International Journal of Computer Information Systems and Industrial Management Applications.
ISSN 2150-7988 Volume 11 (2019) pp. 124-131

Received: 8 Jan, 2019; Accepted: 10 March, 2019; Published: 7 May, 2019

Analysis of EM-AEDEEC Protocol at Various Levels of Heterogeneity

Ushus Elizebeth Zachariah[1] and Lakshmanan Kuppusamy[2]

[1, 2] School of Computer Science and Engineering, Vellore Institute of Technology
Vellore, 632014, India
ushus@vit.ac.in

***Abstract*: Heterogeneous Wireless Sensor Networks are widely used to perform real-time applications like military surveillance, environmental monitoring and health care systems. Since sensor nodes are battery powered, developing an energy efficient algorithm to increase the network life time is a challenging problem. This paper proposes a multilevel energy efficient protocol, namely EM-AEDEEC, in which we extend the heterogeneity up to k-level. The protocol is analyzed for network life time and network stability. The experiments are carried out in a simulated grid of size 100 * 100 with varying number of sensor nodes. The simulation results demonstrate that with the increase in initial energy from 0.25 to 0.5 to 1.0 Joules, the stability of the network is almost doubled in the case of Euclidean distance measure and an increase of 7% network life time with Manhattan distance.**

Keywords: WSN, Energy Efficiency, Clustering, Distance metric.

I. Introduction

In today's world, the rise in demand of smart devices and the advancements in communication technology has created new dimensions for Wireless Sensor Network (WSN). The projected market value of WSN at the end of another 4 years from now is $ 93.86 billion. Three years ago, it was approximately 1/3rd of the expectation ($ 29 billion). Since real-time surveillance and AI are at the verge to take over the conventional modus operandi at organizations, energy efficient WSNs will certainly have an upper edge. This technology comprises of similar/dissimilar types of sensor, clever to monitor various environmental situations. The conventional areas where WSNs are proved to be successful include monitoring of temperature, pressure and relative humidity, etc. [1]-[4]. The other application domains include various aspects of everyday life and industry, like target tracking, precision agriculture, home appliance and inventory tracking, healthcare [3], [5].

Advancements in Wireless communication and MEMS technology made possible to the availability of 'smart sensors'. The acceptance and the convenience of modern micro WSNs are based on its capability to make the effective use of sensing units, data collection and processing modules and the energy efficient transmission protocols [6]. Wireless Sensor Networks (WSN) are a collection of very minute sensors spatially dispersed in an area of requirement, and are usually called nodes. These nodes have the capability of sensing the environment, can process the sensed information and are able to communicate among each other. These are usually controlled by a central station called Base station or Sink node. Due to miniature size, the powerful technology has wide spectrum of application domains varying from simple monitoring applications to critical operations like military surveillance etc. [6], [7].

The nodes in WSN are resource constrained and it work with the help of a backup battery which has a limited energy. In the case of all monitoring applications, energy efficiency is one of the dominant factors. Hence, in a less efficient network, as the battery drains out, the down nodes cannot communicate in the wireless sensor network. Since the nodes are independent after they are deployed in the interested area(s), once the sensor drains out, it is difficult to recharge the battery. Since the nodes have to run for a longer periods of time from months to years, consumption of energy is a crucial factor in these networks [8].

To develop an Energy efficient mechanism requires specific set of requirements which vary from one application to another. The major requirements include scalability, coverage, latency, Quality of Service, Security, mobility and robustness. There exists interdependency between the application requirements and the energy efficient protocols [3], [6], [9].

To improve the network life time in WSN different methods exist in the literature like data reduction mechanisms, optimization of radio modules, energy efficient routing and so on [10]-[13]. In this paper, we address the problem of energy consumption in multilevel heterogeneous WSN using clustered approach. In Clustered architecture, the nodes are organized into groups known as clusters. Each cluster has a Cluster Head (CH) and is responsible for coordinating and transmitting the data from nodes to the base station. By balancing the energy consumption (through rotating the CH), turning off certain nodes (while CH transmits data to BS) and improving network scalability, the specific advantages of clustered approach are attained [3], [5], [8], [14], [15]. It has been observed from the literature that researchers have developed various energy efficient protocols like LEACH,

TEEN, HEED, PEGASIS, SEP, DEEC, BEENISH, AEDEEC for both homogeneous and heterogeneous environments [19], [25], [20], [26], [21], [22], [27], [31].

There are various multilevel energy efficient protocols like LE-MHR, hetDEEC-3, MLHEED-N [28]-[30]. In this paper, we provide an extension to AEDEEC protocol up to seven levels by varying with different parameters such as initial energy values, location of base station (BS), distance metric and node density. We consider the energy parameters are 0.25, 0.5, 1.0 Joules and the location of BS are center and corner. We also use two distance metrics namely Euclidean and Manhattan which are widely used in the literature [19], [24], [27], [31]. The performance of the proposed protocol is analyzed under the above mentioned metrics.

