Journal of Theoretical and Applied Information Technology
20th March 2014. Vol. 61 No.2

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

NEW APPROACH TO IMPROVING LIFETIME IN HETEROGENEOUS WIRELESS SENSOR NETWORKS BASED ON CLUSTERING ENERGY EFFICIENCY ALGORITHM

[1]ELAHMADI CHEIKH, [2] CHAKKOR SAAD, [3]BAGHOURI MOSTAFA,
[4]HAJRAOUI ABDERRAHMANE

Department of Physics,
Team: Communication and Detection Systems,
University of Abdelmalek Essaâdi, Faculty of Sciences, Tetouan, Morocco
E-mail: [1]elahmadi13@gmail.com, [2]saadchakkor@gmail.com, [3]baghouri.mostafa@gmail.com,
[4]ab_hajraoui@hotmail.com

ABSTRACT

The major challenge for wireless sensor networks is energy consumption minimization. Wireless transmission consumes much more of energy. In the clustered network, a few nodes become cluster heads which causes the energetic heterogeneity. Therefore the behavior of the sensor network becomes very unstable. Hence, the need to apply the balancing of energy consumption across all nodes of the heterogeneous network is very important to prevent the death of those nodes and thereafter increase the lifetime of the network. DEEC (Distributed Energy Efficient Clustering) is one of routing protocols designed to extend the stability time of the network by reducing energy consumption. A disadvantage of DEEC, which doesn't takes into account the cluster size and the density of nodes in this cluster to elect the cluster heads. When multiple cluster heads are randomly selected within a small area, a big extra energy loss occurs. The amount of lost energy is approximately proportional to the number of cluster heads in this area. In this paper, we propose to improve DEEC by a modified energy efficient algorithm for choosing cluster heads that exclude a number of low energy levels nodes due to their distribution density and their dimensions area. We show by simulation in MATLAB that the proposed approach increases the number of received messages and prolong the lifetime of the network compared to DEEC. We conclude by studying the parameters of heterogeneity that proposed technique provides a longer stability period which increases by increasing the number of nodes which are excluded from the cluster head selection.

Keywords: *Wireless Sensor Networks, Clustering Algorithm, Multi-Level Heterogeneous Networks, Energy-Efficiency, DEEC Protocol, Network Lifetime.*

1. INTRODUCTION

Wireless sensor networks are an emerging technology that has a wide range of potential applications including environment monitoring, smart spaces, medical systems and robotic exploration... Such a network normally consists of a large number of distributed nodes that organize themselves into a multi-hop wireless network [1]. However, the sensor nodes are usually powered by batteries and thus have very limited lifetime if no power management is performed. The sensor node contains four basic building blocks of components, those are sensing unit, processing unit, radio unit, and power unit [2]. These sensors are able to communicate with each other to collaboratively detect objects, collect information and transmit messages. However, as sensors are usually small in size, they have many physical limitations such as battery, computational power and memory. The important part of energy is consumed in the communication circuit which must be minimized. Because of those limitations, energy-efficient techniques are main research challenges in wireless sensor networks. A number of techniques have been proposed to solve these problems. The major challenge is the energy consumption, In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of small groups called clusters. Each cluster has a cluster head, and a number of member nodes [2]. So, designing energy-efficient protocols becomes a serious parameter for increasing the lifetime of nodes [3], the famous techniques adopted by the most clustering algorithms are selecting cluster-heads with more residual energy and rotating cluster-heads periodically to balance the energy consumption of the sensor nodes over the network. There are two type of routing protocols for extending the lifetime of the network: centralized and distributed algorithms. It is realized that centralized algorithms are less scalable and robust than distributed algorithms [14]. Among distributed approaches developed to reduce energy consumption and to guarantee well balanced distribution of the energy load between nodes of the network [4]. Most clustering solutions are proposed: LEACH protocol using cluster heads dynamically elected based on an optimal probability model, HEED which selects the cluster-heads stochastically. The election probability of each node is correlative to the residual energy. All those protocols assume that the sensor networks are homogeneous [15]. SEP scheme is proposed for the two-level heterogeneous wireless sensor networks, which is composed of two types of nodes according to the initial energy. SEP prolongs the stability period of the network [4].furthermore, DEEC (Design of a distributed energy-efficient clustering algorithm) [15], is used in heterogeneous wireless sensor networks. This protocol is based on the election of cluster head by the balance of the probabilities of the remaining energy for each node, it use the average energy of the network as the reference energy, the cluster-heads are elected by a probability based on the ratio between the residual energy of each node and the average energy of the network.

