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hetADEEPS: ADEEPS for Heterogeneous Wireless Sensor Networks

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Abstract

The deterministic energy efficient protocol for adjustable sensing range (ADEEPS) is one of the important protocols for enhancing the lifetime of a wireless sensor network. This protocol however considers the underlying network of homogeneous nature. In this paper, we propose hetADEEPS (heterogeneous ADEEPS) protocol that considers the underlying network of heterogeneous nature. The heterogeneous network model is parameterized that has 3-level heterogeneity. The proposed model can describe 1-level, 2-level and 3-leel heterogeneity and accordingly the hetADEEPS is referred as hetADEEPS-1, hetADEEPS-2 and hetADEEPS-3. The performance of the hetADEEPS is compared with that of the hetALBP. The hetALBP is Load Balancing Protocol with Adjustable sensing range (ALBP) that has the underlying network of heterogeneous nature. As the level of heterogeneity increases, the network lifetime increases. Furthermore, decreasing the value of the model parameter increases the network lifetime.

Keywords: *Energy efficiency, sensor nodes, heterogeneity, lifetime, wireless sensor networks*

1. Introduction

The importance of wireless sensor networks (WSNs) lies in their applications in various areas such as military, floods, volcano, chemical plant monitoring, and many more applications. A WSN contains hundreds or thousands of sensor nodes, each equipped with a battery. Based on the battery of the sensor nodes in a WSN, their sensing, computing, and communication abilities are decided. A sensor node has the ability to sense an event in its surrounding. It can perform simple computations and communicate to its peers. It can also directly exchange information with the external base station if no sensor node is designated for that purpose. A sensor consists of processing unit, sensing unit, transceiver and power unit, which perform various functions in it. Depending on the application, a sensor may have some other units such as location finding unit and mobilizer. The utility of a WSN lies in the fact that it is easily deployable, less costly, and does not require a fixed infrastructure. The crucial application of a WSN is that it can be used to collect information in such environments wherein it is not possible in any other way [1, 2]. Besides their utilities in a variety of applications, the developments in MEM-based sensor technology have attracted researchers towards the WSNs. In last couple of years, different kinds of protocols have been developed as the traditional protocols are not suitable due to energy constraints in the WSNs [3, 4]. The energy of a WSN is the most critical parameter as it decides its lifetime. Therefore, it should be used most efficiently; otherwise the WSN cannot

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monitor the desired environment for a long time. A WSN is said to be homogeneous if, all sensor nodes in it have same battery life; otherwise it is said to be heterogeneous. There have been many studies for estimating the lifetime of a homogeneous WSN in literature [5-10] and accordingly several protocols have been designed. The common approaches used in the WSN protocols are clustering, adjustable sensing range, scheduling, and load balancing. There are several protocols that use clustering approach in homogeneous WSNs, but very few are meant for heterogeneous WSNs. Same is the case for non-clustering approaches and heterogeneous WSNs.

The load balancing protocol (LBP) [6] and deterministic energy efficient protocol for sensing networks (DEEPS) [7] are two important protocols that use load balancing and scheduling, respectively. These protocols have been further improved by incorporating the adjustable sensing range and these new protocols are named as load balancing protocol with adjustable sensing range (ALBPS) and deterministic energy efficient protocol for sensing networks with adjustable sensing range (ADEEPS), respectively [9]. In this paper, we discuss ADEEPS for the heterogeneous model of WSNs and call it as hetADEEPS. This underlying network model is capable to provide 1-level, 2-level and 3-level heterogeneity and accordingly the hetADEEPS is named as hetADEEPS-1, hetADEEPS-2, and hetADEEPS-3. Here 1-level heterogeneity refers to homogeneous network model in which all sensor nodes have equal amount of battery. Thus, the hetADEEPS-1 may also be called as homogeneous ADEEPS - the original ADEEPS. It is observed that the lifetime of a WSN is longer for using the hetALBP and hetADEEPS protocols than their respective original counterparts: ALBP and ADEEPS that are meant for homogeneous WSNs. Furthermore, the hetADEEPS performs better than the hetALBP for all levels of heterogeneity and, also, as the level of heterogeneity increases, the network lifetime increases. Same is the case if the value of model parameter decreases.

