International Journal of Research in Management, Science & Technology (E-ISSN: 2321-3264)
Vol. 5, No. 1, 103-108, April 17
Available at www.ijrmst.org

An Energy Efficient Evolutionary Algorithm based Clustering Protocol for WSNs

Nitin Mittal[1*], Amanjeet[2#]

[1]Department of Electronics and Communication Engg. Chandigarh University, Mohali, Punjab, India-140413

[2]Department of Physics, Chandigarh University, Mohali, Punjab, India-140413

[#]Department of Applied Sciences, Prannath Pranami Institute of Management & Technology, Hisar, Haryana, India-125001

[1] Corresponding author mittal.nitin84@gmail.com

Abstract- **Wireless sensor networks (WSNs) is an emerging area for the reserchers for its easiness in deployment. WSNs are ad- hoc networks in which small sensor nodes are scattered to form network. These sensor nodes having limited resources in terms of energy, memeoy and power etc. WSNs are rapidly growing technology which is very useful for numerous environment applications. In this research, the main target is on escalassions of network lifetime. The technique of clustering in which aggregation of data is being taken place at the end of cluster head (CH) inclines specific eloquent factors to enlarge life-span of the network. In this paper, a hybrid biogeography based optimization (BBO) with differential evolution (DE), namely BBO/DE is introduced for optimal selection of CHs. BBO is a latest biogeography inspired method, in which migration operator is used for exchanging the data/information among different solutions. On the other hand DE is best known for its global optimization. The hybrid combination of BBO and DE effectively counter-balances the exploitation of BBO followed by exploration of DE. This approach generates the number of best candidate solutions. Further, the simulation results demonstrate that the schemed algorithm outperforms as compared to existing algorithms in terms of system lifetime and energy dissipation.**

Keywords— Wireless Sensor Network, Differential Evolution, Biogeography Based Optimization, clustering, Network Lifetime, Residual energy.

I. INTRODUCTION

Wireless Sensor Network (WSN) is organized by partially spreading sensor nodes and radio signals are used for sharing of information in-between them. These nodes are densely and randomly deployed over the specific area, this specific area have to be monitored to collect the sensing information, and then process this collected information and transferred it to the base station (BS). WSNs can use for numerous applications such as military, commercial, environmental and medical applications [1]. Sensor nodes are basically discriminate by limited resources constraints on the basis of energy, bandwidth and memory. The issue of miniaturizing the energy utilization is a vital fundamental in the architecture of sensor network. Besides this, WSN design also claims some other fundamentals such as cost, fault tolerance, reliability and scalability.

Since a huge number of nodes are grouped together and worked together in a network and these nodes exchange the information/data using direct transmission in which nodes directly send the data to BS. In such case, those nodes will demise out quickly which are located far away from the BS [2]. To deal with this issue, minimum transmission energy technique was developed. In this approach, data is forwarded to the BS via multi-hop. This approach also arises the same problem as in direct transmission. The only difference is that distant nodes remain alive than the nodes nearer to the BS. The reason responsible for early expiry of nodes is burden of all routing data traffic over nodes near to BS. Clustering is an efficient technique which handles all above confrontation to some extent.

A. Clustering in WSNs

Clustering technique effectively reduces the energy consumption and increase the network lifetime, in this nodes are arranged into cluster and there is one leader node known as cluster head (CH). The non-CH nodes sense the sensing area and collect the information and transmitted this information to CH. CH is responsible for further transmitting the information to BS. The numbers of clustering algorithms are developed in order to reduce energy consumption problem in different scenarios of the network.