In this paper, we present a new energy efficient approach that improves DEEC by extending in the maximum the network lifetime. This algorithm is based on the threshold selection to choose the optimal nodes as cluster heads by excluding a number of low energy levels nodes due to their distribution density and their dimensions area. We assume that all the nodes of the sensor network are equipped with different amount of energy, which is a source of heterogeneity. This is a kind of doping which can energize the sensor networks in order to prolong the lifetime of the network Thus, the nodes with high initial and residual energy will have more chances to be the cluster-heads with the new threshold election. We show by simulation that proposed approach provides a longer stability period and increase the number of effective messages compared to other classical clustering algorithms (LEACH and DEEC).

2. RELATED WORK

There exist two types of distributed clustering techniques used to reduce energy consumption: the homogeneous and heterogeneous clustering algorithms. It is very difficult to design heterogeneous clustering schemes due to their complexity on the contrary of homogeneous protocols. Currently, WSN are more possibly heterogeneous networks than homogeneous ones.

Actually, clustered routing protocol has gained increasing attention from researchers because of its potential of extending WSN lifetime. Heizelman and Kopa [5] designed and implemented the first distributed and clustered routing protocol with low energy consumption [4].

LEACH [16], performs well, but its performance become badly in the heterogeneous network as shown by [4], [19]. PEGASIS [17] it is an improved version of LEACH as nodes will be organized to form a chain, which can be computed by each node or by the base station. However, excessive delay is introduced for distant nodes, especially for large networks. SEP performs poorly in multi-level heterogeneous networks and when heterogeneity is a result of operation of the sensor network [4], [15]. In HEED [18] a stochastic algorithm used to define the cluster-heads based on probability election of each node which is correlative to the residual energy. Q. Li, Z. Qingxin and W. Mingwen are proposed Distributed Energy Efficient Clustering Protocol (DEEC) [15]. This clustering protocol is based on multi level and two level energy heterogeneous schemes. The cluster heads are selected using the probability utilizing the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster-heads for nodes are different according to their initial and residual energy. A particular algorithm is used to estimate the network lifetime, thus avoiding the need of assistance by routing protocol [15].

Since the network nodes are deployed randomly in a monitoring zone, the aim problem of DEEC that it doesn’t takes into account the cluster size and density of nodes in the clusters to elect their heads. When multiple cluster heads are randomly selected within a small area, a large additional loss of energy occurs because the election of cluster heads is performed periodically where the density of nodes is high and therefore the distance between these nodes will be very small. The amount of lost energy is approximately proportional to the number of cluster heads in this area. In the face of this scenario, it is necessary to minimize the number of candidate's nodes to be cluster heads because it is unnecessary to elect a large number of heads in a condensed and narrow cluster.

3. PROPOSED APPROACH

In this section, we describe the heterogeneous wireless sensor network model which includes cluster formation and maintaining optimum number of clusters.

3.1 Heterogeneous network model

In our model, we assume that there are N sensor nodes, which are evenly scattered within a M×M square region and organized into clusters hierarchy for aggregate data by cluster heads to base station which is located at the center of this region. Nodes have low mobility or stationary as assumed at [15], [16]. In the two-level heterogeneous networks advanced nodes fraction m with a times more energy than the others which have an initial energy E_0. The total energy is assumed as follow:

$$E_{total} = N(1-m)E_0 + NmE_0(1+a) = NE_0(1+am) \quad (1)$$

In multi-level heterogeneous networks, the clustering algorithm should consider the discrepancy of initial energy, E_{total} is expressed by:

$$E_{total} = \sum_{i=1}^{N} E_0(1+a_i) = E_0\left(N + \sum_{i=1}^{N} a_i\right) \quad (2)$$

3.2 DEEC Cluster-head selection algorithm

n_i denotes the number of rounds to be a cluster-head for the node s_i, and we refer to it as the rotating epoch. In DEEC protocol, we choose different $n_i = \frac{1}{p_{opt}}$ based on the residual energy of $E_i(r)$ node s_i at round r.