The rest of the paper is organized as follows. Section 2 describes the related work. The proposed network model is discussed in Section 3 and Section 4 discusses the simulation results for analyzing the performance of our protocol. Finally, the paper concludes by providing some further research directions.

This paper is an extended and revised version of [31].

II. Related Work

Since the last couple of years wireless sensors have drawn many attentions to researchers because of its wide variety of applications in industrial and commercial [5], [17]. The major challenges in WSN are to maximize the network life, several approaches have been already proposed in the literature [7], [17]. This section deals with some of the existing protocols with clustering mechanism to improve the network life time.

W.B.Henizelman et al. [19] discussed the first protocol named LEACH (Low energy Adaptive clustering Hierarchy), is an adaptive clustering protocol, in which it performs the operation in two rounds known to be setup and steady state phases. In setup phase cluster are organized and in the next phase data are transmitted to base station. This protocol conserves the energy by means of randomized rotation of cluster heads and by aggregating the data. Even though it increase network life and uneven distribution of clusters can cause an impact on the performance of the network. Hybrid Energy efficient Distributed [20] algorithm is an energy efficient protocol in which it uses residual energy and node density as the parameters for the cluster head selection. HEED is a multi-hop protocol with hybrid approach, the nodes only require local information to form the clusters, and terminates the operation in O (1) iteration. Here also the communication overhead is more due to the random selection of cluster heads.

In [21], the authors discussed a stable election protocol (SEP) developed for heterogeneous environment. This protocol considered two kinds of nodes namely normal and advanced, in which the advanced nodes are equipped with more energy than the normal nodes. The CH is elected based on the initial energy of the node. The protocol improves the network life time and stability compared to LEACH. Kumar et al. [9] discussed an energy efficient heterogeneous clustered scheme (EEHC) for WSN, which has three levels of heterogeneity. The approach used here is weighed election probability for cluster head selection. EEHC is compared with the result with LEACH protocol and EEHC shows the better performance with a reliable network life time.

DEEC Protocol was proposed by [22] which also had two levels of heterogeneity as well multiple energy levels. Here the CH is selected based on the probability of residual energy and average energy of the network. Usually the node with higher energy level gets the higher chance of becoming the cluster head. DEEC performs better when compared to SEP and LEACH. DDEEC protocol [23] is an extension to DEEC and selects the CH based on the residual energy alone. Hence during the initial rounds, the advance node has the highest probability to become the cluster head. In the later stages, when the energy is dissipated, the advanced node will have the same probability as the normal node to become the CH. Saini and Sharma [24] introduced a new protocol namely E-DEEC which has three levels of heterogeneity normal, advanced and super nodes. It uses the same procedure as DEEC algorithm, with an extension to one more level called the super nodes, this protocol prolongs the network life time and stability period compared to DEEC algorithm.

BEENISH [27] is an energy aware protocol considered four levels of heterogeneity, selection of CH is based on residual and average energy of the network. It achieves longer stability period, increased network life time compared to the existing DEEC, DDEEC and E-DEEC. Recently, energy aware protocol was introduced namely, AEDEEC protocol [31] which uses four type of nodes. The approach uses the same as DEEC with varying distance metric and energy level parameters. The protocol performs 1.43 times better network life time when compared with DEEC, DDEEC and EDEEC.

In [28] the authors proposed a life time extended multilevel heterogeneous routing protocol (LE-MHR) which discussed both vertical and horizontal heterogeneity for k levels by varying heterogeneity parameters. The result shows better performance in terms of stability, distribution of cluster head and improvement of network life time compared to SEP, MCR and EEMHR.

Similarly Singh S [29] proposed n-level heterogeneity based HEED protocol and extended up to MLHEED-n. They have taken the residual energy and node density as parameter elements to choose the cluster head. The proposed approaches have taken n to be the value of six and it has shown increased throughput and reduction in energy consumption. Samayaveer Singh et.al [30] discussed a hetDEEC algorithm, with a single model parameter. When the single model parameter value is zero, it becomes homogeneous network; similarly it extends up to three levels. hetDEEC considers weighted election probability and threshold function to choose the cluster member and cluster heads. The proposed method shows improvement in network life time by utilizing the network energy efficiently.

Even though the attributes such as less complexity and quick path discovery are highly positive for single-hop route construction, it is incompetent to handle the network stability and load balancing. It struggles to discover the link in extensive networks and also the extension of network capacity is limited. Hence, by reducing both the packet drop count and the energy dissipation, multi-hop algorithms are preferred to satisfy the extended performance demand in all adverse conditions [16] – [18].

In this paper, we propose a protocol named EM-AEDEEC (Enriched Multilevel–Augmented Enhanced Distributed Energy Efficient Clustering Algorithm) which is an extension to AEDEEC protocol scheme that was discussed in the preliminary of this paper. In the proposed EM- AEDEEC, the network is deployed randomly by varying the energy level, location of base station and distance metric, we analyzed the performance of our EM-AEDEEC algorithm in terms of network life time. The proposed EM-AEDEEC initially selects the cluster head (CH) based on the energy level, and alters the CH at each epoch to reduce the pace of energy drain. Usually the nodes with higher initial energy are given priority to be elected as the CH. At the end of each round, a different CH is elected based on the residual energy of the nodes and average energy of the network. The neighboring nodes of each CH are elected separately using Manhattan / Euclidean distance. The result shows that the proposed EM-AEDEEC has higher network lifetime when use Manhattan distance metric and stability is more in Euclidean distance.

