ENERGY EFFICIENT AGGREGATION WITH DIVERGENT SINK PLACEMENT FOR WIRELESS SENSOR NETWORKS

Prakashgoud Patil[1] and Umakant P Kulkarni[2]

[1] Master of Computer Applications
B.V.B.College of Engineering & Technology, *Hubli-580031, Karnataka, India*
prpatilji@gmail.com
[1]Computer Science & Engg. Department
S. D. M. College of Engineering and Technology, Dharwad, Karnataka India
upkulkarni@yahoo.com

ABSTRACT

In WSN the data aggregation is a means for condensing the energy requirement by reducing number of transmission by combining the data and sending the final required result to the base station. The lifetime of the WSN can be improved by employing the aggregation techniques. During the process of aggregation the numbers of transmission are reduced by combining the similar data from the nearby areas. By using the clustering technique and aggregating the correlated data greatly minimize the energy consumed in collecting and disseminating the data. In this work, we evaluate the performance of a novel energy efficient cluster based aggregation protocol (EECAP) for WSN. The main focus in this proposed work is to study the performance of our proposed aggregation protocol with divergent sink placements such as when sink is at the centre of the sensing field, corner of the sensing field or at a location selected randomly in the sensor field. We present experimental results by calculating the lifetime of network in terms of number of sensing rounds using various parameters such as – average remaining energy of nodes, number of dead nodes after the specified number of sensing rounds. Finally the performance of various aggregation algorithms such as LEACH, SEP and our proposed aggregation protocol (EECAP) are compared with divergent sink placements. The simulation results demonstrates that EECAP exhibits good performance in terms of lifetime and the energy consumption of the wireless sensor networks and which can be as equally compared with existing clustering protocols.

KEYWORDS

Wireless Sensor Network (WSN); Clustering; Cluster Head (CH); Aggregation; Energy Metrics.

1. INTRODUCTION

In WSN the data aggregation is a means for condensing the energy requirement by reducing number of transmission by combining the data and sending the final required result to the base station. The lifetime of the WSN can be improved by employing the aggregation techniques. During the process of aggregation the numbers of transmissions are reduced by combining the similar data from the nearby areas.A sensor node is generally resource constrained with relatively small memory, restricted computation capability, short range wireless transmission-receiver and limited built-in battery power. WSN become increasingly useful in variety of critical applications such as environmental monitoring, smart offices, health care, battle field surveillance and transportation and traffic monitoring. In most applications of sensor networks the nodes are deployed randomly. Sensor nodes will establish a network by communication with the nodes within their radio range. In most applications, it is impossible to replace or recharge battery of sensor nodes. Energy expenditure of sensor nodes has to be done carefully in order to prolong life of sensor network. Clustering with data aggregation is one of the solutions to

DOI : 10.5121/ijasuc.2013.4204

increase lifetime of sensor network.Data aggregation suppresses the duplicate packets and sends combined data to the base station thus it minimizes the transmission and achieves the energy efficiency. It is one of the important technique because it reduces the number of packets transmission, reduce theenergy consumption, increase the network lifetime and increase successful data transmission ratio [1-2].

2. Review on Data Aggregation Techniques

In direct transmission technique every node transmits the data directly to the sink node in WSN. The cost of transmitting data is expensive in the direct transmission and more energy is consumed by each sensor in each rounds. So, in direct transmission technique the nodes die quickly due to their participation in each sensing round [4].In order to solve this problem many clustered based protocols are designed for Sensor Networks [7,8].

The WSN is classified as Homogeneous and Heterogeneous networks based on the types of nodes. All the nodes are identical in the homogeneous networks and Heterogeneous network may consist of different types of nodes [3]. Most of the current clustering algorithms are homogeneous schemes, such as LEACH [7] and SEP [8].

In case of cluster based WSN, every cluster have the cluster head. The cluster head performs data aggregation and it has a capability to transmit data at long distance to reach sink node. In LEACH protocol the energy expenditure in each round is uniform because it selects the cluster head periodically. In LEACH algorithm the cluster head selected based on the probability. The cluster formation by the LEACH may not produce efficient clusters. LEACH improves the system performance lifetime and data accuracy of the network but the protocol has some limitations such as the elected cluster head will be concentrated on one part of the network and clustering terminates in a constant number of iterations. The performance of LEACH is not good in heterogeneous network. SEP [9] is developed for the two level heterogeneous network, which includes two types of nodes called advanced and normal nodes.

3. Wireless Sensor Network Model

The Wireless Sensor Networks(WSN) is a different type of networking in the field of wireless which consist of thousands of autonomoussensor nodes in the sensing field which are spatially distributed to monitor physical or environmental conditions [9-12]. In our design we assumed N number of nodes in M x N network field as shown in Figure 2. The following characteristics are assumed to simplify the WSN model.The nodes are energy constrained devices which runs on limited batteries. In WSN the communication links are symmetric and node are having same capabilities and resources in terms of battery power and processing capabilities. Nodes are deployed in the sensing region.