The rest of the paper is organized as follows. Section 2 reviews the related work and Section 3 discusses a 3-level heterogeneity network model for wireless sensor networks. Section 4 discusses the simulation results and, finally, the paper is concluded in Section 5.

2. Related Works

The main goal of a WSN protocol is to prolong the network lifetime so that a region can be monitored for longer time. Different approaches have been used in designing the WSN protocols that include clustering, adjustable sensing range, scheduling, load balancing, or their different combinations. The protocols that follow clustering approach include low energy adaptive clustering hierarchy (LEACH) protocol and its variants [11, 12], stable election protocol (SEP) [13], deterministic energy efficient clustering (DEEC) protocol [14], and energy efficient hierarchical clustering (EEHC) protocol [15]. The protocols that follow adjusting sensing range and scheduling techniques include LBP [6-8], DEEPS [7, 8], ALBPS [9, 10], ADEEPS [9, 10]. In a clustering protocol, the sensors are organized into clusters and some sensors are designated as cluster heads. A cluster head receives data from other sensors located in its cluster and transmits that data to the base station after aggregation. In some protocols such as hybrid energy efficient distributed (HEED) protocol [16], the cluster heads can receive data from the sensor nodes that are located in some neighboring clusters. Thus, these types of protocols use intra- and inter- cluster communication. In a protocol that follows adjusting sensing range and scheduling technique, all sensors have the capability to send/receive data to/from the base station; however, at any point of time, some sensors (not all sensors) are in active states that monitor the environment. Other sensors are in sleep or idle state so that they can conserve their energy for future use. The sensors in these types of protocols assume one more state, called vulnerable state. This state is a transitional state in which a sensor node decides to go to either active or sleep state. The main goal of these types of protocols is to keep minimum number of sensors in active state so that minimum possible energy is used by the network in monitoring. This helps prolonging the network lifetime. The load balancing protocol (LBP) [6] is one of the important protocols using above approach. It however requires homogeneous network model. In [7, 8], a deterministic energy efficient protocol for sensing networks (DEEPS) is discussed in which a target can be sensed by two or more sensor nodes. However, only one sensor that senses it with maximum energy becomes active sensor for that target and other sensors become idle. The DEEPS provides longer network lifetime than the LBP. The LBP [6-8] and DEEPS [7, 8] have been extended by providing adjustable sensing range. The resulting protocols, called ALBP and ADEEPS, respectively [9, 10], provide further longer network lifetime. It has been found that, using heterogeneity in a WSN, its lifetime can be increased [14, 15, 17, 18]. The work [13] discusses SEP protocol by considering 2-level heterogeneity in a WSN and [14] discusses distributed energy efficient clustering (DEEC) protocol by considering 2-level and multi-level heterogeneity. Both the SEP and DEEC protocols use same network model for 2-level heterogeneity. The SEP protocol has been extended as Deterministic–SEP (D-SEP) [19] that considers its original model for 2-level heterogeneity, for 3-level from [18] and multilevel from DEEC protocol [14]. In [20], LEACH protocol has been discussed for 2-level heterogeneity. The multilevel heterogeneity model for the DEEC protocol is an extension of 2-level heterogeneous model obtained by allocating different energy levels to the sensor nodes from a given energy interval.

In this paper, we discuss ADEEPS for heterogeneous network model, called hetADEEPS, and compare the results with that of the ALBP, called as hetALBP, for the same network model. We observe from the simulation results that the hetADEEPS provides longer lifetime than that of the hetALBP. Furthermore, the hetADEEPS-3 has longer network lifetime than that of the hetADEEPS-2 that in turn provides longer lifetime than that of the hetADEEPS-1 protocol. In next section, we discuss heterogeneity model for WSNs.