A. *Our Contributions*

This paper is an extension of AEDEEC protocol that was introduced by us in [31]. In that paper, we analyzed the performance of the network life time based on varying energy parameters, 0.25, 0.5 Joules and heterogeneity level up to 4 and are named them normal, advanced, super and ultra-super. In this revised version of the paper, we extend the energy heterogeneity to k levels, where k is a finite number. More specifically, we modify the energy efficient algorithm [24] that works for any finite k. The obtained results are presented in tables and figures to analysis the network life time and stability.

III. Our Proposed Protocol

In this section, we discuss the details of our proposed protocol, which is an extension to AEDEEC protocol obtained by modifying the distance metric and the levels of heterogeneity.

We consider a network model consisting of N number of sensor nodes which are randomly distributed over M * M region with one Base Station. The Base Station is located either at the center or at the corner. As the proposal deals with energy heterogeneity WSN, the nodes are differed by different energy values. For example if we consider only two levels of heterogeneity, we have two types of nodes namely, Normal nodes and Advance nodes. Normal nodes are claimed to be level l nodes and advanced nodes are level 2 nodes. The energy of level 1 node is less than the energy of level 2 nodes.

We extend this and consider up to k-level of heterogeneity where k=7. Let ` $E_0$ ` be the initial energy of node. The energy of other nodes are assigned according to the given energy model. Let ` $m_i$ ` defines the nodes of energy at each level.

We use the first order model reputed in [19], [22], [24]. The model describes about the energy dissipation of a data over a distance `d'. The Energy dissipated for transmitting and receiving j -bit message is given by equation eqn.1 and eqn.2 respectively.

$$E_{tx}(j,d) = \begin{cases} j * E_{elect} + j * \varepsilon_{fs} d_2 \ if \ d \le D \\ j * E_{elect} + j * \varepsilon_{mp} d_4 \ if \ d > D_0 \end{cases} \quad (1)$$

$$E_{rx}(j,d) = j * E_{elect} \quad (2)$$

where E_{elect} is the energy required to run the transmitter and receiver circuit. ε_{fs} and ε_{mp} represents the free space and multi path models respectively. ` d ` is the distance between the sender and receiver. The threshold Distance D_0 is evaluated by

$$D_0 = \sqrt{\varepsilon_{fs} / \varepsilon_{mp}} \quad (3)$$

A. *Cluster head election and selection methodology*

EM-AEDEEC protocol uses the same strategy of AEDEEC [31] for the cluster head selection, however the levels are extended to any fixed k using the eqn.4. Number of nodes in the k^{th} level is computed as follows,

$$n_k = n * m * \prod_{i=0}^{k} m_i * (1 - m_k) \quad (4)$$

The algorithm below discusses the procedure to elect the CH.

Algorithm: Cluster Head (N)

Input: p – Desired percentage of cluster heads
r - Current round
G – Nodes that has not been the cluster head for last 1/p rounds
Output: Cluster head

Begin Round

$\forall i \in N$, *choose* S_i^* *which has* max *energy*

$$E\, S_i^* = \max_{i \in N} E_i$$

$$CH = S_i^* \ if \ T(S) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \dfrac{1}{p} \right)} & if \ Si \in G \\ 0 & otherwise \end{cases} \quad (5)$$

End Round

The probabilities of the k are given by eqn.6; Threshold for the CH selection is calculated by substituting these equations in the eqn. 5 of the above algorithm.

$$P(i) = \frac{p * Ei(r) * (1 + a_j)}{k} \quad (6)$$

Where $a_{j=0}$ for level 1, $a_{j=c} + a_j \ \forall j > 0$. Let c be 0.25, 0.5, 1 and k is given by

$$k = 1 + \sum_{i=0}^{k} (m_i * a_i) * E_a \quad (7)$$

where $E_i\ (r)$ is the energy available and E_a is the average energy. The average energy is calculated by,

$$E_a = \frac{E_t * \left(1 - \frac{r}{r_{max}}\right)}{N} \quad (8)$$

where E_t the total energy, r_{max} denotes the total number of rounds of the network life time and N is the total number of nodes. The r_{max} is given by ,

$$r_{max} = \frac{E_t}{E_r} \quad (9)$$

where E_r is the total amount of energy which is dissipated in the network during each round and could be evaluated by

$$E_r = j\left(2NE_{tx} + NE_{DA} + K\varepsilon_{mp}\, d_1^4 + N\varepsilon_{fs}\, d_2^2\right) \quad (10)$$

Where E_{DA} is the data aggregation cost, d_1 is the average distance between the cluster head and sink and d_2 is the average distance between cluster members and cluster head. The distance d_1, d_2 and K could be calculated as in [22], [31].

