Energy Efficient Clustering Protocol using Self Organizing Map in MANET

X. S. Asha Shiny[1*] and R. Jagadeesh Kannan[2]

[1]Department of Computer Science and Engineering, St. Peter's University, Chennai – 600054, Tamil Nadu, India;
ashashiny91@yahoo.in
[2]School of Computing Science and Engineering, VIT University, Chennai – 632014, Tamil Nadu, India;
rjagadeeshkannan@gmail.com

Abstract

Objective: Cluster analysis has been recognized as a key research topic in variety of fields including energy improvement. The main intend of this research is to maximize the lifetime of the network. **Methods:** In this manuscript, an Energy Efficient Clustering Protocol using Self Organizing Map (EECPSOM) in MANETs is designed. This application can cluster sensor nodes based on additional parameters such as energy levels and weight of sensor nodes. Self Organized Mapping (SOM) helps in forming clusters so that nodes with higher energy attract the nearest nodes with low energy levels. **Results:** The proposed method enables us to form energy balanced clusters and distribute the energy consumption in an equivalent manner. **Conclusion:** Simulation results prove that the proposed algorithm minimizes the use of energy and makes it energy efficient so that it can extend the lifetime of the network.

Keywords: Clustering, Energy, Mobile Ad Hoc Network, Self Organized Mapping

1. Introduction

Mobile Ad Hoc Networks (MANETs) are a promising area of application for emergent computing techniques. Traditional distributed-system techniques based on strong consensus and global knowledge are breaking down due to the decentralization and dynamism inherent in these environments. The present approaches to routing in these environments observe individual MANETs as separate from existing infrastructure and view the network nodes as homogeneous. On the other hand, wireless infrastructures are increasingly considered to be a community service that should be provided by local authorities in the network. The portable devices in these environments exhibit various levels of processing like power, mobility and connectivity, but existing approaches do not consider these characteristics. In these networks, mobile nodes collectively learn and self-organize to exploit any fixed or temporary network infrastructure in the environment.

Today, cluster based routing protocols are well known schemes for extending MANETs lifetime. The problem of clustering has been approached in numerous diverse ways such as hierarchical clustering, partitioning clustering, fuzzy clustering, density based clustering and topology based clustering methods. Hierarchical clustering models the data structure into a dendrogram, or tree, of which the root node is considered as the entire data set and the leaf node is a datum. Each level represents a nested clustering result. Popular agglomerative or bottom-up methods include single linkage, complete linkage, average linkage, centroid linkage and variants include Birch, Cure and Chameleon. The common disadvantages of hierarchical clustering are that the determination of the optimum number of clusters heavily depends on the choice of a suitable cluster validity index and the computational cost is expensive since the measure has to be carried out for a variety of possible cluster numbers. The general SOM topology structure is described in Figure 1.

Deployment of ad-hoc network leads to many challenges such as limited battery power, limited bandwidth, multi hop routing, dynamic topology and security. But the major issue in MANET is energy consumption since

Weights (W)

Vectors (V)
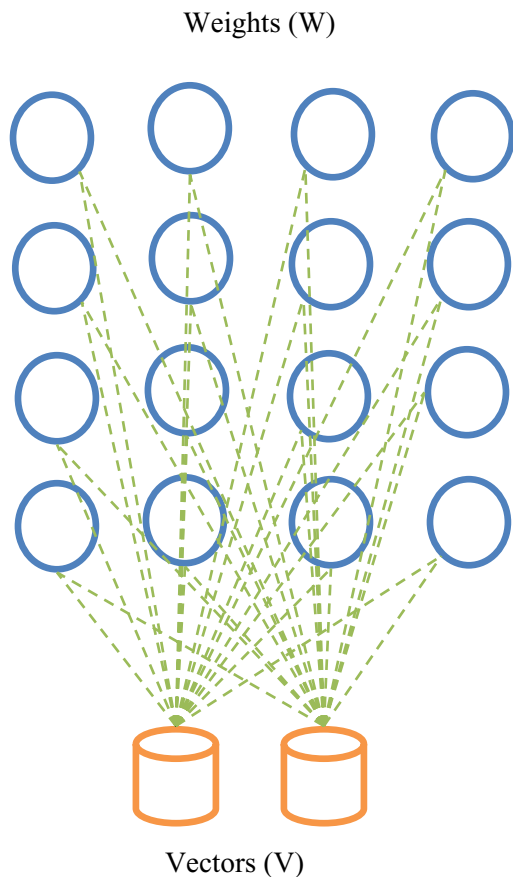
Figure 1. SOM Topology Structure.