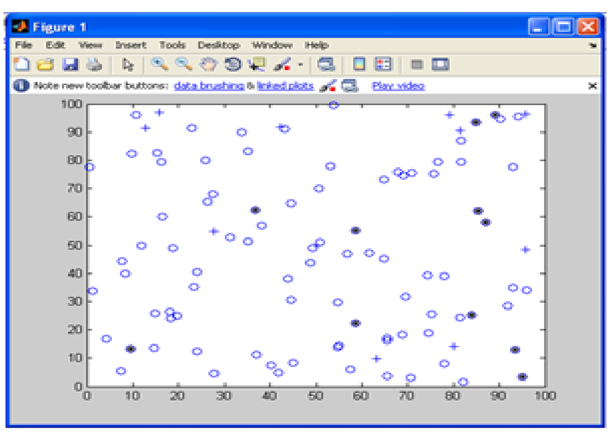


Figure 1 Sensor Network Model

Normally the position of the sink node or base station is at the centre of the field. In our experiment the position of the base station or sink node is divergent. There is one Base Station (BS) which is located at the centre / corner or at any random location of the sensing field. It is assumed that the node senses the environment and sends data in each round.
In this work, we mainly focus on the performance of the proposed algorithm for different sink positions. In WSN environment each node senses the environmental parameters and sends data to the sink node. Our aim is to maximize the sensor network lifetime by following the aggregation technique and to analyze the network efficiency in terms of energy when the sink node placed different places.

4. RADIO ENERGY DISSIPATION MODEL

The energy dissipation model is significant in designing WSN. To simulate Wireless Sensor Network most of the authors used free space propagation model in the literature. In WNS, large amount of energy is consumed by the communication subsystem. To minimize the energy requirement, one should need to control the redundant communication using aggregation techniques by avoiding the transmission of redundant data. The energy consumption model used in our work is similar to the energy model proposed by Heinzelmanet. Al [7,8] and is as show in the figure 2.

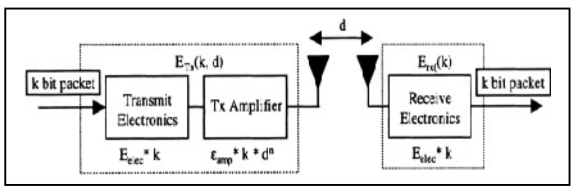


Figure 2 Radio Energy Model

The free space (d^2 power loss) and multipath model (d^4 power loss) were used depending transmitter and receiver distance. The threshold is set for the distance. If the distance is less than the specified value the free space model (E_{fs})is used and multipath model ($E_{amp.}$) is used when the distance between the transmitter and receiver is more than the threshold value. The total energy expenditure to transmit K-bit message at a distance d calculated using equation-1.

$$E_{tx}E(k.d) = \begin{cases} K.E_{elec} + K.E_{fs}d^2 if d < d_0 \\ K.E_{elec} + K.E_{amp.}d^4 if d \geq d_0 \end{cases} \quad (1)$$

Where E_{elec} is the energy spent to operate the transceiver circuit and which depends on factors such as the digital coding, modulation, filtering, and spreading of the signal.Amplifier energy, $E_{fs}d^2$ or $E_{amp.}d^4$, are the energy expenditure of transmitting one bit data to achieve an acceptable bit error rate and is dependent on the distance of transmission in case of free space model and multipath fading model. In simple term, this depends on the distance to the receiver and the acceptable bit-error rate.
Value of threshold distance d_0 is given by equation-2.

$$d_0 = \sqrt{\frac{E_{fs}}{E_{amp.}}} \quad (2)$$

5. OBJECTIVE AND SCOPE

The main objective of this proposed work is to improve upon the existing clustering protocol and propose an optimized algorithm for the clustering in order to prolong network lifetime. Prolonging network lifetime is the way to provide energy efficient WSNs [6]. The main aim of this proposed work is to study the performance of our proposed aggregation protocol with divergent sink placements such as when sink is at the centre of the sensing field, corner of the sensing field or at a location selected randomly in the sensor field.

5.1 Problem formulation

LEACH cluster-heads are stochastically means not deterministically selected. The cluster head selection for the round is based on the random number generated between 0 and 1. The random number generated is compared with a threshold T(n), if the random number is less than the Threshold value then the node will become cluster head for that round.The threshold is set as per the equation-3.

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (3)$$

where G is the set of nodes which are not elected as cluster head in the last r rounds.
P- is the cluster head probability or percentage of node to become CH.
r - Number of the current round. G - Set of nodes that have not been cluster head.
Every node becomes a CH exactly once within 1/p round.