If nodes have different amounts of energy, p_i of the nodes with more energy should be larger than p_{opt} Let $\bar{E}(r)$ denotes the average energy at round r of the network, which can be obtained by:

$$\bar{E}(r) = \frac{1}{N}\sum_{i=1}^{N} E_i(r) \quad (3)$$

To calculate $\bar{E}(r)$ we have:

$$p_i = p_{opt}\frac{E_i(r)}{\bar{E}(r)} \quad (4)$$

Where G is the set of nodes that are eligible to be cluster-heads at round r, n_i is chosen based on the residual energy $E_i(r)$ at round r of node s_i as follow :

$$n_i = \frac{1}{p_i} = n_{opt}\frac{\bar{E}(r)}{E_i(r)} \quad (5)$$

When the networks are heterogeneous, the reference value of each node should be different according to the initial energy. In the model of multi-level heterogeneous networks, the weighted probability shown as:

$$p(s_i) = \frac{p_{opt}N(1+a_i)E_i(r)}{\left(N+\sum_{i=1}^{N} a_i\right)\bar{E}(r)} \quad if\ s_i \in G \quad (6)$$

Thus we can estimate the average energy $\bar{E}(r)$ of r^{th} round as follow:

$$\bar{E}(r) = \frac{1}{N}E_{total}\left(1-\frac{r}{R}\right) \quad (7)$$

Where R denote the total rounds of the network lifetime. Let E_{round} denote the energy consumed by the network in each round. R can be approximated as follow:

$$\bar{E}(r) = \frac{E_{total}}{E_{round}} \quad (8)$$

The total energy dissipated in the network during a round is equal to:

$$E_{round} = L(2NE_{elec} + NE_{DA} + k\varepsilon_{mp}d_{toBS}^4 + N\varepsilon_{fs}d_{toCH}^2) \quad (9)$$

$$d_{toBS} = \frac{M}{\sqrt{2\pi k}}, \quad d_{toCH} = 0.765\frac{M}{2} \quad (10)$$

Where k is the number of clusters, E_{DA} is the data aggregation cost expended in the cluster-heads.

3.3 Proposed Cluster-head selection algorithm

We assume the same assumptions that proposed in DEEC, to improve this protocol we add the following assumptions:

- Two or even more cluster heads are very closely located and the distance between them becomes negligible.
- Cluster heads are randomly selected within a small area.

As illustrated in Figure1, CH1, CH2 and CH3 are three very closely located cluster heads with their cluster members.

According to data communication model, the energy that a cluster head consumes is the sum of that consumed in receiving data and that in sending data, as follow:

$$E_{CH} = lE_{elec}N_{mem} + l\varepsilon_{mp}d_{toBS}^4 + lE_{DA}(N_{mem}+1) + lE_{elec} \quad (11)$$

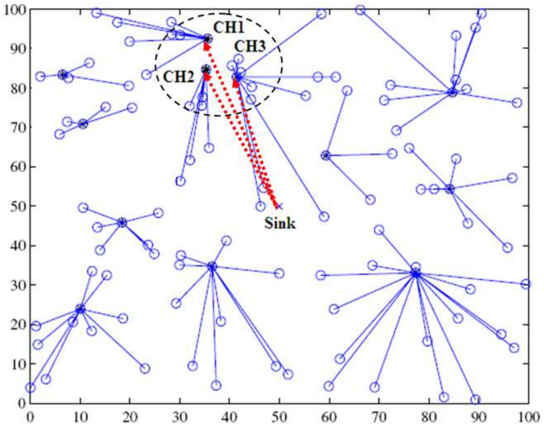

Figure 1: Multiple cluster heads in a small area

N_{mem} is the number of members in a cluster, d_{toBS} is the distance between the cluster head and the Sink, l is the length of data.