nodes are usually mobile and are operated by battery. The failure power in a mobile node affects its functionality and the overall network lifetime performance. To extend and strengthen the life time of the network ad-hoc routing protocol should consider consumption of energy in the network. Efficient minimum energy routing schemes can greatly reduce energy consumption and extends the lifetime of the network. Different routing protocols are designed for MANET which meets some of challenges explained above. But, they do not consider the energy-efficient routing. A scheme using SOM is designed which uses energy efficient routing to route the data.

The rest of this paper is organized as follows. The section 2 will analyze the related works. Section 3 describes the review of SOM. In Section 4, the proposed method Energy Efficient Clustering Protocol using Self Organizing Maps (EECPSOM) in MANET is presented. The section 5 describes the simulation results and comparative performance analysis. Finally the conclusion and future work are presented in section 6.

2. Related Work

In[1], a novel energy efficient cluster formation algorithm based on a multi-criterion optimization technique is presented. Our technique is capable of using multiple individual metrics in the Cluster Head (CH) selection process as input while simultaneously optimizing on the energy efficiency of the individual sensor nodes as well as the overall system in the network. The designed technique is implemented as a distributed protocol in which each node makes its decision based on local information only. The feasibility of this technique is demonstrated with simulation results and it is shown that the designed techniques outperforms all other well known protocols including LEACH, EECS and HEED that results in a significant increase in network life.

Main approaches for energy conservation schemes have been surveyed in[2] for WSN. The energy consumption for a sensor node is listed and major directions to energy conservation were discussed. This paper was concluded with insights for research directions about energy conservation in WSNs.

In[3], the most important possible application of neural networks in reduction of energy consumption of WSNs is presented. Neural Networks are considered as intelligent tools which show great compatibility with WSN's characteristics. According to neural network topologies, another classification for neural network based methods can be accessed such as SOM, Back Propagation Neural Networks, Recurrent Neural Networks, Radial Basis Functions etc.

The paper[4] studies the existing clustering algorithms which have been classified and some representatives in each category are described. After analyzing the strengths and the weaknesses of each category an important characteristic of WSNs is pointed out for further improvement of energy efficiency for WSNs. The important feature of directional data traffic towards the data sink in sensor networks was analyzed and emphasized.

In paper[5], different approaches to clustering are considered for the SOM. The use of hierarchical agglomerative clustering and partitive clustering using K-means are investigated. When the number of SOM units is large to facilitate quantitative analysis of the map and the data similar units need to be clustered or grouped. The two-stage procedure, first using SOM to produce the prototypes that are then clustered in the second stage is found to perform well when compared with direct clustering of the data and to reduce the computation time.

The paper[6] provides a technical overview of MANETs and describes their long term potential. It describes major technical challenges including networking, real-time services and software. MANETs can bring a paradigm shift in the way networks are organized and operated and can even lead to a fundamental change in the relationships between information technology and societal organization. The article also contains an overall description of our long term research project as a design of these concepts called terminodes.

SCAN[7] describes a unified network layer security solution for such networks that protect both routing and data forwarding operations through the same reactive approach. This scheme does not apply any cryptographic primitives on the routing messages. As an alternative, it protects the network by detecting and reacting to the malicious nodes. The local neighboring nodes collaboratively monitor each other and sustain each other while no single node is superior to the others in the network. This method also adopts a novel credit strategy to decrease its overhead as time evolves. This scheme exploits localized collaboration and information cross-validation to protect the network in a self-organized approach. Through both analysis and simulation results, the effectiveness of SCAN is demonstrated in a highly mobile and hostile environment.