5.2 The limitations of the LEACH protocol

Although energy consumption is a critical problem in WSNs, LEACH does not consider the remaining energy of nodes when selecting CHs. Since CH election is probabilistic, a node with very low energy has a good chance of becoming a CH. When this node dies, the entire cluster is dysfunctional. It is possible that some CHs are located within close proximity of each other. This indicates that CHs are not well distributed in the network. In worst case scenario all CHs may be located near the edge of the network. If cluster heads are selected unfavourably near the edge of the network, in such situations some nodes have to bridge long distance to reach a cluster head. This may result in unfavourable cluster head selection in later rounds

5.3 Proposed Approach

In our proposed approach, we have developed novel aggregation algorithm by modifying the LEACH threshold equation by multiplying with Node Remaining Energy Coefficient (NREC) as given in the equation-9 and 10.

$$NREC = \left[\frac{NRE}{NME} + \left(rs\ div \frac{1}{P}\right)\left(1 - \frac{NRE}{NMAX}\right)\right] \quad (4)$$

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \times NREC \quad (5)$$

Where r is the number of consecutive rounds in which node has not been cluster head.

The flowchart for the proposed protocol is as per the given in figure-3. The following section describes the details of our approach.

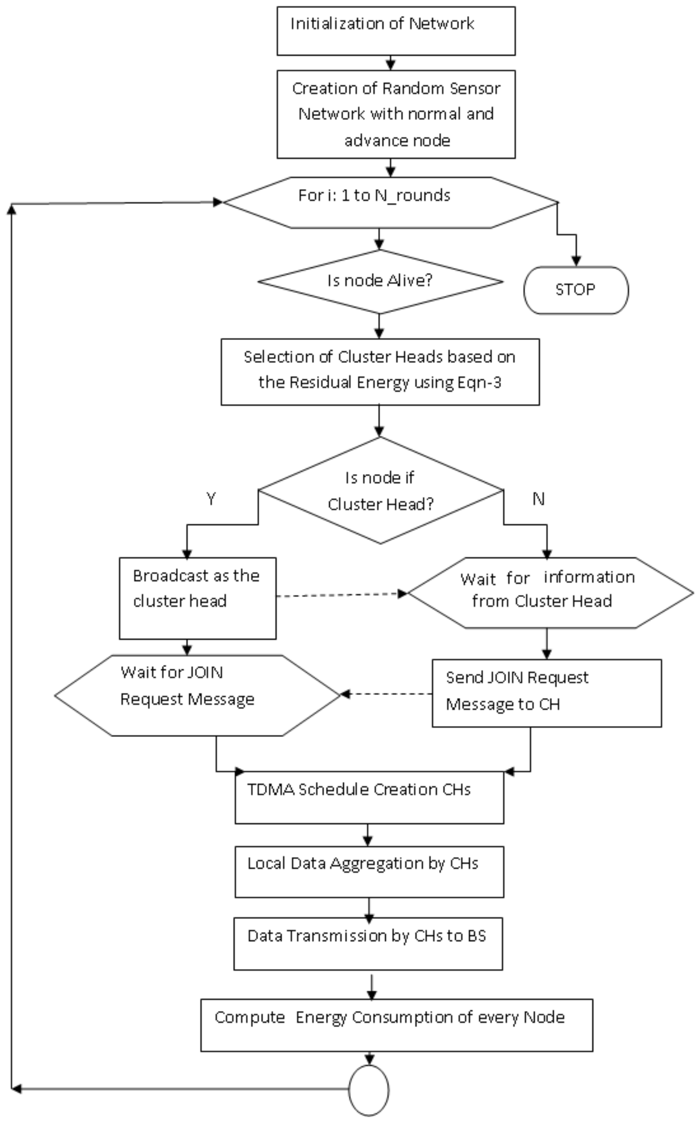


Figure 3 Flowchart for EECAP

Initialization of Network

This requires the initialization for the following parameters- Size of Sensing Field (Xm X Ym) , Number of Nodes (N), Position of Sink Node(Xs,Ys), Parameters for radio energy dissipation model such as the energy expedited to transmit , receive and amplify.

Creation of Random Sensor Network

After the initialization phase, the number of nodes are deployed on the field to create the senor network. Sink node is positioned at the centre / cornet / at any random location of the sensor field.

Cluster head Election and Node Association

If a node is elected as a cluster head during last q round where $q < r$ or it has received cluster head announcement from the neighbouring nodes during a particular round, a node withdraws its participation to be elected as a cluster head during that round and decide to join one of the cluster heads from which it has received cluster head announcement and having highest RSSI (Received Signal Strength Indicator) amongst all received cluster head announcements. If a node which is neither a cluster head nor a member node will send data directly to the base station.