The amount of energy that cluster heads CH1, CH2 and CH3 consume during data transfer is:

$$E_{CH1} = lE_{elec}N_{mem1} + l\varepsilon_{mp}d^4_{CH1toBS} + lE_{DA}\left(N_{mem1}+1\right) + lE_{elec} \quad (12)$$

$$E_{CH2} = lE_{elec}N_{mem2} + l\varepsilon_{mp}d^4_{CH2toBS} + lE_{DA}\left(N_{mem2}+1\right) + lE_{elec} \quad (13)$$

$$E_{CH3} = lE_{elec}N_{mem3} + l\varepsilon_{mp}d^4_{CH3toBS} + lE_{DA}\left(N_{mem3}+1\right) + lE_{elec} \quad (14)$$

Where N_{mem1}, N_{mem2} and N_{mem3} are the number of members in clusters CH1, CH2 and CH3, respectively, $d_{CH1toBS}$, $d_{CH2toBS}$ and $d_{CH3toBS}$ are the distances between the three cluster heads and the Sink, Therefore, the total energy consumed by the three clusters is:

$$\begin{aligned} &E_{CH1}+E_{CH2}+E_{CH3} = \\ &lE_{elec}\left(N_{mem1}+N_{mem2}+N_{mem3}\right) \\ &+lE_{DA}\left(N_{mem1}+N_{mem2}+N_{mem3}+3\right) \\ &+l\varepsilon_{mp}\left(d^4_{CH1toBS}+d^4_{CH2toBS}+d^4_{CH3toBS}\right) \\ &+3lE_{elec} \end{aligned} \quad (15)$$

When CH1, CH2 and CH3 are very close, we can have:

$$d_{CH1toBS} \approx d_{CH2toBS} \approx d_{CH3toBS} = d \quad (16)$$

Then the equation (15) becomes:

$$\begin{aligned} &E_{CH1}+E_{CH2}+E_{CH3} = \\ &lE_{elec}\left(N_{mem1}+N_{mem2}+N_{mem3}\right) \\ &+lE_{DA}\left(N_{mem1}+N_{mem2}+N_{mem3}+3\right) \\ &+3l\left(E_{elec}+\varepsilon_{mp}d^4\right) \end{aligned} \quad (17)$$

From equation (18) we can conclude that when:

$$\begin{aligned} &l\left(E_{elec}+\varepsilon_{mp}d^4\right) > \\ &lE_{elec}\left(N_{mem1}+N_{mem2}+N_{mem3}\right) \\ &+lE_{DA}\left(N_{mem1}+N_{mem2}+N_{mem3}+3\right) \end{aligned} \quad (18)$$

The total energy consumption when there are three cluster heads is approximately thrice of that when there is only one cluster head. It can be seen later that when multiple cluster heads are chosen based on the residual energy, as shown in equation (7), within a small region in the monitoring zone, a significant portion of energy is lost during the network evolving. The lost energy is proportional to the number of cluster heads noted by s in this area. Thus the probability threshold (5), which each node s_i uses to determine a cluster-head in each round, becomes in our proposed approach as follow:

$$T\left(s_i\right) = \begin{cases} \dfrac{p_i}{1-p_i\left(r \bmod \left(\dfrac{1}{p_i} - \dfrac{\alpha}{N \times p_i}\right)\right)} & if\ s_i \in G \\ 0 & Otherwise \end{cases} \quad (19)$$

Where α is the number of nodes that are excluded from the cluster head threshold selection due to their location and distribution density reason, with an initial value of 0. When s increases, $T(s_i)$ increases as well, therefore the chances of nodes that are eligible to be cluster heads decreases. Indeed, with this algorithm we can save the lost energy caused by the election of these cluster heads excluded and extend the lifetime of the network. The analytical method to calculate the number s is a perspective of this work.