Heinzelman *et al.* [2] developed an energy efficient low adaptive clustering hierarchy protocol (LEACH). The basic architecture of LEACH is shown in figure 1. In LEACH the sensor nodes arranged into clusters, each and every cluster has their own CH which is responsible for delivering the information i.e. sensed information by leaf nodes to the BS. if the CH is chosen is fixed throughout the lifetime of the system, then the CH would die quickly. Thus LEACH, uses randomization process in which randomized rotation of CH is done. LEACH uses TDMA scheduling. In LEACH knowledge of location information is not required. The LEACH protocol operates in terms of rounds. The CHs nodes broadcast their status by sending advertisement message to other nodes. In this manner the load is equally distributed among all nodes. The non-CH nodes choose which cluster it wants to join. This is determined on the basis of minimum energy requirement. Aggregation is data is done by CH and further processed the aggregated data to BS.

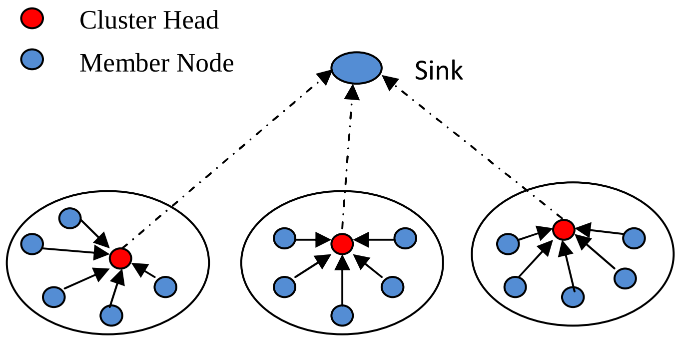

Fig. 1 Clustering in WSNs

In this paper, hybrid BBO/DE based clustering algorithm is developed in order to improve the lifespan of network. The main goal of this work is the formulation of a new objective function. It is tailored to meet the following conflicting goals: maximal stability period, besides this minimizing energy consumption throughout the network lifetime.

The remaining part of the paper is formulated as follows: Section II provides concise explication of the significant papers. The presumptions respecting the radio model is described in section III. The proposed Hybrid BBO/DE based CH election schema is evaluated in section IV and design of fitness function is also analyzed in this section. Next section accommodates the performance evaluation based on simulation results. In next section conclusion and future scope is discussed.

II. RELATED WORK

LEACH [2] is first routing protocols based on clustering where, sensor nodes organized into cluster and CH node is chosen in every cluster. The sensing information is forward to BS through CH. The CH performs the function of aggregation to compress the size of data packet. The aggregated data is sent by CHs to the BS. The decision for election of CH is taken on basis of threshold given in equation 1. The sensor nodes randomly pick the random number between 0 and 1. To become a CH for a particular round, the number chosen by node should be less than below stated threshold value. This threshold is given by:

$$T(n) = \begin{cases} \frac{p}{1-p\left(r \bmod \left(\frac{1}{p}\right)\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Where, r represents the current round, desired percentage of selection of CHs is denoted by P and (P≤5%), the group of nodes which have not elected as CHs in last $\frac{1}{p}$ rounds are represents by G. After the CH selection phase, schedule phase comes, in this phase the CHs allocates the time schedule for data transmission to its member nodes. According to that time schedule leaf nodes must sends the sensed information.

Many routing protocols are introduced in order to increase the performance of LEACH. Centralized version of LEACH is proposed which is opposite of LEACH. In LEACH, the nodes are organized into clusters themselves without any central control but in case of LEACH-C, the nodes are categorized into cluster by BS.

Stable election protocol (SEP) was introduced for clustered heterogeneous WSNs [3]. This protocol helps to improve the stability period of hierarchical clustering process. In this, initial energy consider while election of CHs.. The energy of advanced nodes is greater as compared to normal nodes and has greater probability to become CHs.

Extension of SEP (E-SEP) has been proposed [4], which consider the three-tier node classification. The three tier node hierarchy considers the normal, intermediate and advanced nodes. The key idea behind the election of CHs is their energy levels autonomously. SEP-E improve the network lifetime and also increase the stability period.