If a node is a cluster head it will collect data from the member nodes, aggregate them and send it to base station. Member nodes will be activated and send its data to cluster head as per the TDMA schedule sent by the cluster head. For the rest of the time member nodes will remain into SLEEP state to save energy and reactivated at the end of the round time.

6. Implementation and Performance Evaluation

To evaluate the performance of EECAP protocol, Simulation experiments are carried out in Matlab (2009a) [14]. The results of EECAP are compared with performance of the LEACH and SEP with Divergent Sink Placement basis of average node remaining energy and the longevity of the network. The initial values for the various parameters for the senor network have been set and the details are given in the table -1.

Table1:Network Initial Parameters

Parameters	Value
Sink Position	a) Centre b) Corner c) Random
Network Field(xmxym)	(100X100)
Number of Nodes (n)	100
Normal Node Initial energy (Eo)	0.5 J
Message Size	4000 Bits
Eelec	50nJ/bit
Efs	10nJ/bit/m
Eamp	0.0013pJ/bit/
EDA	5nJ/bit/signal
do(Threshold Distance)	70m
Popt	0.1

In our analysis the following parameters have been used to compare the performance of aggregation algorithms with divergent sink placement.

Average Remaining Energy of Node (AREN): This is measure of average energy remaining in all the nodes after each epoch. The energy spent by each node includes operations like transmitting, receiving, sensing, aggregation of data etc. This is calculated by taking summation of energy present in each node after each round divided by the number of nodes.

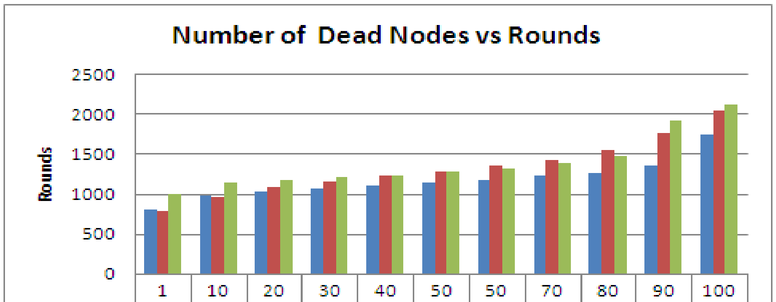
Total number of Dead Nodes (TNDN): The lifetime of the network is measured by the total number of deadnodes (TNDN) in the network after specified number of rounds.

Stability period (SP): The stability period indicates the steadiness of the network. It is the time from the start of the network operation and death of the first node in the WSN. This is also referred as “stable region” of a network.

The performance of EECAP is evaluated at divergent sink positions such as – first time when the sink node is at the centre of the sensor field, second time when the sink node is at the corner of the sensing field and lastly the sink node is positioned at a random location in the sensor field.

7. Results

The figure 4 and 5 shows the number of dead nodes versus sensing rounds. In our proposed protocol, the first sensor node dies on 1002- sensing round. Whereas, the first node dies quiet earlier in LEACH(807 round) and SEP(792 round) protocol. In LEACH protocol first sensor node dies on 807th round and in SEP first sensing node dies on 792 rounds. This clearly indicates that the stability of our proposed algorithm is better in its initial operation i.e. almost of about 1250 sensing rounds.



	1	10	20	30	40	50	50	70	80	90	100
LEACH	807	976	1042	1077	1113	1145	1185	1229	1276	1360	1755
SEP	792	970	1082	1162	1235	1292	1357	1433	1557	1766	2050
ECAP	1002	1138	1172	1206	1235	1278	1321	1385	1489	1920	2123

Figure 4 Number of Nodes Dead vs Rounds

The figure 5 shows the lifetime comparison for the LEACH, SEP and EECAP (proposed) algorithms using line graph which shows that the performance of the proposed protocol is stable and consist throughout all the rounds as compared with LEACH and SEP.

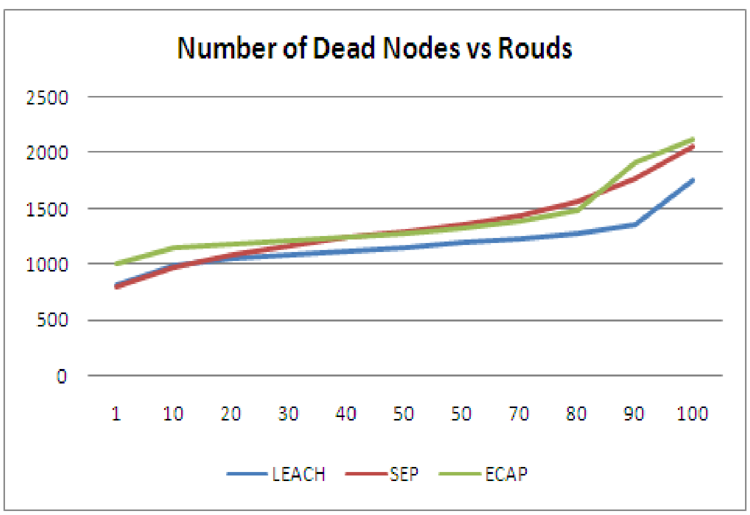


Figure 5 Number of Nodes Dead vs Rounds

The figure 6 shows the performance of LEACH protocol with divergent sink placement such as when the sink node is located at the centre of the sensor field, when the sink node is placed at the corner of the sensing field and at any random position in the sensor field. It is observed that the performance of LEACH protocol is slightly better when the sink node is positioned at the centre of the sensing field.