4. SIMULATION RESULTS

The proposed approach has been implemented in MATLAB and the performance has been evaluated by simulation, the lifetime of the network is measured in terms of rounds when the first sensor node dies. The base station is assumed in the center of the sensing region. All the parameters values including the first order radio model characteristic are mentioned in the table1 below. To compare the performance of the proposed approach with DEEC protocol, the effect caused by signal collision and interference in the wireless channel is ignored, a multi-level heterogeneous network is considered. In this simulation, the value of multi-level heterogeneity is fixed in a_{max}=3.

Table 1: Parameters used in simulations

Parameter	Value
Network area	100 m×100 m
Number of nodes	100
E_0	0.5 J
E_{elec}	50 nJ/bit
ε_{fs}	10 pJ/bits/m^2
ε_{mp}	0.0013 pJ/bit/m^4
$E_{Tx}=E_{Rx}$	50 nJ/bit
E_{DA}	50 nJ/bit/message
$d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$	70 m
Packet Size	4000bits
P_{opt}	0.05

The effect of varying α on the lifetime of the network and on the number of packet messages received in the base station is studied in different scenarios as shown in table2:

Table 2 : Simulation scenarios

Parameters	a	α
Scenario1	3	3
Scenario2	3	9
Scenario3	3	12

Thus, each node in the sensor network is randomly assigned different energy levels between a closed set [E_0, $E_0(1+a_{max})$].

In the simulation results figures 2, 4 and 6 the lifetime evolution of the network for each scenario, whereas figures 3, 5 and 7 shows the number of packet messages received in the base station per round for each scenario. The tables 3, 4 and 5 provides statistics on the number of dead nodes per rounds as well as the percentage increase in the lifetime of the network for the proposed approach compared to DEEC protocol.

It is very clear that the proposed approach gives a lifetime network greater than DEEC protocol whether for the first dead node rounds or for all dead nodes rounds due to their remaining energy. In DEEC protocol all nodes die early on the contrary of the proposed approach in which all nodes die tardily for all studied scenarios. On the other hand, the energy efficiency of the proposed approach improves significantly the number of packets message received which increases with a remarkable manner by increasing α.

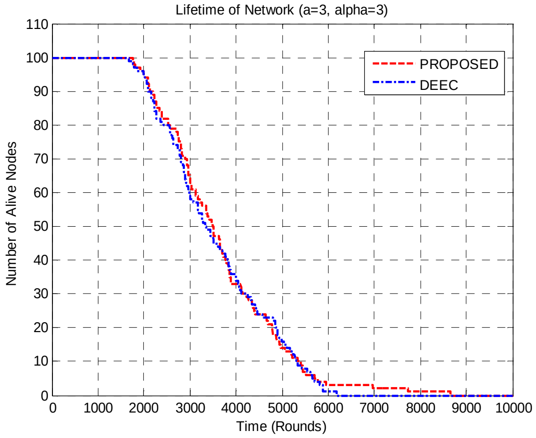

Figure 2 : Number of alive nodes over time (Scenario1)

Table 3: Number of dead nodes per rounds (Scenario1)

	DEEC	PROPOSED	INCREASE
First dead	1671	1770	5,92 %
All-dead	6192	8660	39,86 %

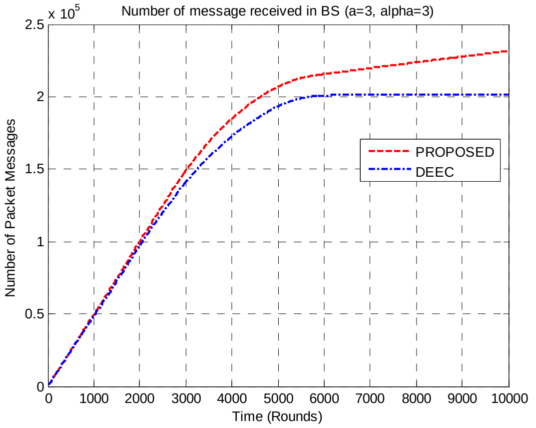

Figure 3: Number of packet messages received per round (Scenario1)