3. Proposed Heterogeneity Model

We represent our heterogeneous model using a single parameter for the sake of simplicity. The total network energy using the model parameter α (0< α <1) is defined in the following form:

$$E_{total} = \alpha * N * E_1 + \alpha^2 * N * E_2 + (1 - \alpha - \alpha^2) * N * E_3 \quad (1)$$

Here N represents the total number of nodes in the network. This model describes a network that can have 1-level, 2-level, and 3-level heterogeneity depending upon the value of the parameter α. The nodes may be referred to as type-1, type-2, and type-3 nodes, whose energies are denoted by E_1, E_2, and E_3, respectively. Without loss of generality, we may assume that $E_1 < E_2 < E_3$. The number of nodes of type-1, type-2, and type-3 are $\alpha * N$, $\alpha^2 * N$, and $(1 - \alpha - \alpha^2) * N$, respectively. The type-3 nodes are assumed to be in the smallest number as these are the costliest nodes and the type-1 nodes being cheapest are taken in maximum numbers. The number of type-2 nodes lies between the number of type-1 and type-3 nodes. If the value of parameter α is taken as zero, the model (1) consists of one type of nodes and the network model may be considered as having 1-level heterogeneity or homogeneous WSN. If the parameter α takes the value of $(\sqrt{5}-1)/2$, the model (1) consists of two types of nodes and the network model may be considered as 2-level of heterogeneity. This value of α indeed makes the third term in (1) as zero. This particular value of α is derived as a (positive real number) solution of the following equation:

$$1-\alpha-\alpha^2=0 \qquad (2)$$

The solution of (2) is $(\sqrt{5}-1)/2$, which is the maximum value, α can have. It may be mentioned that Eq. (2) has two solutions: one negative and one positive, but we are interested in positive one (0< α <1). For any value of α assuming values in the interval $(\alpha_{LB}, (\sqrt{5}-1)/2)$, the model (1) consists of three types of nodes and the network model may be considered as having 3-level heterogeneity. The value of α_{LB} is determined by the energy levels of all types of nodes (refer (4)) and its lower bound is determined (refer (10)). We need to define the parameter α in terms of different energy levels with the condition that, for $\alpha = 0$, E_3 should be equal to E_1. It can be satisfied for a positive real number n $\geq$2 by the following relation:

$$\alpha = \frac{E_3-E_1}{n*(E_3-E_2)} \qquad (3)$$

This relation (3) simply says that if there is one type of nodes in the network, then those nodes are made as type-1 nodes rather than type-3. For 3-level of heterogeneity, we need to have $\alpha \in (\alpha_{LB}, (\sqrt{5}-1)/2)$. Using the value of α from (3), we can have

$$\alpha_{LB} < \frac{E_3-E_1}{n*(E_3-E_2)} < \frac{(\sqrt{5}-1)}{2} \qquad (4)$$

It gives

$$n*\alpha_{LB}*(E_3-E_2) < E_3-E_1 \qquad (5a)$$

$$n*\left(\sqrt{5}-1\right)*E_2 < 2*E_1+(n*\left(\sqrt{5}-1\right)-2)*E_3 \qquad (5b)$$

We find out the value of $\alpha_{LB}$by solving (5a) with the constraints $E_1 < E_2 < E_3$.

Let $E_2 = \delta_1 E_1$ and $E_3 = \delta_2 E_2$, where $\delta_1 > 1$, $\delta_2 > 1$. Then, $E_3 = \delta_2\delta_1 E_1$ and (5a) gives

$$n*\alpha_{LB}*(\delta_2\delta_1-\delta_1) < \delta_2\delta_1-1 \qquad (6)$$

It may be written as

$$\delta_2\delta_1 < \frac{n*\alpha_{LB}*\delta_1-1}{n*\alpha_{LB}-1} \qquad (7)$$

Since δ_1 and δ_2 are positive quantities, the numerator and denominator both should be positive quantities. Thus, we have

$$n*\alpha_{LB}-1 > 0 \qquad (8a)$$

$$n*\alpha_{LB}*\delta_1-1 > 0 \qquad (8b)$$

From (8a) & (8b), we have

$$\alpha_{LB} > \frac{1}{n} \quad (9a)$$

$$\alpha_{LB} > \frac{1}{n*\delta_1} \quad (9b)$$

Thus, we have

$$\alpha_{LB} > max\left\{\frac{1}{n*\delta_1}, \frac{1}{n}\right\}$$

Since $\delta_1 > 1$, we have the lower bound of α, i.e. α_{LB} as follows:

$$\alpha_{LB} > \frac{1}{n} \quad (10)$$

We have three types of nodes for the value of α having in the interval $\left(\frac{1}{n}, \frac{\sqrt{5}-1}{2}\right)$ and the network has 3-level heterogeneity. Increasing the value of n will increase the range of α for 3-level heterogeneity. We have taken n as 2 in our simulation results.

