ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(8), DOI: 10.17485/ijst/2016/v9i8/87961, February 2016* ISSN (Online) : 0974-5645

Efficient 2-level Energy Heterogeneity Clustering Protocols for Wireless Sensor Network

R . Shantha Selva Kumari[1*], A. Chithra[2] and M. Balkis Devi[3]

[1]Department of ECE, Mepco Schlenk Engineering College, Sivakasi - 626005, Tamil Nadu, India; r_sskp@yahoo.com
[2]Department of ECE, K.LN. College of Information Technology, Madurai - 630612, Tamil Nadu, India; a_chithira@yahoo.com
[3]Communication and Networking, K.L.N. College of Information Technology, Madurai - 630612, Tamil Nadu, India; balkisdevi19@gmail.com

Abstract

Background/Objectives: Wireless Sensor Network consists of a large number of sensor nodes that are randomly deployed in inaccessible areas where battery replacement or recharging is not possible. Hence energy consumption is a major issue in these networks. Clustering is a key technique that increases the battery lifetime. The sensor networks can be homogeneous or heterogeneous. In heterogeneous network, the nodes have different resource heterogeneity like link and computation and energy. Lot of work has been done on energy heterogeneity to increase the network lifetime. **Methods/Statistical Analysis:** This paper analyses the two level energy heterogeneity protocols. The two level energy heterogeneity protocols with normal and advance nodes prove to have better network lifetime and stability period than the homogeneous protocols like LEACH. Findings: Out of the heterogeneous protocols, ZSEP has better network lifetime, throughput and stability period than SEP and DEEC. But though the lifetime of LEACH is higher than SEP, the protocol has smaller stability period and throughput. **Improvements/Applications:** LEACH is a homogeneous protocol while SEP, ZSEP, DEEC are heterogeneous protocols. This paper analyzes the performance of LEACH, SEP, ZSEP and DEEC. Heterogeneous networks are used to monitor hostile environments with longer network lifetime and stability period.

Keywords: Clustering, Energy Efficient, Heterogeneity, Network Lifetime, Wireless Sensor Network

1. Introduction

Wireless Sensor Network (WSN) is made up of a large number of battery powered sensor nodes. These nodes have limited battery energy which is not rechargeable or replaceable[1]. But technological development and advancement in wireless communication has enabled WSN to have wide applications in hostile environments. WSN can operate on unattended harsh environments in which human-in-the-loop monitoring scheme are risky or not feasible. In WSN, sensor nodes are randomly deployed in the sensing field to measure the physiological parameters like temperature and pressure[2]. As these sensor nodes are battery limited thousands of nodes have been deployed. Hence managing such large networks require scalability and efficient management strategies. A good number of researches are going on the energy consumption of sensor nodes. The sensor network can be homogeneous or heterogeneous.

2. Clustering

Clustering is a technique where nodes are grouped into clusters[3] and every cluster has a Cluster Head (CH). Every cluster member forwards the sensed data to the CH[4,5]. The CH coordinates the data gathering and aggregates the data in a particular cluster. Clustering reduces energy consumption and increases life time of the network. Figure 1 shows the clustered architecture of Wireless Sensor Network with the Base Station (BS) at the center.

** Author for correspondence*

2.1 Why Clustering is required in WSN?

Cluster architecture increases the spatial reuse of resources and guarantees performance achievement and system capacity. These clusters may be overlapping or non-overlapping and equal or unequal in size. CHs form the virtual backbone for inter cluster routing.

2.2 Advantages of Clustering[6]

- Clustering reduces the routing table size stored in individual nodes.
- It conserves communication bandwidth.
- Prolongs network lifetime by performing data fusion and aggregation.
- It improves the scalability of the network as it minimizes the central organization and promotes local decisions.