Now the round is started and at the end of each round, the energy dissipated is reduced from the initial energy of the node by using the following equation, separately for cluster head and Normal nodes. Let E_{disch} is the energy dissipated at CH and E_{disnn} is the energy dissipated at Normal nodes.

$$E_{disch} = \begin{cases} j * \left(E_{tx} + E_{DA} + \left(\varepsilon_{mp} * j * d^4\right)\right) if\ d_{optBS} > D_0 \\ j * \left(E_{tx} + E_{DA} + \left(\varepsilon_{fs} * j * d^2\right)\right) if\ d_{optBS} \le D_0 \end{cases} \quad (11)$$

$$E_{disnn} = \begin{cases} j * \left(E_{tx} + E_{DA} + \left(\varepsilon_{mp} * j * d^4\right)\right) if\ d_{optCH} > D_0 \\ j * \left(E_{tx} + E_{DA} + \left(\varepsilon_{fs} * j * d^2\right)\right) if\ d_{optCH} \le D_0 \end{cases} \quad (12)$$

In the above discussed energy dissipation evaluation d_{optBS} and d_{optCH} are calculated using the Euclidean distance as given in equations.

$$d_{optBS} = \sqrt{(x_i - x_b)^2 + (y_i - y_b)^2} \quad (13)$$

Where (x_i, y_i) and (x_b, y_b) are the positions of cluster head and base station.

$$d_{optCH} = \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2} \quad (14)$$

Where (x_i, y_i) and (x_c, y_c) are the positions of cluster members and cluster head. In our proposed protocol, the parameter calculation of d_{optBS} and d_{optCH} is modified by using the Manhattan distance as shown in the equation below. The reason behind using this distance metric is to help the users to use the proposed protocol in real time environment deployment as well.

$$d_{optBS} = |x_i - x_b| + |y_i - y_b| \quad (15)$$

$$d_{optCH} = |x_i - x_c| + |y_i - y_c| \quad (16)$$

We describe the entire procedure of *proposed protocol* in the following algorithm.

Repeat

{

Begin Round

{

Step: 1 Choose the Cluster Head CH
Step: 2 Transmit the data from sensor nodes to CH
Step: 3 Transmit the data from CH to Base Station
Step: 4 Compute the Energy dissipation both at CH and Normal nodes

}

End Round

} Until number of rounds <= 7000.

IV. Results and Discussions

This section discusses the different scenarios considered for evaluation of the proposed protocol. The simulation shows a comparative analysis among Euclidean and Manhattan distance metric at varying parameters like node density, heterogeneity level and distance metric are evaluated and also compares the performance of proposed protocol with LE-MHR with grid size of 200 * 200.

A. *Simulation parameters and Scenarios created*

We evaluated the performance of proposed protocol o Intel® Core ™ i5- 7200U CPU @ 2.50GHz with 64-bit Operating System and implemented the proposed protocol on MATLAB 2017b. The radio parameters used for the simulations are shown in Table 1.

Simulations are performed in five different scenarios. The deployment network is tested under different cases of heterogeneity by varying the number of sensor nodes deployed, location of Base station and energy. if we consider a grid size of 100 * 100 with 100 sensor nodes deployed and 4 energy levels with 0.25J is the base energy and percentage of nodes at different levels is calculated using the eqn.4., as m =0.4, m_0= 0.3 and m_1=0.3 then, there will be 61 normal nodes with 0.25 J energy, 28 advanced nodes with 0.5 J energy, 8 super nodes with 0.75 J energy and 3 nodes with 1J energy.

Parameters	Value
Area of interest	(100,100)
Node density	0.01 ,0.005
E_0(initial energy)	0.25J,0.5J,1J
Size of message(j)	4000 bits
E_{tx}	50nJ/bit
E_{rx}	50nJ / bit
ε_{fs}	10nJ/bit / m^2
ε_{mp}	0.0013/pJ/bit/ m^4
E_{DA}	5nJ/bit/signal
p	0.1

Table 1. Simulation Parameters

B. Simulation results

The simulation results are given below, separately for five different cases (Case1 to 5)

1) Case1: Analysis of Network life time with location of base station as center and number of nodes, 100.

In this simulation we done the analysis of network life time of various heterogeneity levels in both Euclidean and Manhattan as the distance metric. Here we considered First node dead (FND) and Last node dead (LND) as the measures for analyzing the network life time. The notations used in the graphs are shown in Table 2. Figure. 1 and Figure. 2 show the FND and LND for a 100* 100 region with varying energy parameters 0.25,0,5 1J and heterogeneity levels 1,2,3,4,5,6,7 with location of the base station at the center. Based on the study, we can see that energy with 1J shows better results.