The problem of key management in MANET was addressed in[8]. A fully self organized public key management system was proposed that does not rely on any trusted authority or fixed server. It allows users to generate their public-private key pairs to issue certificates and to perform authentication regardless of the network partitions and without any centralized services. A vital feature of this scheme is that key authentication is still possible even when the network is partitioned and nodes can communicate with only a subset of other nodes.

SAPID, 'A Self-organized Agent-based architecture for Power-aware Intrusion Detection' in wireless ad-hoc networks was designed in[9]. The SAPID is segregated into two phases. Based on a power level metric and a hybrid metric that determine the duration and kinds of traffic that can be supported by a network-monitoring node, potential ad-hoc hosts are identified by repetitive training using an Adaptive Resonance Theory module approach.

In paper[10], the case when each node is its own authority is considered and tries to maximize the benefits it gets from the network. More precisely it is assumed that the nodes are not willing to forward packets for the benefit of other nodes in the network. This difficulty may arise in civilian applications of MANETs. In order to stimulate the nodes for packet forwarding a simple mechanism is designed based on a counter in each node. The behavior of the proposed mechanism is studied analytically and by means of simulations and in detail the way in which it could be protected against misuse.

To increase the packet forwarding rate, Residual Energy based Reliable Multicast Routing (RERMR) was proposed[12] based on optimized multicast backbone construction. Initially, the multicast backbone is constructed based on trustable loop and trust factors. The backbone is maintained by means of cluster group members. Reliable path is calculated based on stability of links and residual energy is saved based on signal strength and distance. A Survey of Factors Influencing Network Lifetime in Delay Tolerant Network was proposed in[13].

To improve the network lifetime, Energy aware Data Aggregation with Sink Relocation (EDASR) technique was proposed in[14]. To compute and communicate data to sink, the nodes that are closer to sink will consume additional energy than others. Based on the residual energy sink will relocate to another position. During Energy Aware Data Aggregation (EADA) both the Hop Count (HPC) and shortest distance to reach the sink is considered for clustering.

3. Review of Self Organizing Maps

A SOM or Self Organizing Feature Map (SOFM) is a type of Artificial Neural Network (ANN). It belongs to the type of competitive learning networks and is trained using unsupervised learning to produce a low-dimensional discredited representation of the input space of the training samples called a map. SOM can be used to detect features inherent to the problem.

SOMs operate in two modes: Training and Mapping mode. The first Training mode builds the map using input examples. It is a competitive process called vector quantization. SOM consists of components called nodes or neurons. Associated with each node is a light vector of the same dimension as the input data vectors and a position in the map space. The normal arrangement of nodes is a regular spacing in a hexagonal or rectangular grid. SOM describes a mapping from a higher dimensional input space to a lower dimensional map space. The practice for placing a vector from data space onto the map is to find

the node with the closest light vector to the vector taken from data space and to assign the map coordinates of this node to the vector.

3.1 The SOM Algorithm

The SOM can be studied in 6 steps.

1. Each node's weights are initialized.
2. A random vector is chosen from the set of training data and presented to the network.
3. The Best Matching Unit (BMU) is calculated in (1) using the distance between the input vector and the weights of each node.

$$BMU = \sqrt{\sum_{i=0}^{n}(V_i - W_i)^2} \qquad (1)$$

   where

   V = current input vector.
   W = node's weight vector.
   n = number of weights.

4. The radius of the neighborhood is calculated around the BMU in (2). The size of the neighborhood decreases with each iteration.

$$\sigma(t) = \sigma_0 \exp\left(-\frac{t}{\lambda}\right) \qquad (2)$$

   where

   $\sigma(t)$ = width of the lattice at time t.
   σ_0 = width of the lattice at time t_0.
   t = time.
   λ = time constant

5. Each node in the BMU's neighborhood has its weights adjusted to become more like the BMU. The nodes that are closest to the BMU are altered more than the nodes furthest away in the neighborhood and are given in (3) and (4).

$$W(t+1) = W(T) + \theta(t)L(t)(V(t) - W(t)) \qquad (3)$$

$$\theta(t) = \exp\left(-\frac{dist^2}{2\sigma^2(t)}\right) \qquad (4)$$

   where

   θ = influence rate
   σ = width of the lattice at time t.