An energy efficient heterogeneous clustered (EEHC) [5] scheme is investigated by Kumar *et al.* in which three types of nodes are considered. Nodes under first level are known as normal nodes, second level nodes are advanced node and third level nodes are super nodes. Sensor node becomes CH on the basis of its initial energy with respect to other nodes.

Like EEHC, Enhanced heterogeneous LEACH [6] introduces which deals with CH election in heterogeneous networks. In this, two level of node heterogeneity is introduced. In EHE-LEACH, a fixed distance based threshold is used by each node to choose between direct communications with the BS or cluster based communication. Sensor nodes use direct communication if BS is located nearest to its location otherwise use multihop communication in order to transmit data.

A distributed energy-efficient clustering (DEEC) technique is introduced which consider the two parameters during election of CHs and DEEC considers three level of heterogeneity. It uses the initial energy level and remaining energy level for the election of CHs. [7]. DEEC has longer stability period and it is well suited for multi-level heterogeneous.

A new evolutionary based routing protocol (ERP) is introduced by Bara *et al.* for clustered heterogeneous WSNs [8]. Bio-inspired algorithms extend the network lifetime but reduce the stability period. It deals with problem of routing in clustered based network by designing new fitness function which considers parameters like ratio of intra- cluster distance to and inter- cluster distance and CH count. This protocol helps in increasing network lifetime as well as stability in heterogeneous WSNs.

Hierarchical cluster based routing (HCR) protocol introduced by Hussain *et al.* [9], where selection of CHs depends upon various factors. Genetic algorithm (GA) is used for the optimization process. As the population contains various chromosomes and best chromosomes is used for generation of next population. At the end of round, best fitness chromosome is evaluated and population is updated accordingly. HCR outperforms as compared to other clustering algorithms.

Distance based residual energy efficient stable election Protocol is introduced for both homogenous and heterogeneous WSNs environments [11]. Residual energy consider during CH election but other parameters such as node's respective distance from the BS and the number of successive rounds in which node does not become CH are also considered. Three level of heterogeneity is considered and this protocol increases the network lifetime for both homogeneous and heterogeneous WSNs.

III. ENERGY DISSIPATION RADIO MODEL

The first order radio communication model is used for the calculation of energy consumption at the end of transmitter and receiver. For the execution of radio hardware such as power amplifier and radio electronics, the energy is spent at the end of transmitter. In addition to this, for the execution of radio electronics the energy dissipation at the end of receiver is shown in figure 2.

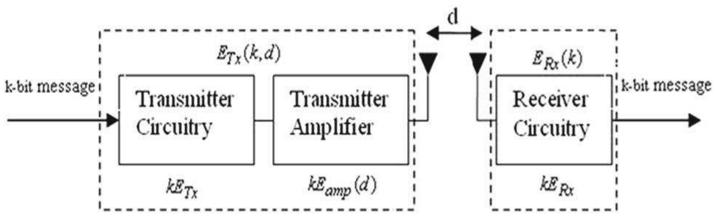

Fig. 2 Energy Dissipation Radio model

Total energy consumption is depends upon distance if the distance between transmitter and receiver is lower as compared to threshold (d_0) value then free space model is used. In case of where the distance exceeds the threshold value, in that case multipath fading model will be used. For the transmission of m bit message the total energy consumption over the distance d is given as:

$$E_{Tx}(m,d) = E_{Tx}(m) + E_{amp}(m,d)$$
$$E_{Tx}(m,d) = mE_{Tx} + kE_{amp}(d) \qquad (2)$$

The term E_{Tx} is radio energy distraction for transmitter and $E_{amp}(d)$ is per bit amplification energy basically proportional to square of distance but in case of where distance exceeds the threshold d_0 (known as crossover distance) then $E_{amp}(d)$ proportional to d^4. $E_{amp}(d)$ is given by

$$E_{amp}(d) = \begin{cases} \epsilon_{friss\_amp}\ d^2 & : d < d_0 \\ \epsilon_{two\_ray\_amp}\ d^4 & : d \geq d_0 \end{cases} \qquad (3)$$