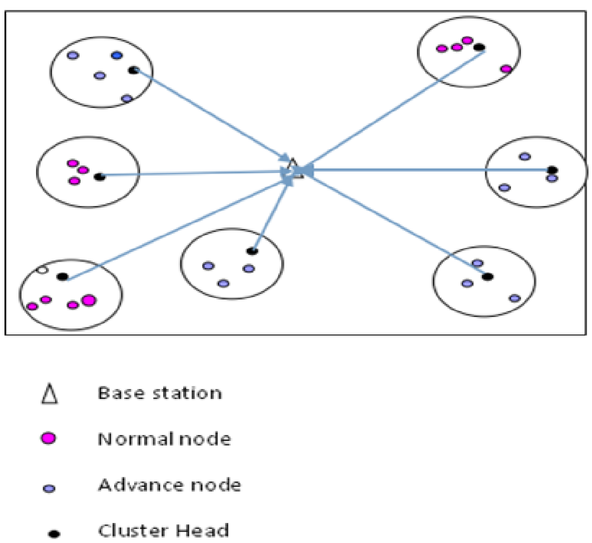

Figure 1. Clustered architecture of Wireless Sensor Network with Base Station at the center.

The CH selection strategy may be classified as deterministic, adaptive and hybrid[7,8].

2.2.1 Deterministic Scheme

Here the CHs are selected based on the attributes like Node – Id and Node degree.

2.2.2 Adaptive Scheme

In this scheme, the CHs are selected based on the resource information like residual energy, energy dissipated during last round and initial energy. The adaptive scheme is further classified based on the initiation of the CH selection. They are Base Station assisted or self organized i.e. Probabilistic. The probabilistic is further divided into fixed parameter or resource adaptive.

2.3 Need for Heterogeneity

Wireless Sensor Network can be homogenous or heterogeneous. In homogeneous network, all the sensor nodes have the same capabilities in terms of energy, computation and storage. In heterogeneous network, the nodes have different resources. They are classified as link, computational and energy heterogeneity[9]. Computational heterogeneity nodes have more powerful processor with higher computational capability than others while link heterogeneity nodes have better bandwidth and energy heterogeneity nodes are line powered and we can replace the batteries. The energy heterogeneity has proved in giving better lifetime.

3. Prepare Energy Model

A fixed network which includes sensor nodes and Base Station is taken into consideration in this paper. It is assumed that the energy consumption of the sensor is due to the radio transmission and reception. The radio model stated in[10] as in Figure 2 is used.

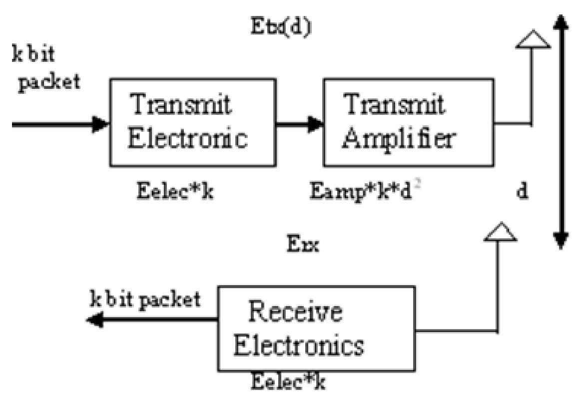

Figure 2. Energy model of sensor node.

The energy consumed in transmitting one message of size 'k' bits over a transmission distance 'd 'is given by:

$$Etx(k,d)=k(Eelec+Ramp*d^{\lambda}) \quad (1)$$

Where:

K = Length of the message.

D = Transmission distance between transmitter and receiver.

Eelec = Electronic energy.

Eamp = Transmitter amplifier.

λ = Path loss component ($2 \leq \lambda \leq 4$).

The energy consumed in the message reception is given by:

$$Erx = Eelec * k \quad (2)$$

Hence from (1) and (2) the total energy consumption when the sensor receives a message and forwards it over a distance d is given by:

$$Etot(d) = k(Eelec + Eampd^{\lambda}) \quad (3)$$

4. LEACH (Low Energy Adaptive Clustering Protocol)

LEACH[10] is a homogeneous hierarchical clustering protocol. The key features of LEACH are:

- Adaptive clustering and randomized rotation of CHs.
- Data aggregation reduces the global communication.
- Cluster setup and control is done by local coordination and control.
- Application specific data processing.

In LEACH, nodes randomly elect themselves as CH. The data communication in this protocol is based on single-hop communication model[11]. The operation is broken into rounds. In advertisement phase, all the cluster heads transmit with same energy using CSMA protocol. In the setup phase, clusters are organized which constitute the steady state phase and data transfer phase. Since LEACH is a homogeneous network it does not conserve the heterogeneous nodes in terms of initial energy. The energy saving scheme is not effective and in addition LEACH depends only on the spatial density of the sensor network.