6. Repeat from step 2 for enough iteration for convergence.

4. Proposed Method

The existing system[11] used only energy levels and co ordinates of nodes as input parameters and there is no information of direction and no vector is used. In order to use the effectiveness of cluster based routing algorithms in increasing MANETs lifetime, a new Energy Efficient Clustering Protocol using Self Organizing Map (EECPSOM) is presented. The classic idea for topological clustering is developed for extending life time of the network with enough network coverage and with high energy levels. Energy based clustering can create clusters with equivalent energy levels. Therefore in entire network energy consumption would be better balanced. Depending on the weight vector and energy levels, the CH is selected on each round in the network. The steps that come under proposed system are listed below.

4.1 Initialization

The final step is to initialize the random deployment of n number of homogeneous sensor nodes in a given place and with the same energy level in the network.

4.2 Cluster Composition

The second step is the cluster set up or cluster composition. The proposed method uses a two phase clustering method SOM. SOM is selected for clustering because it is able to reduce the dimensions of multi-dimensional input data and visualize the clusters in to a map. The usage of SOM makes use of data pretreatment including dimension reduction, regrouping and visualization gained by SOM. Therefore the sensor nodes are first clustered using the SOM. The variables that are considered as SOM input dataset is x and y co-ordination of every node in network space and the energy level of them.

In order to determine weight matrix, Base Station (BS) has to select m nodes with highest energy in the network. Initially assume that the nodes have equal energy level. So the network space can be partitioned to m regions and the nearest node is selected to center of every region. BS knows the optimal number of clusters and their member nodes. The next step is the selection of suitable CHs for each cluster and assigning appropriate roles to each node.

4.3 Selection of Cluster Head

The third step is to select the CH from the set of nodes in the network. Different parameters can be considered for

selecting a CH in a formed cluster. The main objective of this paper is to develop a protocol with efficient energy. Therefore the sensors having the maximum energy level is selected as the CH. For each and every round, the CH gets selected depending upon the energy level and the weight vector. Once the CH selection process is completed, BS assigns appropriate roles to all sensor nodes in the network. Thus altering CH on each round makes successful transmission of data in the network.

4.4 Data Transmission

The final step is the data transmission in the proposed system. After cluster formation and selecting their related CHs, the data packets are sensed at normal nodes to their corresponding CHs. After applying data aggregation functions to received packets by CHs, then the messages are send to the BS. Since energy is the one of the key parameter, the consumption of energy of all the nodes is computed. The energy consumed for transmission of k bits of data over a distance d is computed by (5), (6) and (7).

$$E_{Tx}(k,d) = E_{Tx}(l) + E_{Tx\_amp}(k,d) \qquad (5)$$

$$E_{Tx}(k,d) = \begin{cases} \mathrm{k}.\mathrm{E}_{elec}(k,d) + k.\varepsilon_{friss}d^2 & if\ d \prec d_{crossover} \\ \mathrm{k}.\mathrm{E}_{elec}(k,d) + k.\varepsilon_{two-ray-amp}d^4 & else \end{cases} \qquad (6)$$

For receiving k bits of data, the consumption of energy is calculated by

$$E_{Rx}(k,d) = \mathrm{E}_{Rx-ele}(k) = k.\mathrm{E}_{elec} \qquad (7)$$

where

E_{elec} = energy of electronic transmission / reception.
k = size of message in bit.
d = distance between transmitter and receiver.
E_{tx_amp} = amplification energy.
ε_{friss} = amplification factor.
$d_{crossover}$ = threshold distance in which transmission factors change.

The above steps are repeated until the average energy level of selected maximum energy nodes show a certain percent (say 25%) reduction for first time reclustering and certain percent (say 10%) for next times.

5. Performance Evaluation

The analysis of this scheme is analyzed by using the Network Simulator (NS2). The NS2 is an open source programming language written in C++ and OTCL (Object Oriented Tool Command Language). NS2 is a discrete event time driven simulator that is used to model the network protocols.