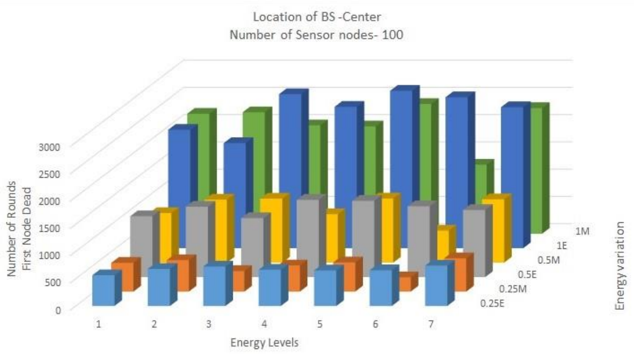

Figure.1. FND with Base station at center and 100 nodes

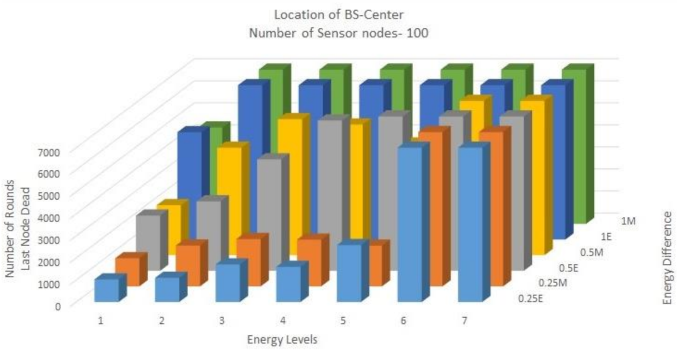

Figure. 2. LND with Base station at center and 100 nodes.

Energy Level	Explanation for Energy Difference (ΔE)
0.25 E	ΔE = 0.25 in Euclidean distance
0.25 M	ΔE = 0.25 in Manhattan distance
0.5 E	ΔE = 0.5 in Euclidean distance
0.5 M	ΔE = 0.5 in Manhattan distance
1 E	ΔE = 1 in Euclidean distance
1 M	ΔE = 1 in Manhattan distance

Table 2. Notations Used in the graph

2) Case 2: Analysis with location of base station as center and number of nodes to be 50.

By analyzing the projected network lifetime for the given energy levels in case-2(See Figure.3 and Figure.4), it is inferred that when the node density is less, the stability of nodes is increased, Here also the energy parameter at 1J shows better result when compared with other energy levels.

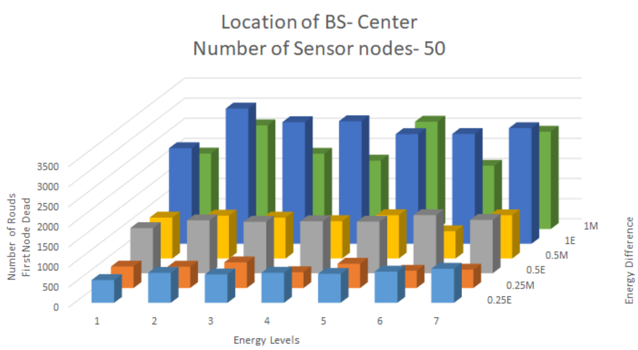

Figure. 3. FND with Base station at center and 50 nodes.

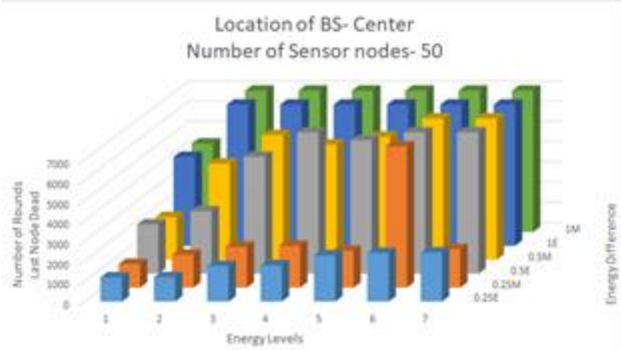

Figure. 4 LND with Base station at center and 50 nodes.

3) Case 3: Analysis with location of base station as corner and number of nodes to be 100

By the experimental study of placing the base station at corner with 100 nodes (see Figure.5 and Figure.6), clear the Manhattan shows the better performance for the last node dead. This indicates increasing the energy parameters have direct impact on the performance of the network.

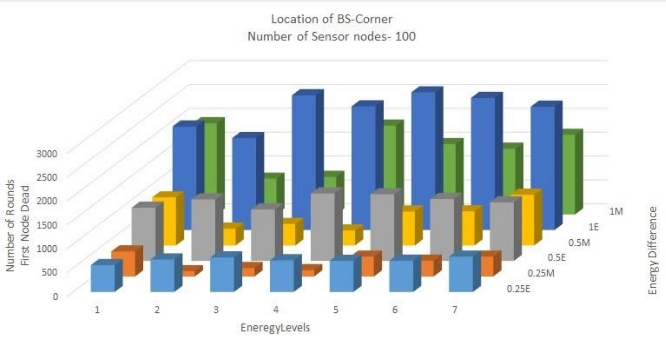

Figure. 5. FND with Base station at corner and100 nodes

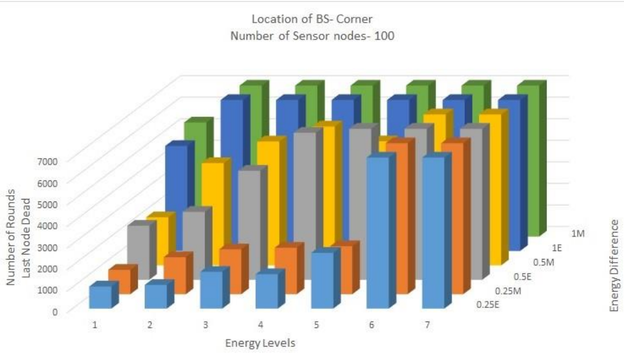

Figure. 6. LND with Base station at corner and 100 nodes.