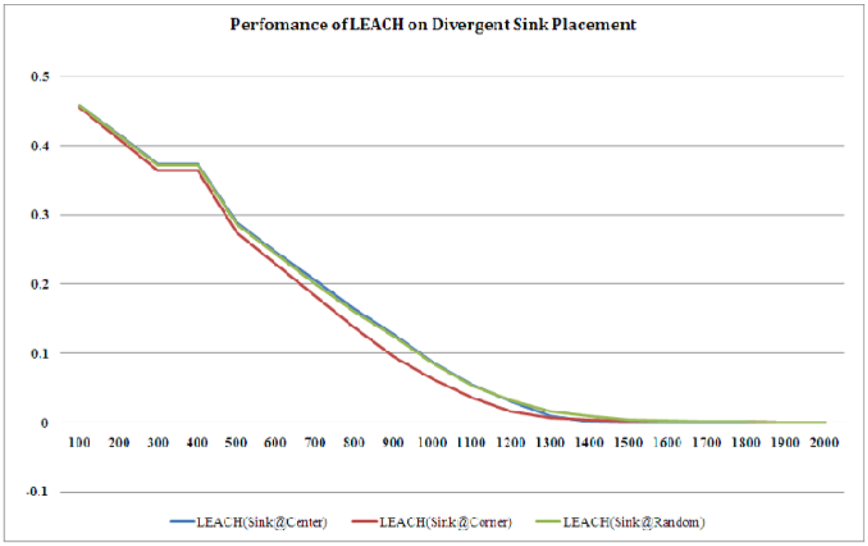


Figure 6 Performance of LEACH on Divergent Sink Placement

The figure 7 shows the performance of SEP protocol with divergent sink placement such as when the sink node is located at the centre of the sensor field, when the sink node is placed at the corner of the sensing field and at any random position in the sensor field. It is observed that the performance of SEP protocol is also slightly better when the sink node is positioned at the centre of the sensing field.

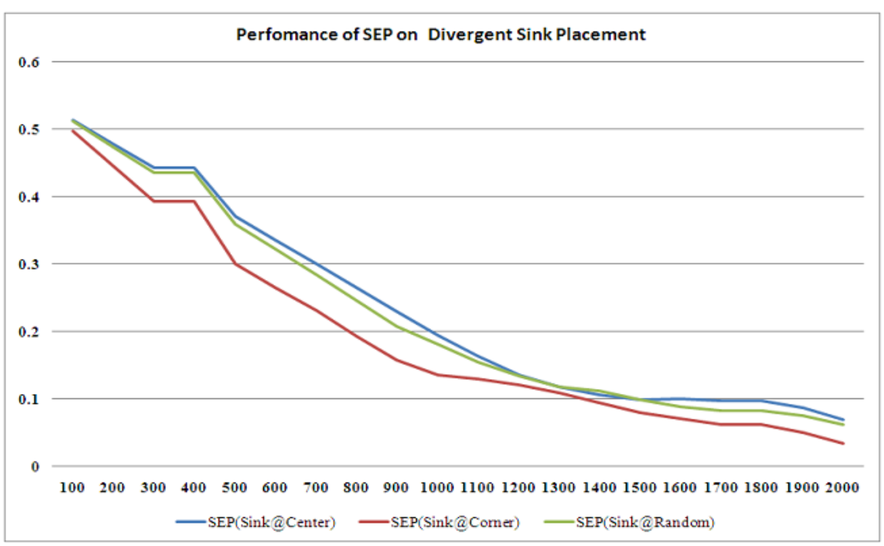


Figure 7 Performance of SEP on Divergent Sink Placement

The performance of EECAP (proposed) protocol with divergent sink placement such as when the sink node is located at the centre of the sensor field, when the sink node is placed at the corner of the sensing field or at any random position in the sensor field is as shown in the figure 8. It is observed that the performance of EECAP protocol is also slightly better when the sink node is positioned at the centre of the sensing field but the there is very small deviation in the performance when the sink node is placed at different places (Centre, Corner and Random) in the sensing field and this indicates that the EECAP will have less impact on change of the sink position in the sensing field.