Where $\epsilon_{friss_{amp}}$ is the transmitter amplification parameter for free space model and $\epsilon_{two\_ray\_amp}$ is transmitter amplification parameter for two ray ground reflection model.
The value of d_0 is given by

$$d_0 = \sqrt{\epsilon_{friss\_amp}/\epsilon_{two\_ray\_amp}} \qquad (4)$$

To receive m number of bits, the radio spends energy is

$$E_{Rx}(m) = mE_{Rx} \qquad (5)$$

IV. PROPOSED APPROACH: A HYBIRD BBO WITH DE

A. Biogeography Based Optimization (BBO)

BBO is a recent optimization algorithm introduced by Simon and refined from study of biogeography [11]. The analysis of biological organisms is known as biogeography. The BBO algorithm considers population of individuals (similar to Genetic Algorithm) called habitats (Islands). Comparable to other algorithms such as GA and PSO, the information is exchanged between two solutions using migration operator. The mutation operation is used in which worst habitat is replaced by best habitat in population. The results demonstrate that BBO has best exploitation capability as compared to other bio inspired algorithms.

B. Differential Evolution (DE)

DE is investigated by Price and Stron in 1997 is simple and direct search algorithm which uses the bottom up approach for global optimization problems [12]. Any information/update regarding distance function and population direction is used for exploration in DE. The main advantages of DE are speed, scalability and robustness.

C. *Hybird BBO with DE*

As discussed earlier, BBO is best known for its exploitation for global optimization. In addition to this, DE explores the best search space. On the basis of these assumptions, the terms exploration and exploitation are combined to make hybrid BBO/DE.

1. Hybrid Migration operator

This operator is necessary stride in BBO/DE algorithm which associates the migration operator of BBO followed by DE as characterized in Algorithm 1. The hybrid migration operator considers two assumptions; first the destruction of good solution would be less. Secondly the mutation process of DE is adequate to explore the novel search region and conformation the method to best solution.

2. Boundary Constraints

For the management of Bound-constrained problems, the trial parameters should be emulated back which offend boundary constraints. The following rehabilitation method is used:

$$X(i) = \begin{cases} l_i + rand_i[0,1] \times (v_i - l_i) & if\ X(i) < l_i \\ u_i + rand_i[0,1] \times (v_i - l_i) & if\ X(i) > v_i \end{cases} \quad (6)$$

$rand_i[0,1]$ is a random variable ranges between 0 and 1.

3. Main procedure

The hybrid BBO with DE scheme is composed by associating the hybrid migration operator followed by DE and the whole procedure is described in algorithm 1. As compared to DE, BBO/DE requires additional computational cost for sorting the habitats and also for calculation of migration rates. Besides this, BBO/DE is adequate for exploring the new search space and the mutation process is carried out using mutation operator of DE. Migration method is used for exploitation of population.

Algorithm 1 Procedure for BBO/DE

1. Generate the initial population P
2. Calculate the fitness value for each individual in P
3. while the halting criterion is not fulfilled *do*
4. Population is sorted from worst to best
5. Mapping of fitness to the number of species is done for each individual,
6. Calculate the immigration rate λ_i and the emigration rate μ_i
7. Customize the population with the hybrid migration operator
8. for i= 1:NP *do*
9. Select three random vector $r_1, r_2 and\ r_3$ from population where $r_1 \neq r_2 \neq r_3 \neq i$
10. $j_{rand} = randint(1, D)$
11. for $j = 1\ to\ D\ do$
12. If $rand(0,1) < \lambda_i$ then
13. If rand $(0,1) < CR\ or\ j = j_{rand}$ then
14. $U_i(j) = X_{r1}(j) + F\left(X_{r_2}(j) - X_{r_3}(j)\right)$
15. else
16. Select X_k with probability μ_k
17. $U_i(j) = X_k(j)$
18. end *if*
19. else
20. $U_i(j) = X_i(j)$
21. end *if*
22. end *for*
23. end *for*
24. for i= 1:NP
25. calculate the value of offspring U_i
26. if U_i is better than P_i then
27. $P_i = U_i$
28. end *if*
29. end *for*
30. end *while*