4) Case 4: Analysis with location of base station as corner and number of nodes to be 50.

The remaining two figures (Figure. 7 & 8) show the performance of the network life time when we consider the base station at corner and nodes to be deployed is 50 in a 100 * 100 region If we analyze the network life time with FND,

.

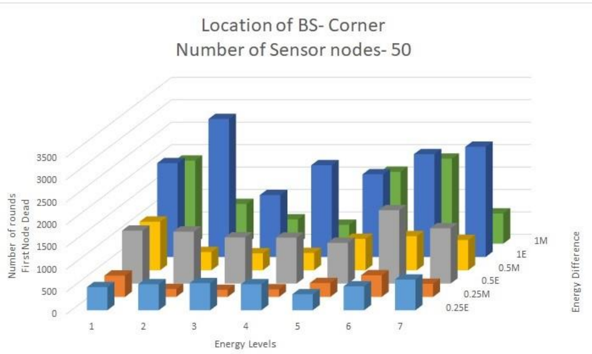

Figure. 7. FND with Base station at corner and 50 nodes

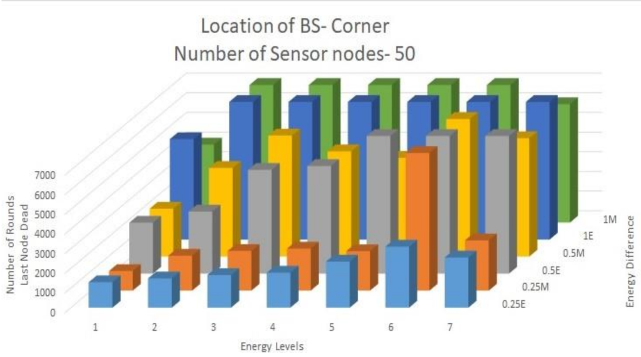

Figure. 8. LND with Base station at corner and 50 nodes

Euclidean metric shows better result compared to Manhattan at all energy levels, but LND will be at least 7% higher in Manhattan metric as minimum 7 nodes (irrespective of 50 * 50 or 100 * 100 grid size) are alive from level 5 and above even after 7000 rounds.

5) Case 5: Analysis on Network Life time.

For the analysis of network life time we consider the Last alive node (LNA) as the metric here. The performance is evaluated when the heterogeneity level is taken as the value of 5 and increasing energy level for higher heterogeneity with a grid size of 200* 200. From [28] we observe that the LNA is fluctuating between 3000 and 4000 rounds for 15 iterations and using that we plotted the graph and is presented in Fig. 9. For the First node dead and Quarter node alive, LE-MHR shows better performance compared to our protocol. Our protocol shows better performance when we consider LNA as the metric. It shows (see Figure.9) over 40% improvement in the network life time.

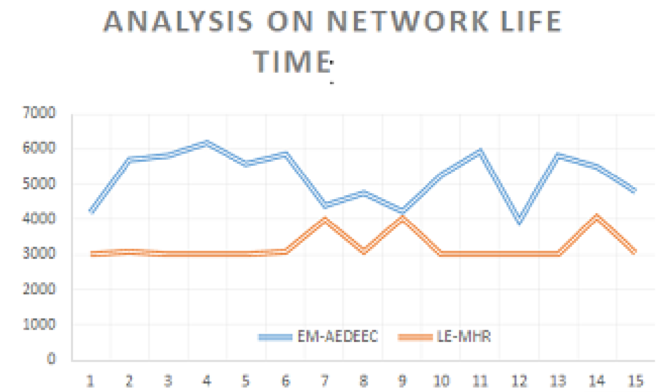

Figure. 9. Network Life time comparison among LE-MHR and EM-AEDEEC.

C. Discussions

In the preceding sub-section, a comprehensive evaluation and comparison are performed through five different cases (Case 1 – 5) to analyze the significance of various parameters in estimating the network lifetime. The EM-AEDDEC protocol has improved the network life time by nearly 40% (see Fig. 9) than the peer algorithm. Irrespective of the number of nodes deployed, if the base station is assumed to be at the center, Manhattan metric has outperformed Euclidean in LND. The LND under the former metric experienced an exponential leverage, particularly at higher energy levels. However the stability of the network is high when we use the Euclidean metric. Both the measures exhibit almost similar performance when the difference in the energy level is moderate or large.