5. SEP (Stable Election Protocol)

This is a two level energy heterogeneity protocol with normal and advanced nodes deployed randomly in the network field as in Figure 3. SEP[12] is based on weighted election probability and a node becomes CH depending on the initial energy in every node. The sink is located at the center of the field. In SEP the probability of the death of the normal node is higher than the probability of the death of the advanced node. The advanced nodes alone are alive during the last rounds as they are nearer to the base station. SEP provides longer stability period and higher throughput to the base station than LEACH.

FAIR protocol is obtained when m = 1in SEP.

$$Pnrm = \frac{Popt}{1+am} \quad (4)$$

$$Padv = \frac{Popt(1+a)}{1+am} \quad (5)$$

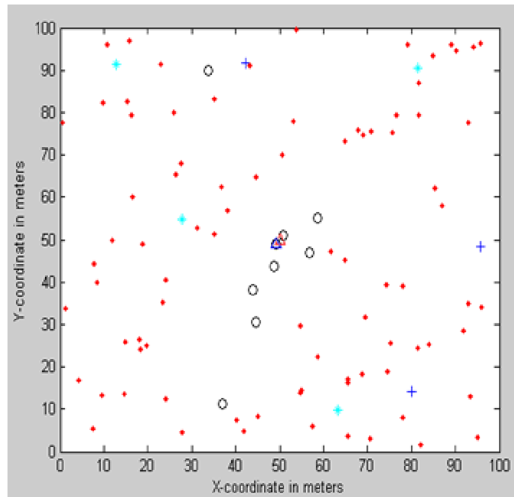

Figure 3. Network architecture of SEP.

Dead node.

Normal node (Alive).

Advance node.

+ Cluster head.

6. ZSEP (Zone Stable Election Protocol)

ZSEP[13] is a two level energy heterogeneity algorithm which uses two techniques to transmit data to the Base Station. The normal nodes transmit data directly to the Base Station and the advanced nodes via CH. In SEP, when the normal and advanced nodes are deployed randomly, the normal nodes with lesser energy than the advanced nodes are placed far away from the Base Station thereby shortening the stability period and decreasing the throughput. This ultimately decreases the efficiency of SEP. To overcome this ZSEP divides the network into three zones: Zone 0, Head Zone 1, Head Zone 2 (Figure 4). The normal nodes deployed in Zone 0 near the Base Station while advanced nodes nearer to the boundaries. The normal nodes sense data and transmit them directly as they are nearer to the Base Station. So, there is no probability of CH selection. As the advanced nodes which are placed farther away from the Base Station are nearer to the boundaries, they transmit through CHs. Hence the probability of selecting a CH is given by:

$$Padv = \frac{Popt(1+am)}{(1+am)} \tag{6}$$

$$T(adv) = \frac{Padv}{1 - Padv(r \bmod (1/Padv))} \tag{7}$$

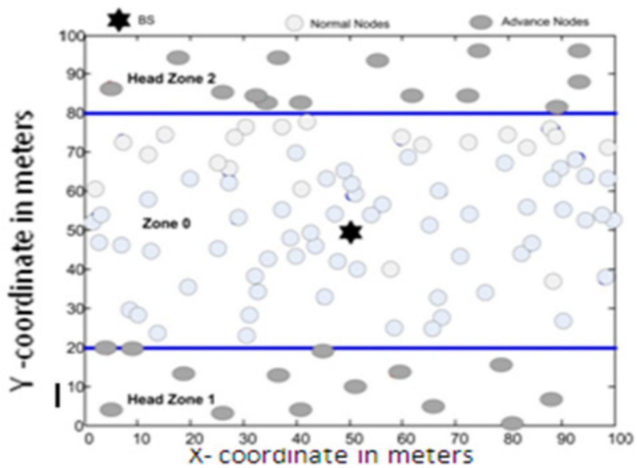

Figure 4. Network architecture of ZSEP.