D. PROPOSED FITNESS FUNCTION FOR HYBIRD BBO/DE

In this section, fitness function is defined for the selection of CHs in BBO/DE. The vital goal of the fitness function is to emend the intra cluster distance, inter cluster distance, residual energy and head count. The fitness function denoted as f for the i^{th} individual is described below:

$$f = min \sum_{i=1}^{4} a_i f_i \quad (7)$$

Subject to $\sum_{i=1}^{4} a_i = 1$

$$f_1 = \frac{\sum_{i=1}^{CHs} \sum_{\forall\ n \in C_i} d(n, CH_j)}{\min_{C_i \neq C_j} \{d(CH_i, CH_j)\}} \quad (8)$$

$$f_2 = \frac{\sum_{i=1}^{N} E(i)}{\sum_{j=1}^{CHs} E(j)} \quad (9)$$

$$f_3 = \left[\max_{i=1,2\ldots N}(m_i + 1)\right] \quad (10)$$

$$f_4 = number\ of\ CHs \quad (11)$$

The fitness function f represents the ratio of intra cluster distance to the inter cluster distance, where CHs denotes the number of CHs in current round, Cj is the i^{th} cluster acclaimed with cluster head CHi and n represents the total number of member nodes in particular cluster C_i. f_2 define the ratio of initial energy of N nodes to the current energy of CHs in the current round. The f_3 function defines the number of transfer time of cluster which consist m_i transfer from node to CH and one transfer from CH to the BS. In this way habitat with best fitness function is selected as the global best solution and sensor node corresponding to best fitness function value is selected as the CH for the current round.

V. SIMULATON RESULTS

The performance of the Hybrid BBO/DE is examined using MATLAB. The 100m×100m network area is considered and BS is positioned at center i.e. 50m×50m. Important parameter which considered during the simulation are describes in Table 1. The performance of Hybrid BBO/DE is evaluated in terms

International Journal of Research in Management, Science & Technology (E-ISSN: 2321-3264)
Vol. 5, No. 1, 103-108, April 17
Available at www.ijrmst.org

of life expectancy of network and energy dissipation of network against ERP, HCR, BBO and DE algorithm.

Table 1 Simulation parameters

parameter	value
Total number of nodes	100
Probability for CH election	0.05
Initial energy	0.5J
Network Dimensions	100m×100m
Locality of Base station	(50,50)
Radio electronics energy (E_{elec})	50 nJ/bit
Energy for Data aggregation (E_{DA})	5 nJ/bit
ϵ_{fris_amp}	100 pJ/bit/m^2
$\epsilon_{two\_ray\_amp}$	0.0013pJ/bit/m^4

Figures 3 and 4 show the result of ERP, HCR, BBO, DE and BBO/DE in premise of number of alive nodes per round and remaining average energy of node. In hybrid BBO/DE, the stability period is larger as correlated to BBO and DE as first node demise after a substantially higher number of rounds. The reason behind this is optimal selection of CH which not considers only residual energy of node but also considers some other important parameter such as ratio of intra cluster distance to inter cluster distance, head count. The energy utilization is counterbalanced among sensor nodes. The proposed algorithm is augmented in as compared with above said protocols.