The simulation is carried out with respect to the location of the base station and various node densities. The base stations are center and corner and the node densities are 100 and 50 with the grid size of 100 * 100. To compare the result with LE-MHR, we also considered the grid size 200 * 200 with node density 100. Table 3 which shows a sample data with respect to nodes density, consider to be 100, base station at the center with Euclidean and Manhattan distance metric.

Energy(J)	Protocol EM-AEDEEC	FND (E)	FND(M)
0.25	Level-4	665	478
	Level-5	652	534
	Level-6	656	261
	Level-7	739	456
0.5	Level-4	1417	888
	Level-5	1399	1176
	Level-6	1299	587
	Level-7	1230	1162
1	Level-4	2590	1969
	Level-5	2886	2380
	Level-6	2769	1266
	Level-7	2586	2304

Table 3. Analysis on different energy levels with distance metric, base station at center, Nodes: 100.

We considered FND dead as the performance measure for network stability and LND as the measure for Network life time. For the analysis of First node dead (Table 3) we have taken the data from level-4 to level-7. While considering the last node dead, energy level is analyzed, if the energy is 0.5 J and 1 J, results shows that even after 7000 rounds the few alive nodes are there in both Euclidean and Manhattan, the latter one have alive nodes ranging 5 nodes to 10 nodes, and former one 1 to 4 nodes. So, with Manhattan distance having node density 100, after 5th level, 7 nodes are alive. Thus, the simulation results show that when we increase the initial energy levels from 0.25 to 0.5 to 1.0, with Euclidean distance the stability is increased almost double (In Table 3, see FND for 0.25J, 0.5J, 1J) and with Manhattan distance the network life time is increased up to 7%.

V. Conclusion

In this paper, we have introduced a new protocol called EM-AEDEEC for energy aware hierarchical clustering scheme that can be applied to Heterogeneous Wireless Sensor networks. The heterogeneity is with respect to different energy levels of node. The CH selection was based on the initial energy at the starting stage and for further rounds, the election was made as per the residual energy and average energy. The residual energy was calculated based on the real-time distance metric called Manhattan distance as one of the parameters. The performance of the protocol was analyzed using network life time. From simulation experiments, we found that EM-AEDEEC increases the network energy life time when the energy level is higher and base station is placed at the center. The stability of the network is excellent when use Euclidean distance, but Manhattan metric shows 7% of improvement in the network life when we use higher energy levels.

The future focus that could be of interests are (i) one can extend this work to dynamic sink rather than a fixed sink (ii) in view of recent approach [13], one can substitute bio-inspired techniques for optimal cluster head selection (iii) design a multipath energy efficient algorithm for heterogeneous wireless sensor network.

References

[1] N. A. Pantazis, S. A. Nikolidakis, D. D. Vergados. “Energy efficient routing protocols in wireless sensor networks: a survey”, *IEEE Communications Surveys and Tutorials*, 15(2), pp. 551–591, 2013.

[2] Modieginyane, K. M., Letswamotse, B. B., Malekian, R., and Abu-Mahfouz, A. M. ”Software defined wireless sensor networks application opportunities for efficient network management: A survey”, *Computers & Electrical Engineering*, 66, pp. 274-287, 2018.

[3] T Rault, A Bouabdallah, Y Challal. ” Energy efficiency in wireless sensor networks: A top-down survey”, Computer *Networks*, (67), pp. 104-122, 2014.

[4] A .Aijaz and A. H. Aghvami, “Cognitive machine-to-machine communications for internet-of-things: a protocol stack perspective”, *IEEE Internet of Things Journal*, 2(2), pp. 103– 112, 2015.

[5] Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. “Wireless sensor networks: a survey”, *Computer networks*, 38 (4), pp.393-422, 2002.

[6] X. Liu. “A survey on clustering routing protocols in wireless sensor networks “, *Sensors*, 12(8), pp.11113–11153, 2012.

[7] S. Tanwar, N. Kumar and J. J. Rodrigues.” A systematic review on heterogeneous routing protocols for wireless sensor network*”, Journal of network and computer applications*, 53, pp. 39-56, 2015.

[8] Al-Karaki, N Jamal, A. E. Kamal. “Routing techniques in wireless sensor networks: a survey”, *IEEE wireless communications*, 11(6), pp. 6-28, 2004

[9] Kumar D, Aseri TC, Patel RB. “EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks”, *Computer Communications*, 32(4), pp. 662-667, 2009.

[10] R. Carrano, D. Passos, L. Magalhaes, C. Albuquerque. “Survey and Taxonomy of Duty Cycling Mechanisms in Wireless Sensor Networks”, *IEEE Communications Surveys & Tutorials*, 16(1), pp. 181–194, 2014.

[11] Kranakis E, Krizanc D, Williams E. “Directional versus omnidirectional antennas for energy consumption and k-connectivity of networks of sensors”. *In International Conference On Principles Of Distributed Systems,* pp. 357-368, 2004.