The parameters used for the simulation of the proposed scheme are tabulated in Table 1. The nodes have to be configured as mobile nodes by using the node-config command. The simulation of the proposed scheme has 47 nodes deployed in the simulation area 700×700. The nodes are moved randomly within the simulation area by using the mobility model random waypoint. The nodes are communicated with each other by using the protocol User Datagram Protocol (UDP). The radio waves are propagated by using the propagation model two ray ground. All the nodes receive the signal from all direction by using the Omni directional antenna. The performance of the proposed scheme is evaluated by the parameters packet delivery ratio, packet loss ratio, average delay, throughput, residual energy and lifetime.

5.1 Packet Delivery Rate

Packet Delivery Rate (PDR) is the ratio of number of packets delivered to all receivers to the number of data packets sent by the source node. The PDR is calculated by (8).

$$PDR = \frac{Total\ Packets\ Received}{Total\ Packets\ Send} \qquad (8)$$

The Figure 2 shows the PDR of the proposed scheme EECPSOM is higher than the PDR of the existing method EBC-S. The greater value of PDR means the better performance of the protocol.

Table 1. Simulation parameters of OCAMP.

Parameter	Value
Channel Type	Wireless Channel
Simulation Time	500ms
Number of nodes	47
MAC type	802.11
Traffic model	CBR
Simulation Area	700×700
Transmission range	250m
Network interface Type	Wireless Phy
Mobility Model	Random Way Point

5.2 Packet Loss Ratio

The Packet Loss Rate (PLR) is the ratio of the number of packets dropped to the number of data packets sent. The formula used to calculate the PLR is given in (9).

$$PLR = \frac{Total\ Packets\ Dropped}{Total\ Packets\ Send} \qquad (9)$$

The PLR of the proposed scheme EECPSOM is lower than the existing scheme EBC-S in Figure 3. Lower the PLR indicates the higher performance of the network.

5.3 Average Delay

The average delay is defined as the time difference between the current packets received and the previous packet received. It is measured by (10).

$$Delay = \frac{\sum_{0}^{n} Pkt\ Send\ Time - Pkt\ Recvd\ Time}{Time} \qquad (10)$$

Figure 4 shows that the delay value is low for the proposed scheme EECPSOM than the existing scheme EBC-S. The minimum value of delay means that higher value of the throughput of the network.

5.4 Throughput

Throughput is the average of successful messages delivered to the destination. The average throughput is estimated using (11).

$$Throughput = \frac{\sum_{0}^{n} Pkts\ Received\ (n)\ ^{*}Pkt\ Size}{1000} \qquad (11)$$

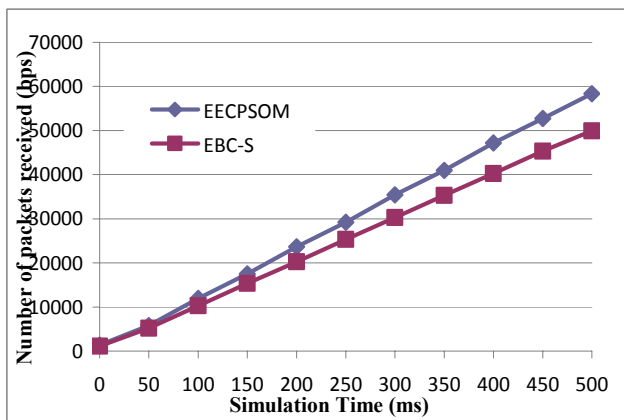Figure 5 shows that proposed scheme EECPSOM has greater average throughput when compared to the existing scheme EBC-S.
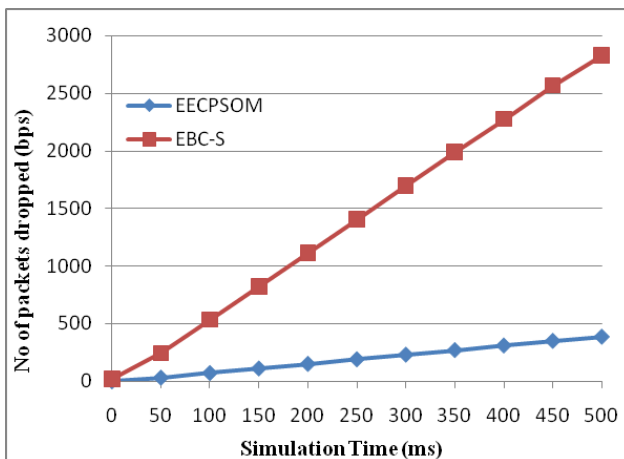

Figure 2.   Packet Delivery Rate.