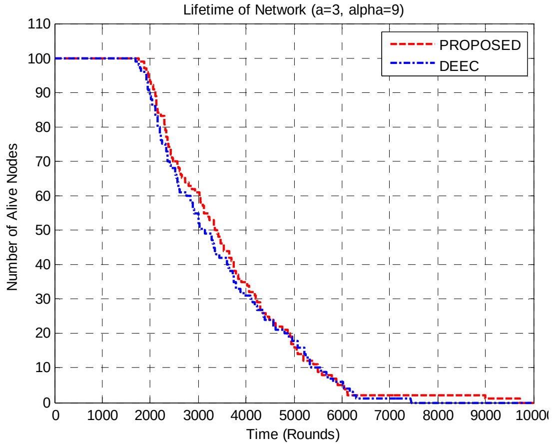

Figure 4: Number of alive nodes over time (Scenario2)

Table 4: Number of dead nodes per rounds (Scenario2)

	DEEC	PROPOSED	INCREASE
First dead	1689	1754	3,85 %
All-dead	7443	9717	30,55 %

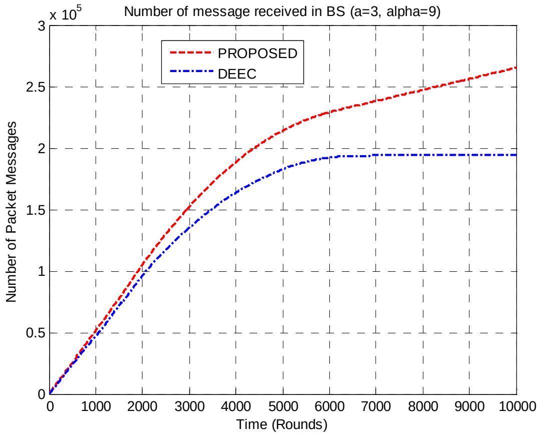

Figure 5: Number of packet messages received per round (Scenario2)

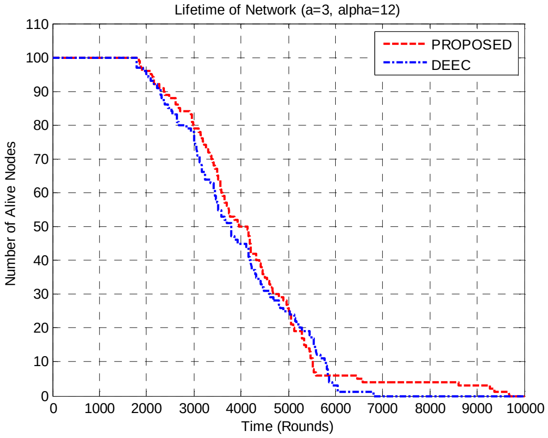

Figure 6: Number of alive nodes over time (Scenario3)

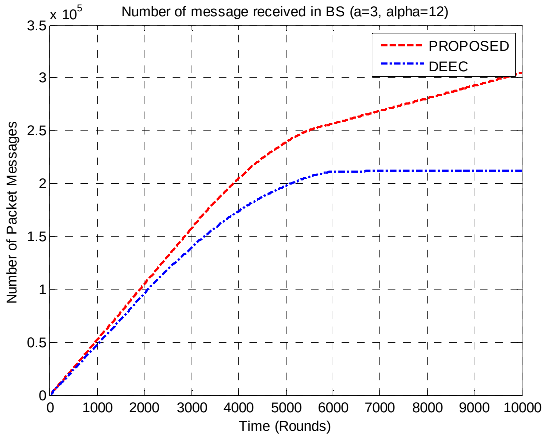

Figure 7: Number of packet messages received per round (Scenario3)

Table 5: Number of dead nodes per rounds (Scenario3)

	DEEC	PROPOSED	INCREASE
First dead	1779	1833	3,04 %
All-dead	6810	9678	42,11 %

Referred to figure 8, the lifetime percentage decreases with increasing α for the first dead node time while this percentage fluctuate between different values and do not keep a monotony for the all dead nodes time when α increase, this is justified by the network instability in this time period. Generally, we can conclude that there has an optimum value of α from which the proposed approach does not provide a better increase of the network lifetime. The determination of the $\alpha_{optimal}$ is a future work of this paper.