[12] Aksu H, Aksoy D, Korpeoglu I.”A study of localization metrics: Evaluation of position errors in wireless sensor networks”, *Computer Networks*, 55(15), pp. 3562-3577, 2011.

[13] Yan J, Zhou M, Ding Z. "Recent advances in energy-efficient routing protocols for wireless sensor networks: A review", *IEEE Access*, 4, pp .5673-5686, 2016.
[14] M. Dong, K. Ota, and A. Liu, "RMER: reliable and energy efficient data collection for large-scale wireless sensor networks", *IEEE Internet of Things Journal*, 3(4), pp. 511–519, 2016.
[15] A. I. Al-Sulaifanie, S. Biswas, and B. K. Al-Sulaifanie, "AHMAC: adaptive hierarchical MAC protocol for low-rate wireless sensor network applications," *Journal of Sensors*, 2017.
[16] Muhammad, A., Wang, F., Xiaopeng, Hu., Asad, M., and Munir, E. U, " Multihopping Multilevel Clustering Heterogeneity-Sensitive Optimized Routing Protocol for Wireless Sensor Networks", *Journal of Sensors*, 17, pp. 1 -14, 2017.
[17] Chandrasekaran, V, Shanmugam, A."A review on hierarchical cluster based routing in wireless sensor networks", *Journal of Global Research in Computer Science*, 3 (2), pp. 12-16, 2012.
[18] Muthukumaran, K., Chitra, K. and Selvakumar C." An energy efficient clustering scheme using multilevel routing for wireless sensor network", *Computers and Electrical Engineering*, 69, pp 642 – 652, 2018.
[19] W. B. Heinzelman, A. P. Chandrakasan and H. Balakrishnan. "Application-specific protocol architecture for wireless micro sensor networks", *IEEE Transactions on wireless communications*, 1(4), pp. 660–670, 2002.
[20] O. Younis and S. Fahmy. "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks", *IEEE Transactions on mobile computing*, 3(4), pp.366-379, 2004.
[21] G. Smaragdakis, I. Matta, A. Bestavros. 'SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks". Boston University Computer Science Department, 2004.
[22] L. Qing, Q. Zhu and M. Wang. "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks", *Computer communications*, 29(12), pp. 2230-2237, 2006.
[23] B. Elbhiri, R. Saadane, and D. Aboutajdine." Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks". In *Proceedings of the 5th International Symposium On I/V Communications and Mobile Network*, Rabat, pp. 1-4, 2010.
[24] P. Saini and A. K. Sharma." E-DEEC- Enhanced Distributed Energy Efficient Clustering scheme for heterogeneous WSN". In *Proceedings of the 1st International Conference On Parallel, Distributed and Grid Computing*, Solan, pp. 205-210, 2010.
[25] A. Manjeshwar and D. P. Agrawal. "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks". In *Proceedings of the 15th International Parallel and Distributed Processing Symposium.* , San Francisco, pp. 2009-2015, 2001.
[26] S. Lindsey and C. S. Raghavendra. "PEGASIS: Power-efficient gathering in sensor information systems". In *Proceedings of the* Aerospace Conference, Big Sky, MT, USA, pp-1125-1130, 2002.
[27] Qureshi TN, Javaid N, Khan AH, Iqbal A, Akhtar E, Ishfaq ,M. "BEENISH: Balanced energy efficient network integrated super heterogeneous protocol for wireless sensor networks", *Procedia Computer science*,19,pp.920-925, 2013.
[28] Tyagi S, Tanwar S, Gupta SK, Kumar N, Rodrigues JJ." A lifetime extended multi-levels heterogeneous routing protocol for wireless sensor networks", *Telecommunication Systems*, pp.43-62, 2015.
[29] Singh S." Energy efficient multilevel network model for heterogeneous WSNs", *Engineering Science and Technology, an International Journal*, 20(1), pp. 105-115, 2017.
[30] Singh S, Malik A, Kumar R. "Energy efficient heterogeneous DEEC protocol for enhancing lifetime in SNs". *Engineering Science and Technology, an International Jounal*, 20(1), pp.345-353, 2017.
[31] Zachariah, U. E., & Kuppusamy, L. An Augmented algorithm for energy efficient clustering. In *proceedings of International Conference on Intelligent Systems Design and Applications*, pp.617-626, 2018.

Author Biographies

Ushus Elizebeth Zachariah obtained her master's degree in Computer Science and Engineering from Satyabhama University, and she is doing her Ph.D. in wireless sensor network. She is currently working as an Assistant professor senior in the School of Computer Science and Engineering at Vellore Institute of Technology. Vellore.

Lakshmanan Kuppusamy received his Ph.D. from IIT Madras, India (2004), in theoretical computer science. He was an ERCIM postdoctoral fellow and did his postdoc in CWI, Amsterdam and INRIA, Rocquencourt. His research interests include formal languages and automata theory, game theory and bio inspired computing models. He has published more than 50 papers in international journals and in refereed international conferences. He is currently working as a professor in the School of Computer Science and Engineering at VIT, Vellore.