7. DEEC (Distributed Energy Efficient Clustering)

This is also an energy aware clustering protocol where every sensor node independently elects itself as CH, based on the initial and residual energy of the nodes. Here DEEC[14] uses the average energy of the network as the reference energy in order to control the energy expenditure of the nodes by adaptive approach. Therefore, DEEC need not have any global knowledge of energy at every election round. When a new epoch begins, every node Si, computes the average probability pi, by the total energy E_{total}, while the estimated value R of the lifetime is broadcasted by the BS. Pi is used to calculate the election threshold T (Si). This threshold decides node Si that has to be CH for the round. The nodes with greater initial energy and remaining energy will have more chances of becoming CHs. The drawback in DEEC is: The advanced nodes are punished in the network particularly when the residual energy gets reduced and they become normal nodes. As a result, they die rapidly reducing the network lifetime. DEEC penalizes always the advanced nodes, especially when their residual energy gets depleted and falls in the range of normal node, Therefore the advanced nodes die quickly than the normal nodes. In DEEC all the nodes must have the knowledge of the total energy and the life time of the network. Average energy of the network is used as Si computes the average probability Pi by the total energy E_{total} while the estimated value R of the life time is broadcasted by the BS. Now Pi is used to get the election threshold T (Si). This threshold decides node Si to be a CH in the current round.

$$Pnrm = \frac{PoptEi(r)}{(1+am)Eave(r)} \tag{8}$$

$$Padv = \frac{(1+a) * PoptEi(r)}{(1+am)Eavg(r)} \tag{9}$$

$$T(i) = \begin{cases} \dfrac{Pi}{1 - Pi(r \bmod 1/Pi)} & \text{if Si} \in \text{G} \\ 0 & otherwise \end{cases} \tag{10}$$

8. Simulation and Result

The Wireless Sensor Network field is 100m x 100m and the Base Station is placed at the center of the field at 50m x 50m. Let N be the total number of nodes and 'm' be fraction of N called advanced nodes. The initial energy of normal and advanced are E_0, and E_0 (1+a) where 'a' is the additional energy factors between normal and advanced. The total energy of two level heterogeneous networks is give by[15]:

$$Etotal=N*E_0*m*(1+a)+N*(1-m)*E_0 \tag{11}$$

$$Etotal=N*E0*(1+m) \tag{12}$$

This indicates that there are N* (1-m) normal nodes and N*m advanced nodes. Based on their probability equations the threshold values are calculated for all above algorithms. If the random number chosen by the nodes are less than or equal to the threshold value, that is elected as CH. Figure 5 shows the number of dead nodes in FAIR, LEACH, SEP, ZSEP and DEEC. The stability period of ZSEP has 53.05% enhancement than LEACH, 43.07% enhancement than SEP, 23.26% enhancement than DEEC. Figure 6 shows the number of alive nodes in the rounds of the protocols. Figure 7 shows the through put of SEP, ZSEP and DEEC. Table 1 shows the parameter settings and Table 2 shows the comparison for a = 1 and m = 0.2 for LEACH, SEP, ZSEP and DEEC protocols.

Table 1. Parameter setting

Parameters	Value
Eelec	50nJ
EDA	5nJ
Efs	10pJ/bit/m3
Eamp	0.0013pJ/bit/m2
E0	0.5J
k	4000bits
Popt	0.1

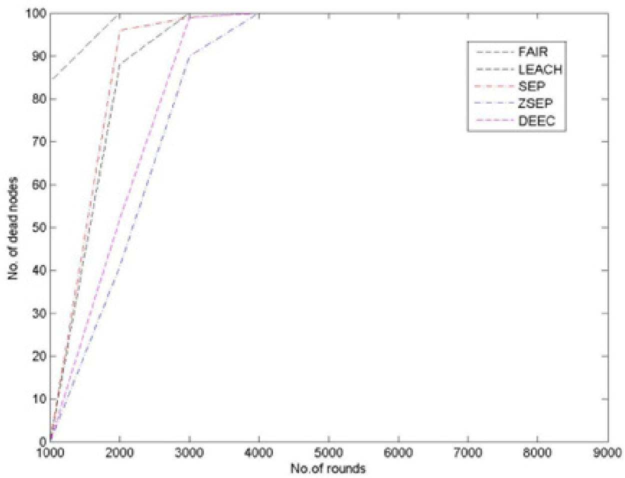

Figure 5. Dead nodes in FAIR, LEACH, SEP, ZSEP, DEEC for a = 1, m = 0.2.