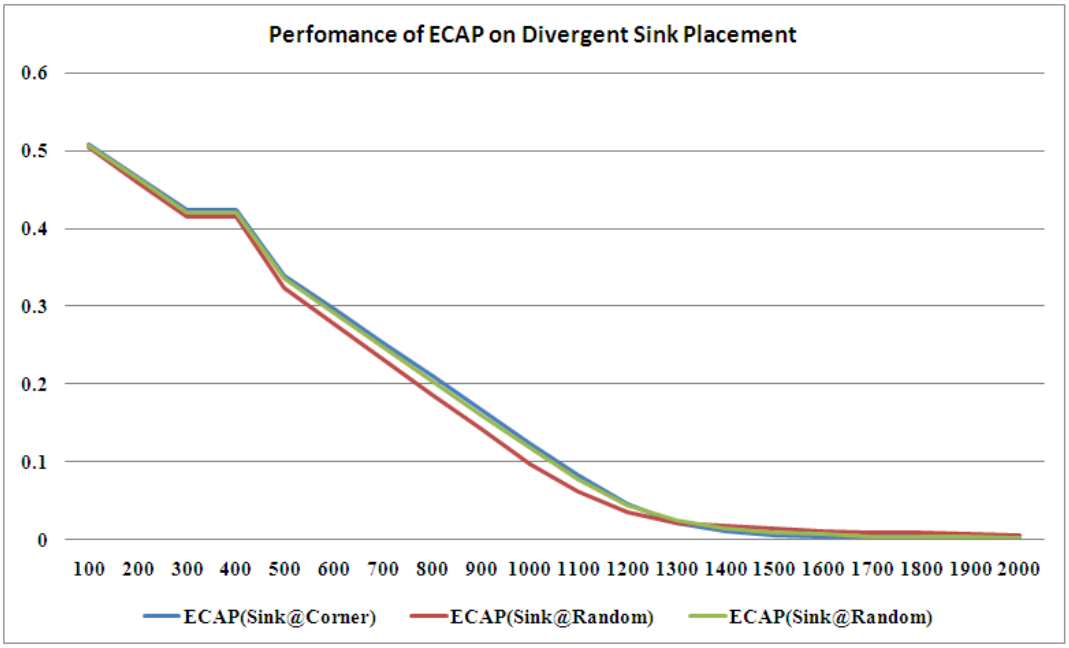


Figure 8 Performance of EECAP on Divergent Sink Placement

After analyzing all plots given in figures [4-10], it shows that the performance of the proposed protocol EECAP almost same as SEP protocol in the initial rounds of its operation and better than the LEACH throughout its lifetime. It is observed that the number of nodes alive at any specified time during the simulation is higher for EECAP as compared to other two protocols.