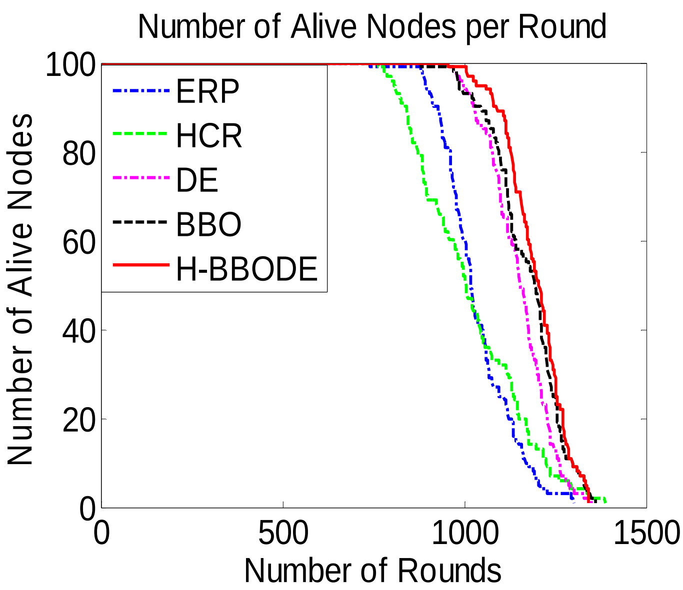

Fig. 3 The number of alive nodes per round.

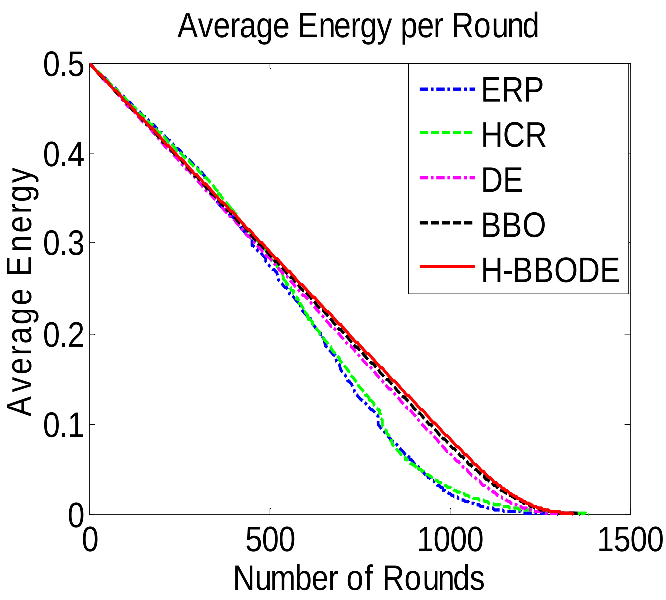

Fig. 4 Average remaining energy per round.

The network lifetime is analyzed in terms first node dies (FND), half node dies (HND) and last node dies (LND). WSNs is application specific protocol, in some of the application whole network should be alive. But in some applications FND should have greater value.

Table 2 Comparison of network lifetime

protocol	FND	HND	LND
ERP	741	1019	1301
HCR	763	1004	**1387**
BBO	917	1174	1377
DE	843	1150	1302
BBO/DE	**993**	**1192**	1344

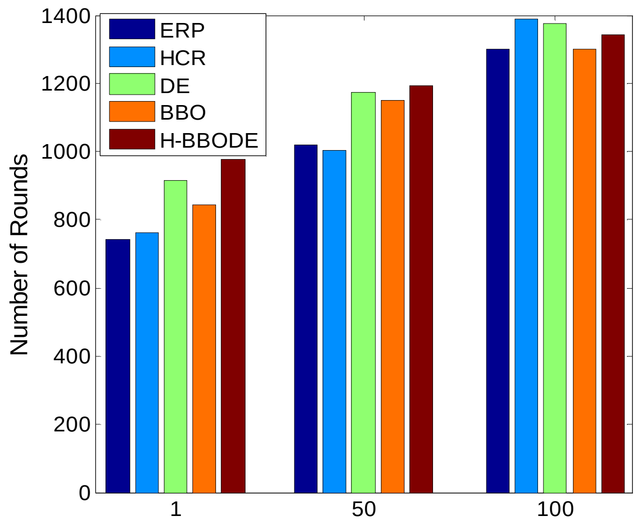

Fig. 5 Performance results for ERP, HCR, DE, BBO and BBODE

The proposed Hybrid BBO/DE outperforms other and single hop communication is used for data transmission in between CH and BS. As correlated to ERP, HCR, BBO and DE, the stability period is larger. The stability period describes that first node demise after a substantially higher number of rounds.

