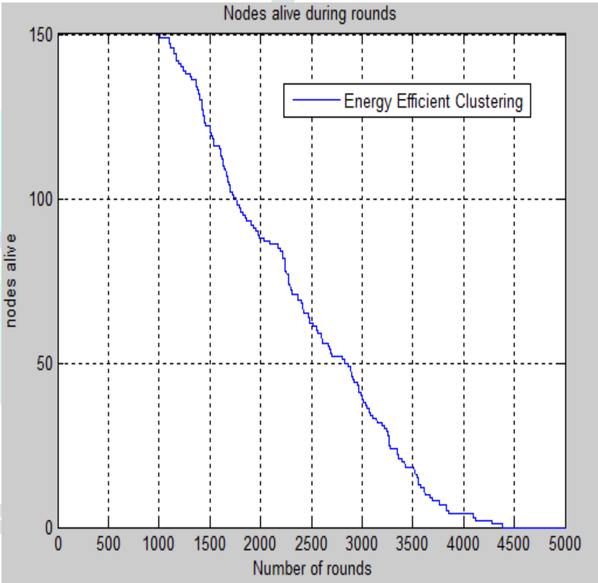

Fig. 3 Alive Nodes during 5000 rounds and 100 nodes

Following Design, parameters are chosen to perform the analysis of the Energy Efficient Clustering (EEC) in a heterogeneous wireless sensor network.

In this example, we analyze the performance of Energy Efficient Clustering (EEC) in a heterogeneous wireless sensor network along with 4000 rounds and 100 nodes. Fig. 2 demonstrates the Dead Nodes during 5000 rounds and 100 nodes. Fig. 3 depicts the Alive Nodes during 5000 rounds and 100 nodes. Fig. 4 shows the Packet sends to BS Nodes during 5000 rounds and 100 nodes. Fig. 5 depicts the Count of Cluster Heads per round during 5000 rounds and 100 nodes. Fig. 6 shows the Dead Nodes, Alive Nodes, Packet sends to BS Nodes, Count of Cluster Head per round during 5000 rounds and 100 nodes.

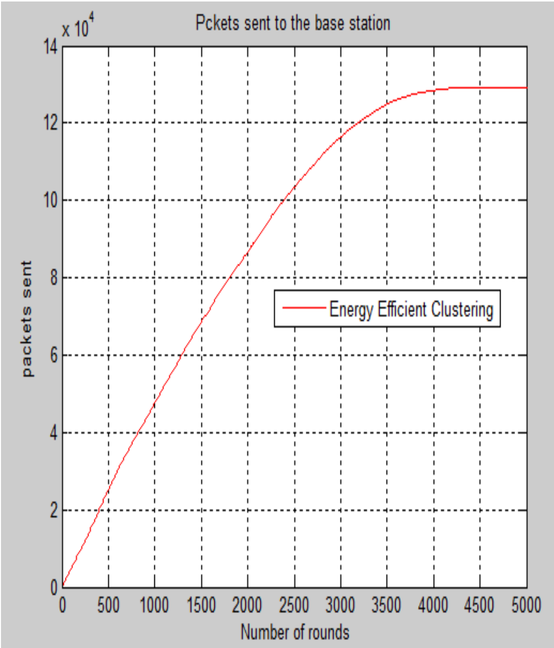

Fig. 4 Packet sends to BS Nodes during 5000 rounds and 100 nodes

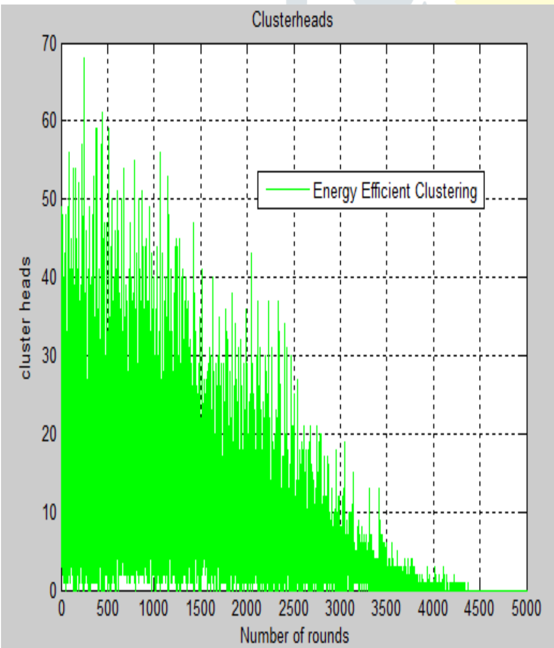

Fig. 5 Count of Cluster Head per round during 5000 rounds and 100 nodes

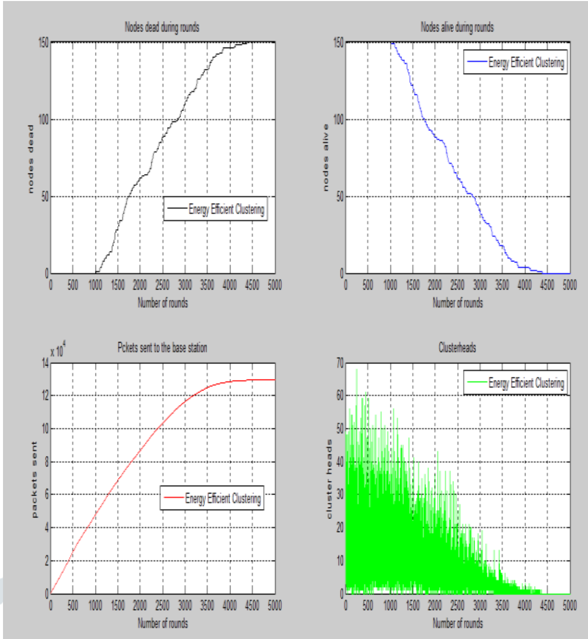

Fig. 6 Dead Nodes, Alive Nodes, Packet sends to BS Nodes, Count of Cluster Head per round during 5000 rounds and 100 nodes