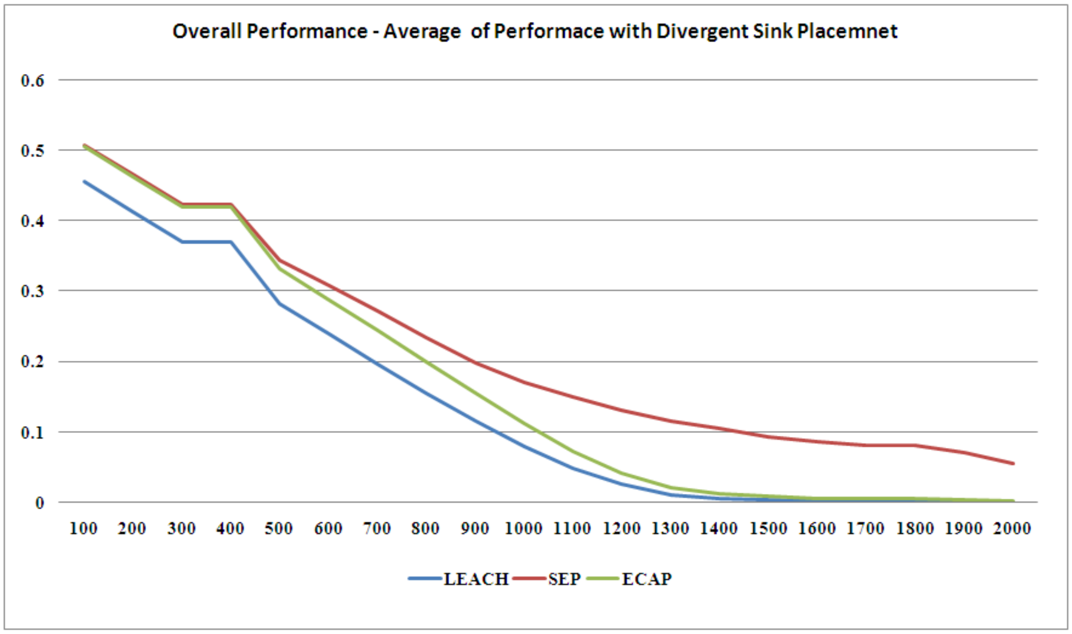


Figure 9 Performance - Sink Placement @ Centre of Sensor Field

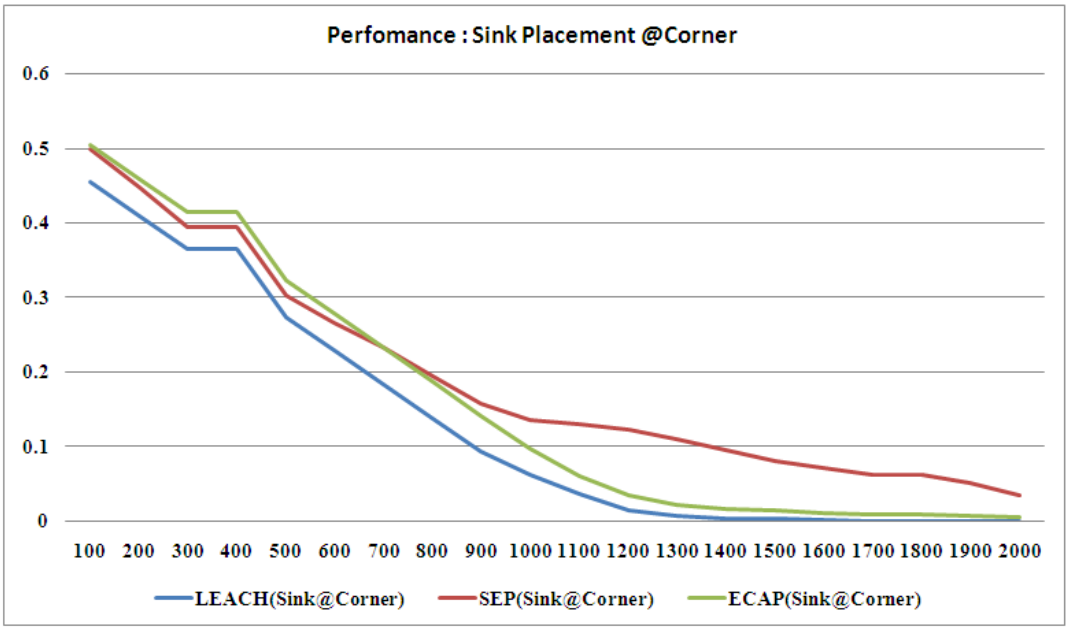


Figure 10 Performance - Sink Placement @ Corner of Sensor Field

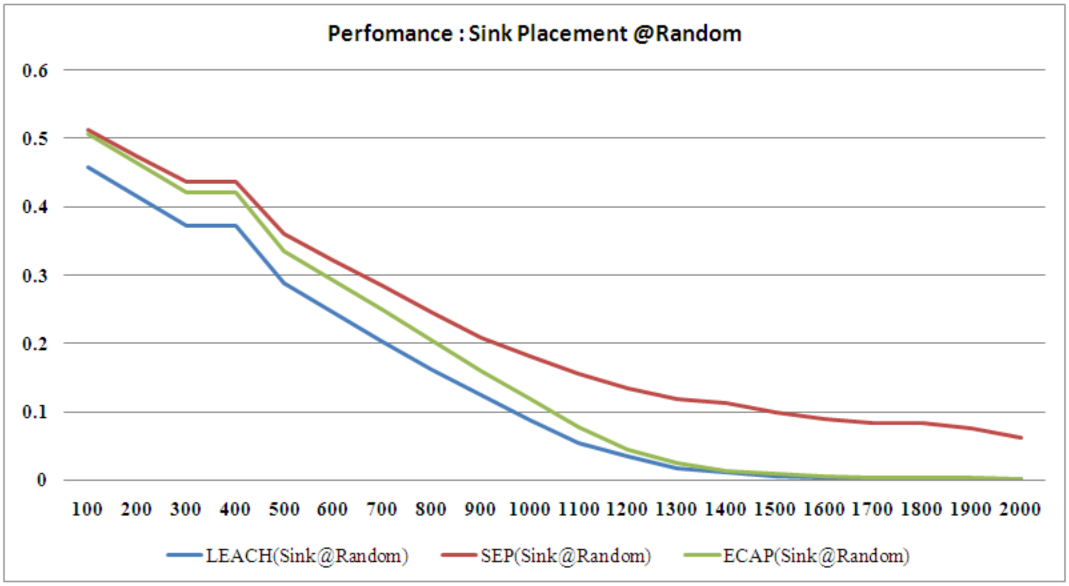


Figure 11 Performance - Sink Placement @ Random Position in Sensor Field

8. CONCLUSION

A major challenge in designing an efficient protocol for wireless sensor networks is maximizing network lifetime when the sink node is not a stationary. We studied and compared the performance of our proposed aggregation protocol with LEACH and SEP with divergent sink placement such as when sink is at the centre, corner or at a location selected randomly in the sensor field. The simulation results demonstrate that EECAP exhibits good performance in terms of lifetime and the energy consumption of the wireless sensor networks. The stability of our proposed algorithm is better during the initial operations of the sensor networks.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey," Computer Networks, vol. 38, no. 4, pp. 393– 422, 2002.