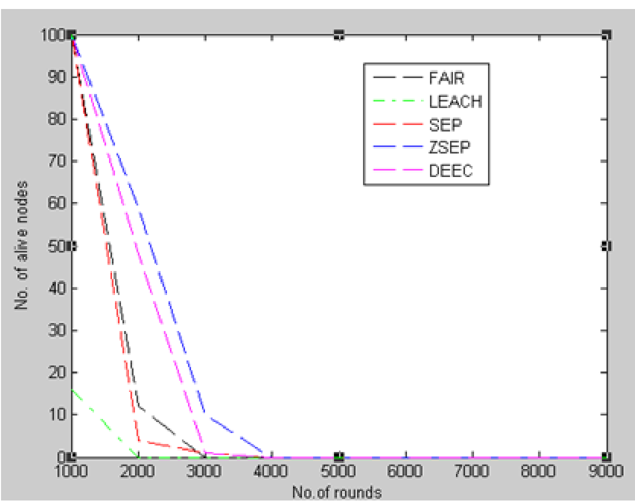

Figure 6. Alive nodes in FAIR, LEACH, SEP, ZSEP, DEEC for a = 1, m = 0.2.

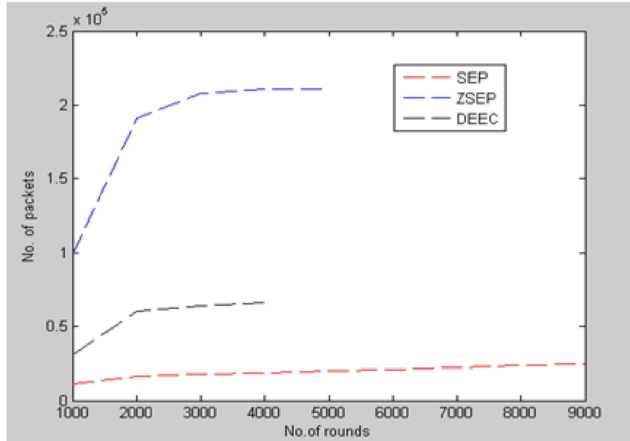

Figure 7. No. of packets transmitted in FAIR, LEACH, SEP, ZSEP, DEEC for a = 1, m = 0.2.

Table 2. Comparison of protocols for a = 1, m = 0.2

Protocol	Stability Period	Network Life time	Throughput
LEACH	1018	4685	1.90X104
SEP	1089	3005	1.9X104
ZSEP	1558	4119	2.11X105
DEEC	1264	3033	6.61X104

However the network lifetime of ZSEP is more than SEP and DEEC. But it is lesser compared to LEACH which does not have any weighted probability as in the rest of the protocols. ZSEP is 37.07% more in network lifetime than SEP and 35.81% more than DEEC. The throughput is also higher in ZSEP compared to SEP, DEEC and LEACH. Since in ZSEP, the data transmission is direct for normal and via CH for advanced nodes. As the normal nodes packets are not aggregated by the CH, they are transmitted directly to the BS and the through put is higher for ZSEP compared to the rest of the protocols. Figure 8 compares the stability period and the network lifetime of FAIR, LEACH, SEP, ZSEP and DEEC.

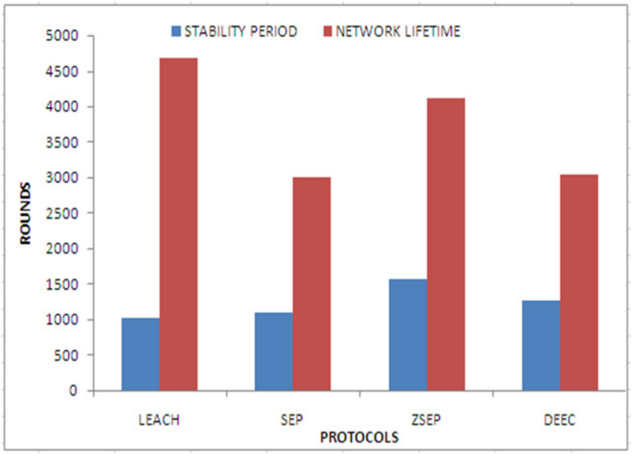

Figure 8. Compares the stability period and the network lifetime of FAIR, LEACH, SEP, ZSEP and DEEC.