VI. CONCLUSIONS

This paper evaluates the energy-efficient clustering (EEF) in heterogeneous wireless sensor networks is presented. Here, we calculate the performance of DEEC clustering algorithms based on control parameters such as stability period, network lifetime, and throughput for a different levels of heterogeneous wireless sensor networks. Energy-efficient clustering performs well under three-level heterogeneous WSNs containing high energy level differences between normal, advanced, and supernodes in terms of the stability period. Simulation results show that the number of alive nodes varies as the network evolves and the first node dies around 1900 round. Result also shows that in Energy Efficient Clustering in Heterogeneous Wireless Sensor Networks unstable region starts very later as compared to other protocols. Results show that in Energy Efficient Clustering in Heterogeneous Wireless Sensor Networks nodes die at a constant rate.

REFERENCES

[1] Zeng, Mengjia, et al. "A heterogeneous energy wireless sensor network clustering protocol." Wireless Communications and Mobile Computing 2019 (2019)
[2] Paolo Santi, Topology control in wireless Ad-hoc

and Sensor networks, Jhon Wiley and son's publication, 2005.

[3] Chen, Yang, Xiaoguang Xu, and Yong Wang. "Wireless sensor network energy-efficient coverage method based on the intelligent optimization algorithm." Discrete & Continuous Dynamical Systems-S 12.4&5 (2019): 887.

[4] Sangaiah, Arun Kumar, et al. "Energy consumption in point-coverage wireless sensor networks via bat algorithm." IEEE Access 7 (2019): 180258-180269.

[5] Raj, Jennifer S., and Abul Basar. "QoS optimization of energy-efficient routing in IoT wireless sensor networks." Journal of ISMAC 1.01 (2019): 12-23.

[6] Hussein, Ahmed, Ahmed Elnakib, and Sherif Kishk. "Linear wireless sensor networks energy minimization using optimal placement strategies of nodes." Wireless Personal Communications 114.4 (2020): 2841-2854.

[7] Li Han, *"LEACH-HPR: An energy-efficient routing algorithm for Heterogeneous WSN*", IEEE International Conference on Intelligent Computing and Intelligent Systems(ICIS),Vol: 2, Pag: 507 – 511, 2010.

[8] Chowdhury, Sultan Mahmood, and Ashraf Hossain. "Different energy saving schemes in wireless sensor networks: A survey." Wireless Personal Communications 114.3 (2020): 2043-2062.

[9] Priyadarshi, Rahul, et al. "Three-level heterogeneous clustering protocol for wireless sensor network." Microsystem Technologies 26.12 (2020): 3855-3864.

[10] Sivasankarareddy, V., and G. Sundari. "Survey on wireless sensor networks: Energy-efficient optimization routing algorithms." Indonesia. J. Electr. Eng. Comput. Sci 19.2 (2020): 756-765.

[11] Qi, Nanjian, et al. "Comprehensive optimized hybrid energy storage system for long-life solar-powered wireless sensor network nodes." Applied Energy 290 (2021): 116780.

[12] Jurado-Lasso, F. Fernando, et al. "Energy-aware routing for software-defined multihop wireless sensor networks." IEEE Sensors Journal 21.8 (2021): 10174-10182.

[13] Yadav, Rakesh Kumar, and Rajendra Prasad Mahapatra. "Energy-aware optimized clustering for hierarchical routing in a wireless sensor network." Computer Science Review 41 (2021): 100417.

[14] Luo, Junhai, et al. "A survey of routing protocols for underwater wireless sensor networks." IEEE Communications Surveys & Tutorials 23.1 (2021): 137-160.

[15] Das, Indrani, Rabindra Nath Shaw, and Sanjoy Das. "Analysis of energy consumption of energy models in wireless sensor networks." Innovations in Electrical and Electronic Engineering. Springer, Singapore, 2021. 755-764.

[16] Jain, Deepika, Piyush Kumar Shukla, and Sunita Varma. "Energy-efficient architecture for mitigating the hot-spot problem in wireless sensor networks." Journal of Ambient Intelligence and Humanized Computing (2022): 1-18.

[17] Yao, Yin-Di, et al. "Energy-Efficient Routing Protocol Based on Multi-Threshold Segmentation in Wireless Sensors Networks for Precision Agriculture." IEEE Sensors Journal 22.7 (2022): 6216-6231.

[18] Akram, Junaid, et al. "Using Adaptive Sensors for Optimised Target Coverage in Wireless Sensor Networks." Sensors 22.3 (2022): 1083.

[19] Akram, Junaid, et al. "Using Adaptive Sensors for Optimised Target Coverage in Wireless Sensor Networks." Sensors 22.3 (2022): 1083.

[20] Jain, Deepika, Piyush Kumar Shukla, and Sunita Varma. "Energy-efficient architecture for mitigating the hot-spot problem in wireless sensor networks." Journal of Ambient Intelligence and Humanized Computing (2022): 1-18.

[21] Yao, Yin-Di, et al. "Energy-Efficient Routing Protocol Based on Multi-Threshold Segmentation in Wireless Sensors Networks for Precision Agriculture." IEEE Sensors Journal 22.7 (2022): 6216-6231.

[22] Akram, Junaid, et al. "Using Adaptive Sensors for Optimised Target Coverage in Wireless Sensor Networks." Sensors 22.3 (2022): 1083.

[23] Akram, Junaid, et al. "Using Adaptive Sensors for Optimised Target Coverage in Wireless Sensor Networks." Sensors 22.3 (2022): 1083.