VI. CONCULSION AND FUTURE WORK

In WSNs, the extensive concerns in designing of routing protocols is extend the stability period, reduce the energy consumption and extend lifetime of system.. In Hybrid BBO/DE, CH selection leans on the residual energy of node, head count and also on ratio of intra cluster distance to inter cluster distance. In this way, utilization of energy reduces to some extent and stability period for FND increases. Hybrid BBO/DE is a threshold based clustering protocol, is appropriate for time critical applications that decrease the energy utilization and upgrade the lifetime of network, it make use of single hop communication to BS from distant CHs. The simulation results indicate that Hybrid BBO/DE is outperforms as compared to ERP, HCR, BBO and DE.

Future work comprises the exertion of sensor mobility into network. Further, multi-hop communication may be applied for data transmission between BS and CH.

References

[1] S. W. S. Y. C. E. Akyildiz, I. F.: Wireless sensor networks: A survey. In Elsevier Sci. B.V. Computer networks 38, vol 1, no. 4: pp. 393–422 (2000).

[2] Heinzelman, W.B., A.P. Chandrakasan, and H. Balakrishnan. 'An Application-Specific Protocol Architecture for Wireless Microsensor Networks'.*IEEE Transactions on Wireless Communications* 1.4 (2002): 660-670.

[3] G. Smaragdakis, I. Matta, A. Bestavros, SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks, in: Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), 2004.

[4] Aderohunmu, Femi A., Jeremiah D. Deng, and Martin Purvis. 'Enhancing Clustering In Wireless Sensor Networks With Energy Heterogeneity'. *International Journal of Business Data Communications and Networking* 7.4 (2011): 18-31.

[5] Kumar, Dilip, Trilok C. Aseri, and R.B. Patel. 'EEHC: Energy Efficient Heterogeneous Clustered Scheme For Wireless Sensor Networks'. *Computer Communications* 32.4 (2009): 662-667.

[6 Kumar, Dilip. 'Performance Analysis Of Energy Efficient Clustering Protocols For Maximising Lifetime Of Wireless Sensor Networks'. *IET Wireless Sensor Systems* (2013): 9–16.

[7] Qing, Li, Qingxin Zhu, and Mingwen Wang. 'Design Of A Distributed Energy-Efficient Clustering Algorithm For Heterogeneous Wireless Sensor Networks'. *Computer Communications* 29.12 (2006): 2230-2237.

[8] Attea, Bara'a A., and Enan A. Khalil. 'A New Evolutionary Based Routing Protocol For Clustered Heterogeneous Wireless Sensor Networks'. *Applied Soft Computing* 12.7 (2012): 1950-1957.

[9] A.W. Matin, S. Hussain, Intelligent hierarchical cluster-based routing, in: Proceedings of the international workshop on mobility and scalability in wireless sensor networks (MSWSN) in IEEE international conference on Distributed Computing in Sensor Networks (DCOSS), pp. 165–172 (2006).

[10] Mittal, Nitin, and Urvinder Singh. 'Distance-Based Residual Energy-Efficient Stable Election Protocol For WSNs'. *Arab J Sci Eng* 40.6 (2015): 1637-1646.

[11]Simon, D. 'Biogeography-Based Optimization'. *IEEE Transactions on Evolutionary Computation*12.6 (2008): 702-713.

[12] Storn, R., Price K.: Differential Evolution – A Simple and Efficient Heuristic for Global Optimization over Continuous Spaces, Journal of Global Optimization, pp 341–359 (1997).