9. Conclusion

Sensor networks are used in remote applications for gathering data. Designing efficient clustering protocols for sensor networks to reduce energy consumption and increase network lifetime is important. In this paper we have compared the performance of two level energy heterogeneity protocols SEP, ZSEP and DEEC have been compared with the homogeneous protocol LEACH. Among the heterogeneous protocols ZSEP has better stability period and network than SEP and DEEC as the nodes are deployed efficiently based on their initial energy levels. The throughput of ZSEP is also higher because the normal nodes transmit directly to the BS and not through CH.

10. References

1. Akyildiz F, Su W, Sankarasubramaniam Y, Cayici E. A survey on sensor networks. IEEE Communications Magazine. 2002 Aug; 40(8):102–14.
2. Toghian M, Morogan MC. Suggesting a method to improve encryption key management in Wireless Sensor Networks. Indian Journal of Science and Technology. 2015 Aug; 8(19):1–17.
3. Mishra N K, Jain V, Sahu S. Survey on recent clustering algorithms in Wireless Sensor Networks. International Journal of Scientific and Research Publications. 2013 Apr; 3(4):1–4.
4. Singh SP, Sharma SC. A survey on cluster based routing protocols in Wireless Sensor Network. Science Direct. Procedia Computer Science. 2015; 45:687–95.
5. Syed SA, Kumaranand TS, Ahmed AS. Energy efficiency distributed routing algorithm based on HAC clustering method for WSN. Indian Journal of Science and Technology. 2014 Nov; 7(S7):66–75.
6. Abbasi AA, Younis M. A survey on clustering algorithms for Wireless Sensor Networks. Computer Communications. 2007 Oct; 30(14-15):2826–41.
7. Deosarkar BP, Yada NS, Yadav RP. Cluster head selection in clustering algorithms for Wireless Sensor Networks: A survey. Proceedings of the International Conference on Computing, Communication and Networking; Virgin Islands, USA. 2008 Dec 8-10. p. 1–8.
8. Ramesh K, Somasundaram K. A comparative study of cluster head selection algorithmsin Wireless Sensor Networks. IJCSES. 2011 Nov; 2(4):153–64.
9. Katiyar V, Chand N, Soni S. Clustering algorithms for heterogeneous Wireless Sensor Network: A survey. International Journal of Applied Engineering Research. Dindigul. 2010; 1(2):273–87.
10. Heinzelman WB, Chandrakasan AP, Balakrishnan H. An application specific protocol architecture for wireless microsensor networks. IEEE Transactions on Wireless Communications. 2002 Oct; 1(4):660–70.
11. Shankar T, Karthikeyan A, Sivasankar P, Neha RR. Implementation of smart sleep mechanism and hybrid data collection technique for maximizing network lifetime in WSN's. Indian Journal of Science and Technology. 2015 May; 8(S9):1–8.
12. Smaragdakis G, Matta I, Bestavros A. SEP: A stable election protocol for clustered heterogeneous Wireless Sensor Networks. Massachusetts: Boston University; 2010. p. 1–11.
13. Faisal S, Javaid N, Javaid A, Khan MA, Bouk SH, Khan ZA. Z-SEP: Zonal-stable election protocol for Wireless Sensor Networks. Journal of Basic and Applied Scientific Research. 2013; 3(5):132–9.
14. Qing L, Zhu M, Wang M. Design of a distributed energy-efficient clustering algorithm for heterogeneous Wireless Sensor Networks. Computer Communications. 2006 Aug; 29(12):2230–7.
15. Kaur J, Gaba GS, Miglani R, Pasricha R. Energy efficient and reliable WSN based on improved LEACH-R clustering techniques. Indian Journal of Science and Technology. 2015 Jul; 8(16):1–6. Doi: 10.17485/ijst/2015/v8i16/70896.