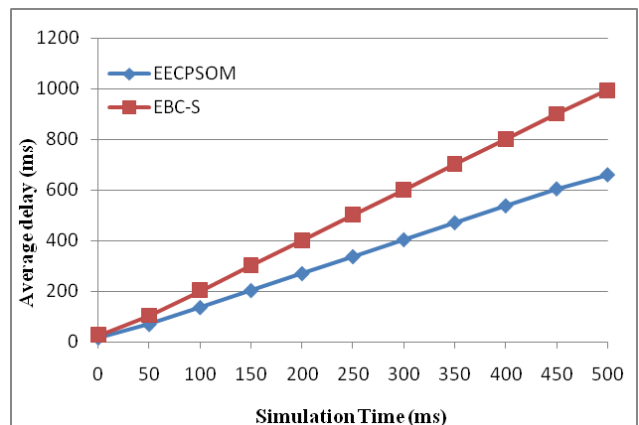**Figure 3.**   Packet Loss Rate.

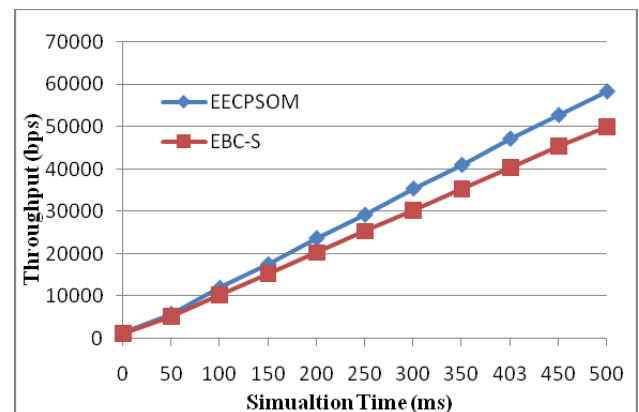**Figure 4.**   Average Delay.

Figure 5.   Throughput.

5.5 Residual Energy

The amount of energy remaining in a node at the current instance of time is called as residual energy. A measure of the residual energy gives the rate at which energy is consumed by the network operations.

Figure 6 shows that the residual energy of the network is better for the proposed scheme EECPSOM when compared with the existing scheme EBC-S.

5.6 Network Lifetime

Network lifetime is defined as the time of first node failure due to the exhaustion of battery power charge during the simulation with a particular routing protocol.

Figure 7 shows that both the EECPSOM and the EBC-S curves fall steeply after the death of the first node. This is a clear indication that there is maximum utilization of node's energy before the entire network dies.
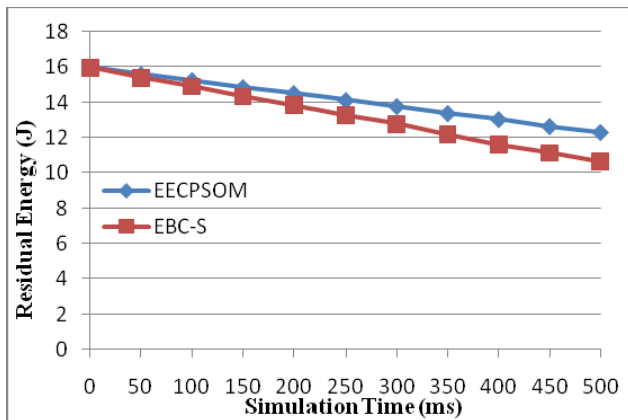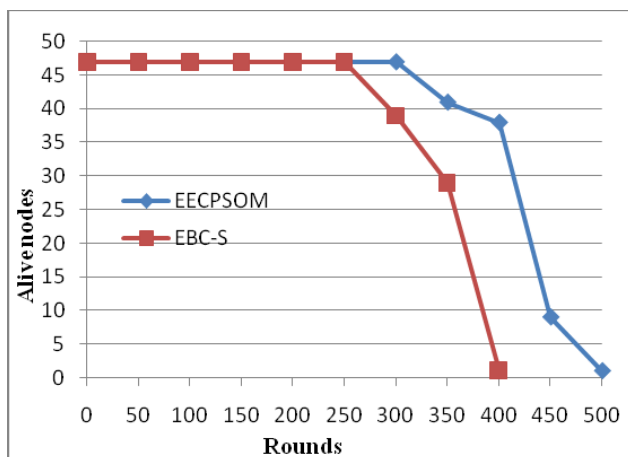

Figure 6. Residual Energy.