4. Simulation Results

In this section, we discuss implementation of ADEEPS protocol for our heterogeneity model, *i.e.*, hetADEEPS-1, hetADEEPS-2, and hetADEEPS-3 as our model can describe 1-level, 2- level and 3-level heterogeneity of a WSN. Two energy models: linear and quadratic energy models are the commonly used energy models in literature [14]. We will also use them. The linear energy model is given by $e_p = c_1 * r_p$, where c_1, a constant, is given by $c_1 = \frac{E}{(\sum_{r=1}^{P} rp)}$ and e_p refers to the energy to cover a target at distance r_p. Here e is the network energy. The quadratic energy model is given by $ep = c_2 * r_p^2$ where c_2, a constant, is defined by $c_2 = \frac{E}{(\sum_{r=1}^{P} r_p^2)}$. We have taken monitoring area of size $100x100M^2$ that hosts 50 targets. The number of sensor nodes varies from 40 to 200 with maximum sensing range as 60M. The energy levels of sensor nodes are taken differently for different levels of heterogeneity. The input parameters used in our simulations are summarized in Table I.

We have implemented our proposed protocols in C++. We discuss the simulation results for various values of α. If we take $\alpha = 0$, there is one type of nodes in the network and the network can be referred as to have 1-level heterogeneity (homogeneous network). The implementation of ADEEPS for such type of WSNs has been termed as homogeneous ADEEPS protocol. The initial energy of a 1-level sensor node is taken as 2 joules, *i.e.*, $E_1 = 2J$.

Table 1. Simulation Parameters

Parameters	Symbols	Values
Number of sensors	S	40 ~ 200
Number of targets	T	50
Sensor initial energy	E_i	2J
Adjustable sensing ranges	(r_1, r_2)	60M
Communication range	r	2* sensing range
1- level heterogeneity	E_1	2
2- level heterogeneity	(E_1, E_2)	(2, 2.5)
3- level heterogeneity	(E_1, E_2, E_3, θ)	(2, 2.5, 6.5, 0.56)

For taking the value of α as $(\sqrt{5}-1)/2$, there are two types of nodes in the network and thus the network is referred as to have 2-level heterogeneity. In this case, the initial energies of type-1 and type-2 nodes are taken as 2J and 2.5J, respectively, *i.e.*, $E_1 = 2J$, $E_2 = 2.5J$. We have carried out simulations several times by taking different initial energies of the sensor nodes. In almost all the cases, we have obtained similar types of results; but we have shown results for a single input values because of the repetitive nature of results.

For the value of α that satisfies the inequality $\alpha_{LB} < \alpha < (\sqrt{5}-1)/2$, the network consists of three types of nodes, which are referred as type-1, type-2 and type-3 nodes. The type-3 nodes have maximum energy, type-2 nodes have less energy than the type-3 nodes and the type-1 nodes have less energy than the type-2 nodes. In this case, the initial energies of the sensor nodes have been taken as 2J, 2.5J, and 6.5J of type-1, type-2 and type-3 nodes, respectively, ($E_1 = 2J$, $E_2 = 2.5J$, $E_3 = 6.5J$). The energy E3=6.5J corresponds to $\alpha = 0.56$. In this scenario also, we have carried out simulations for several sets of initial energies of the nodes and in all cases we have got similar kinds of results. The results for the homogeneous ADEEPS, hetADEEPS-2, and hetADEEPS-3 are shown in Figures 1 and 2, for linear and quadratic energy models, respectively. These figures show graphs for network lifetime with respect to the number of sensors for the sensing range 60M and 50 targets using linear and quadratic energy models, respectively, for homogeneous ADEEPS, hetADEEPS-2 and hetADEEPS-3 protocols. It is evident from these figures that the hetADEEPS-2 protocol provides longer lifetime than the homogeneous ADEEPS protocol and the hetADEEPS-3 protocol provides longer lifetime than the hetADEEPS-2 protocol. We also observe from these figures that increasing the number of sensors increases the network lifetime. It is logically justified because increasing the number of nodes increases the network energy and hence the network lifetime.