[2] Brett A. Warneke, Kristofer S.J. Pister, "MEMS for Distributed Wireless Sensor Networks", Berkeley Sensor and Actuator Center, University of California at Berkeley

[3] V. Mhatre and C. Rosenberg, "Homogeneous vs. heterogeneous clustered sensor networks: A comparative study," in Proceedings of 2004 IEEE International Conference on Communications (ICC 2004), June 2004.

[4] Stephanie Lindsey, CauligiRaghavendra , "Data Gathering Algorithms in Sensor Networks Using Energy Metrics", IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS, VOL. 13, NO. 9, SEPTEMBER 2002

[5] Ramesh Rajagopalan and Pramod K. Varshney, "Data aggregation techniques in sensor networks: A survey", IEEE Communications Surveys and Tutorials, vol. 8, no. 4, 4th quarter ,2006.

[6] Ameer Ahmed Abbasi a, Mohamed Younis b," A survey on clustering algorithms for wireless sensor networks", ELSEVIER

[7] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks" , Proceedings of the 33rd Annual Hawaii International Conference on system Sciences, vol.2, pp. 3005-3014, 2000.

[8] G. Smaragdakis, I. Matta, A. Bestavros, "SEP: A Stable Election Protocol for clustered

heterogeneous wireless sensor networks" , Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), 2004.

[9] Woo-Sung Jung, Keun-Woo Lim, Young-BaeKo, Sang-Joon Park, "A Hybrid Approach for Clustering-Based Data Aggregation in Wireless Sensor Networks,", ICDS, pp.112-117, 2009 Third International Conference on Digital Society, 2009.

[10] L. Qing, Q. Zhu, M. Wang, "Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks". ELSEVIER, Computer Communications 29, pp 2230-2237, 2006.

[11] SumitChaudhary, Neha Singh, AvinavPathak and A.K Vatsa, "Energy Efficient Techniques for Data aggregation and collection in WSN", International Journal of Computer Science, Engineering and Applications (IJCSEA) Vol.2, No.4, August 2012

[12] http://www.mathworks.in/help/matlab/index.html

[13] PrakashgoudPatil, Umakant P Kulkarni, Data Aggregation in Wireless Sensor Networks Using Fuzzy Aggregator, International Conference on Soft-Computing and Engineering Applications – ICSEA2011, IRNet ISBN : 978-93-81583-01-2.

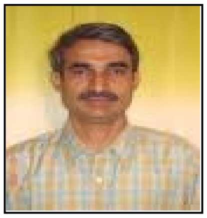
[14] PrakashgoudPatil, Umakant P Kulkarni, Some Issues in Clustering Algorithms for Wireless Sensor Networks, IJCA Special Issue on "2nd National Conference- Computing, Communication and Sensor Network" CCSN, 2011.

[15] PrakashgoudPatil, Umakant P Kulkarni, Effect of Data Aggregation on Wireless Sensor Network Performance, IEEE Conference - TRENDZ IN INFORMATION SCIENCES & COMPUTING – TISC 2011 ISBN 978-1-4222-9009-7

Authors

Prof. PrakashgoudPatil received his Bachelor Degree in Computer Science and Engineering from Karnataka University, Dharwad (Karnataka - India) in 1991 and ME degree in Computer Science from Tapar Institute ofEngineering Technology (TIET), Patiala, Punjab. Presently, he is pursuing Ph.D degree in Computer Research Centre at S.D.M Engineering College, Dharwad affiliated to Visvesvaraya Technological University, Belgaum under the guidance of Dr. Umakant P. Kulkarni.

He is currently working as Associate Professor in Master of Computer Applications Department, B.V.B College of Engineering and Technology, Hubli, Karantak (India). He has presented and published research papers at national and international conferences and reputed journals and won best paper awards. He is also actively involved in the development of business applications using open source software & technologies and his research interests include Computer Networking, Wireless Sensor Networks and Cyber Security.



Prof. Umakant P. Kulkarni received his PhD degree from Shivaji University, Kolhapur. Research Centre:-Walchand College of Engineering & Tech, Sangli, Maharashtra in Nov 2007. He received his Masters degree (M.E) from PSG, Coimbatore. He is currently working as Professor in Computer Science Department, SDMCET, Dharwad, Karnataka. He has published and presented a number of papers in many reputed journals and at International IEEE conferences as well. This apart he also has presented technical talks and tutorials on various aspects of Mobile Agents. His research interests include mobile agents, computer networking, and distributed networking.