Figure 7. Network Lifetime.

6. Conclusion

In this paper, a new Energy Efficient Clustering Protocol using Self Organizing Map (EECPSOM) is proposed in MANETs which applies weight and energy as clustering input parameters and uses the node with maximum energy as wining node. Nodes with maximum energy attract nearest nodes with lower energy in order to create energy balanced clusters. In each rounds the node with highest energy is selected as CH and the data transmission occurs through the same. This proposed method enables to form energy balanced clusters and distribute the energy consumption in an equivalent manner. Simulation results proves that the proposed algorithm minimize the use of energy and makes it energy efficient so that it can extend the lifetime of the network.

7. References

1. Aslam N, Philips W, Robertson W, Kumar S. A Multi-criterion Optimization Technique for Energy Efficient Cluster Formation in Wireless Sensor Networks. In: Information Fusion. Elsevier; 2010.
2. Anastasi G, Conti M, Passarella A. Energy Conservation in Wireless Sensor Networks: A survey. In: Ad Hoc Networks. Elsevier. 2009; 7(3):537–68.
3. Enami N, Moghadam RA, Haghighat A. A Survey on Application of Neural Networks in Energy Conservation of Wireless Sensor Networks. Recent Trends in Wireless and Mobile Networks, WiMo Proceedings. Ankara, Turkey. 2010; 283–94.
4. Wei D, Kaplan SH, Chan HA. Energy Efficient Clustering Algorithms for Wireless Sensor Networks. IEEE Communication Society Workshop Proceeding; 2008.
5. Vesanto J, Alhoniemi E. Clustering of Self Organizing Map. IEEE Transactions on Neural Networks. 2000; 11(3):586–600.
6. Hubaux JP, Gross T, LeBoudec JY, Vetterli M. Toward Self-Organized Mobile Ad hoc Networks. The terminodes project. Communications Magazine. IEEE. 2001; 39(1):118–24.
7. Yang H, Shu J, Meng X, Lu S. SCAN: Self Organized Network-layer Security in Mobile Ad hoc Networks. Selected Areas in Communications. IEEE Journal on. 2006; 24(2):261–73.
8. Capkun S, Buttyan L, Hubaux JP. Self Organized Public-key Management for Mobile Ad hoc Networks. Mobile Computing. IEEE Transactions on. 2003; 2(1):52–64.
9. Srinivasan T, Vijaykumar V, Chandrasekhar R. A Self Organized Agent-based Architecture for Power-aware

Intrusion Detection in Wireless Ad-hoc Networks, Computing and Informatics. International Conference. 2006; 1(6).

10. Butty L, Hubaux JP. Stimulating Cooperation in Self Organizing Mobile Ad hoc Networks. Mob Netw Appl. 2003; 8(5):579–92.

11. Enami N, Moghadam RA. Energy Based Clustering Self Organizing Map Protocol for extending Wireless Sensor Networks lifetime and coverage. Canadian Journal on Multimedia and Wireless Networks. 2010; 1(4).

12. Gopinath S, Nagarajan N. An Optimized Multicast Backbone Routing for Increasing Residual Energy in MANET. Indian Journal of Science and Technology. 2015; 8(13).

13. Jyothi PD, Suriyakala CD. A Survey of Factors Influencing Network Lifetime in Delay Tolerant Network. Indian Journal of Science and Technology. 2015; 8(15).

14. Saranya R, Umamakeswari A. Energy aware data aggregation with sink relocation to improve the network lifetime. Indian Journal of Science and Technology. 2015; 8(S9):312–7.