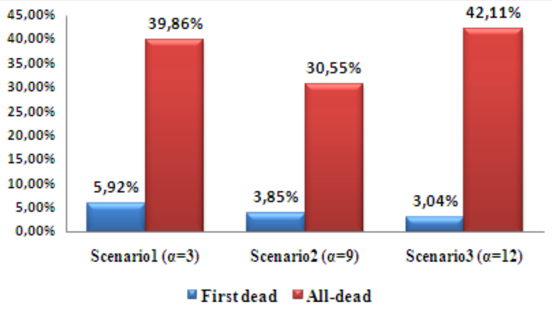

Figure 8: Evolving of lifetime nodes percentage according to different scenarios

It seems clearly in figures 9 and 10, for a fixed value of α=9, that the proposed approach preserves the improvement of the network lifetime whether for the first dead node rounds or for all dead nodes rounds compared to DEEC protocol despite the increase of multi-level heterogeneity value which takes its value from 1 to 5. Therefore, the number of packets message received increases also.

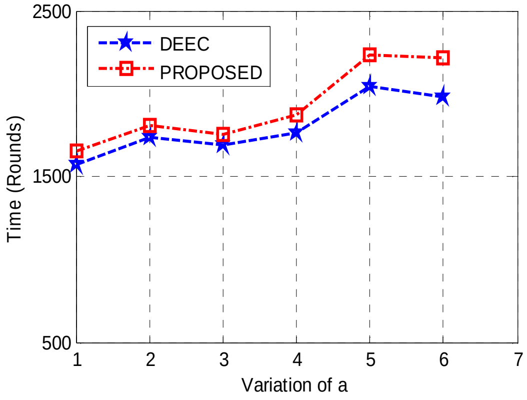

Figure 9: Lifetime of first dead node depending on a (α =9)

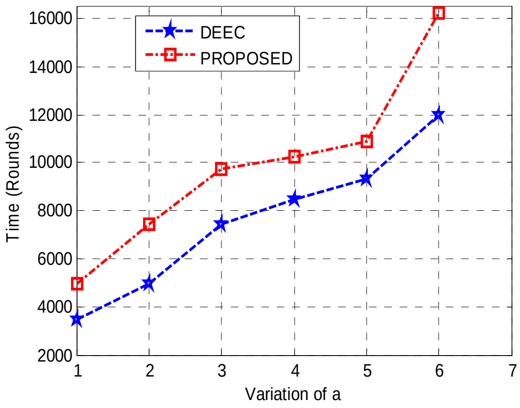

Figure 10: Lifetime of all dead nodes depending on a (α =9)

5. CONCLUSION

In this paper we showed the energy limitation of DEEC protocol when clusters heads are selected closest to others causing a bad management of energy consumption and thereafter reducing the network lifetime. An effective approach is presented to resolve this problem. The proposed solution excludes all nodes which are very close from the set of candidate nodes to be cluster heads by using a new probability threshold to determine a cluster-head in each round. Referred to the simulation results, the proposed technique keeps the residual energy of the nodes, improves the network lifetime and sends more effective data packets to the base station compared to DEEC protocol.

As perspective of this work, the determination of the $\alpha_{optimal}$ is the first challenge, the development of a robust algorithm allowing the localization of the very close nodes which are candidates to be cluster heads is the second challenge.

REFRENCES:

[1] Marcos, Diogenes, "Survey on Wireless Sensor Network Devices", IEEE 2003.

[2] V. Raghunathan, C. Schurgers, Park. S, and M. B. Srivastava, "Energy aware wireless micro-sensor networks", IEEE Signal Processing Magazine 2002, Volume: 19 Issue: 2, Page(s): 40 –50

[3] Rui Tan and al., "Quality-driven volcanic earthquake detection using wireless sensor networks", RTSS '10, pages 271–280, San Diego, CA, USA, 2010.

[4] Chakkor Saad, Baghouri Mostafa, Hajraoui Abderrahmane, "Fuzzy logic approach to improving Stable Election Protocol for clustered heterogeneous wireless sensor networks", Journal of Theoretical and Applied Information Technology, Vol. 53 No.3, July 2013

[5] S. Hussain, E. Shakshuki, A. W. Matin, "Agent-based system architecture for wireless sensor networks", Advanced Information Networking and Applications, Vol. 2, April 2006, pp. 18-20.

[6] Lin SHEN, Liqin WANG, "A Clustering Algorithm Based Geographic Location Information for Wireless Sensor Networks", Sensors & Transducers, Vol. 157, Issue 10, October 2013, pp. 147-152

[7] Kavi Kumar Khedo, Rajiv Perseedoss, and Avinash Mungur, "A wireless sensor network air pollution monitoring system", In International Journal of Wireless and Mobile Networks (IJWMN), Vol.2, No.2, pages 31–45, 2010.

[8] Maneesha V. Ramesh, "Real-time wireless sensor network for landslide detection", In SENSORCOMM '09, pages 405–409, Athens, Greece, 2009.

[9] V. Raghunathan, C. Schurgers, Park. S, and M. B. Srivastava, "Energy-aware wireless micro-sensor networks", IEEE Signal Processing Magazine 2002, Volume: 19 Issue: 2, Page(s): 40 –50.

[10] I. Akyildiz and al., "A Survey on Sensor Networks", IEEE Communication Magazine 2002, vol. 40, no. 8, pp. 102–14.

[11] Debnath Bhattacharyya , Tai-hoon Kim and Subhajit Pal, "A Comparative Study of Wireless sensor networks and their routing protocols" , Sensors (2010), 10, pp.10506-10523.

[12] Yan Zhang,Laurence T.Yang, and Jiming, "Chen RFID and sensor networks: architectures, protocols, security, and integrations" , CRC Press-Taylor & Francis Group (2010).

[13] H. Chan, A. Perrig, "ACE: an emergent algorithm for highly uniform cluster formation, in: Proceedings of the First European Workshop Sensor Networks (EWSN)", January 2004.

[14] Ossama Younis and Sonia Fahmy, "Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy- Efficient Approach", In Proceedings of IEEE INFOCOM, Hong Kong 2004, Transactions on Mobile Computing, 3(4).

[15] Li Qing, Qingxin Zhu, Mingwen Wang, "DEEC: Design of a distributed energy-

efficient clustering algorithm for heterogeneous wireless sensor networks", Computer Communications 29 (2006) 2230–2237.

[16] W.R. Heinzelman, A.P. Chandrakasan, H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", IEEE Transactions on Wireless Communications 1 (4) (2002) 660–670.

[17] S. Lindsey, C.S. Raghavenda, "PEGASIS: power efficient gathering in sensor information systems", in: Proceeding of the IEEE Aerospace Conference, Big Sky, Montana, March 2002.

[18] O. Younis, S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks", IEEE Transactions on Mobile Computing 3 (4) (2004) 660–669.

[19] 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.

[20] Neha Mehndiratta, Manju, Harish Bedi, "Wireless Sensor Network LEACH Protocol: A Survey", International Journal of Emerging Research in Management &Technology ISSN: 2278-9359 (Volume-2, Issue-3)

[21] F. Ren and H. Huang, "Wireless Sensor Network, Journal of Software", vol. 14, no. 7, pp. 1282-1291, 2003.

[22] J. Yu and P. Chong, "A survey of clustering schemes for mobile ad hoc networks", IEEE Communications Surveys & Tutorials, vol. 7, pp. 32-48, 2005.

[23] Sohrabi K, Gao J, Ailawadhi V, Pottie G, "Protocols for self-organization of a wireless sensor network", IEEE Personal Commun. 2007;7(5):16–27

[24] B. Krishnamachari and al., "The impact of data aggregation in wireless sensor networks", Proceedings of the 22nd International conference on Distributed Computing Systems, ICDCSW '02, pages 575–578