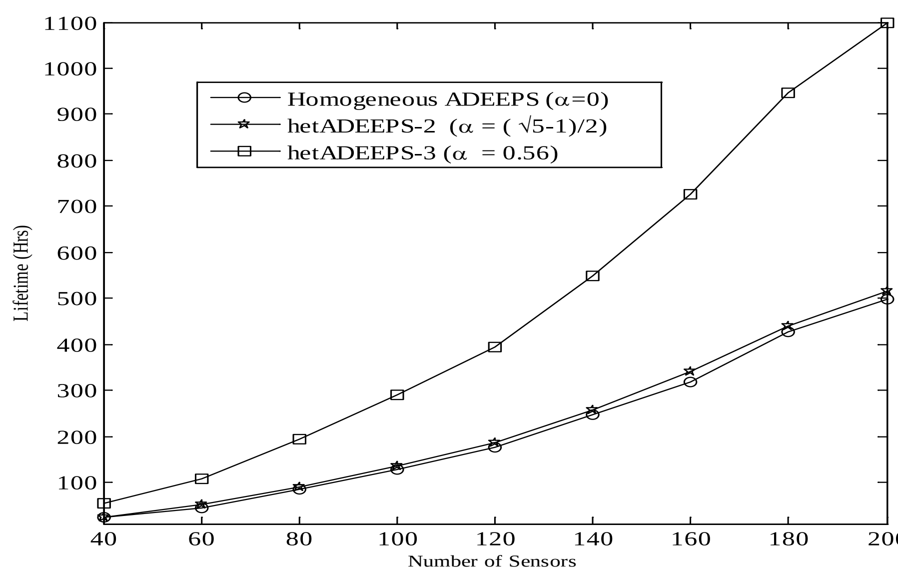

Figure 1. Lifetime vs. Number of Sensors with Sensing Range 60M for 50 Targets using Linear Energy Model

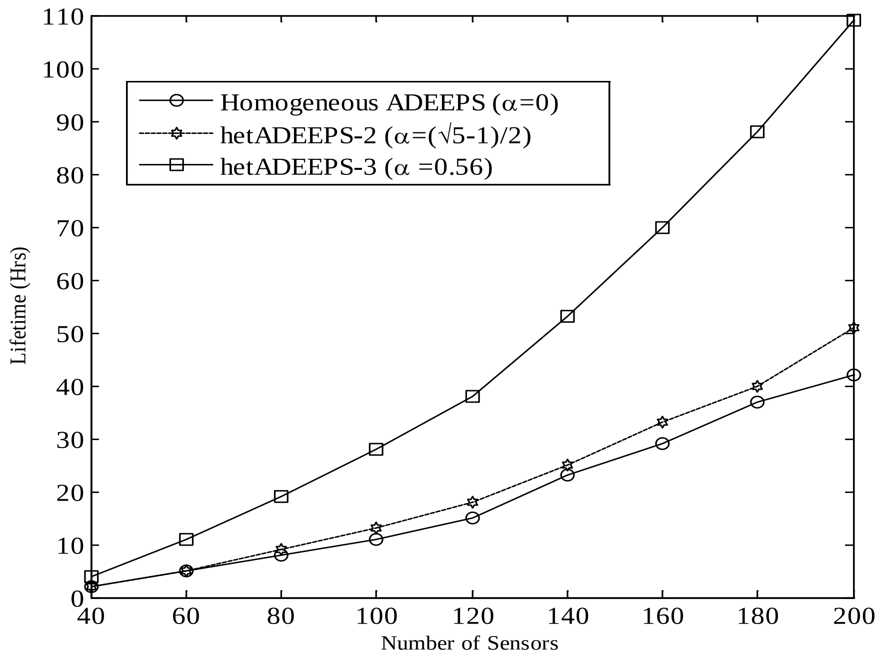

Figure 2. Lifetime vs. Number of Sensors with Sensing Range 60M for 50 Targets using Quadratic Energy Model

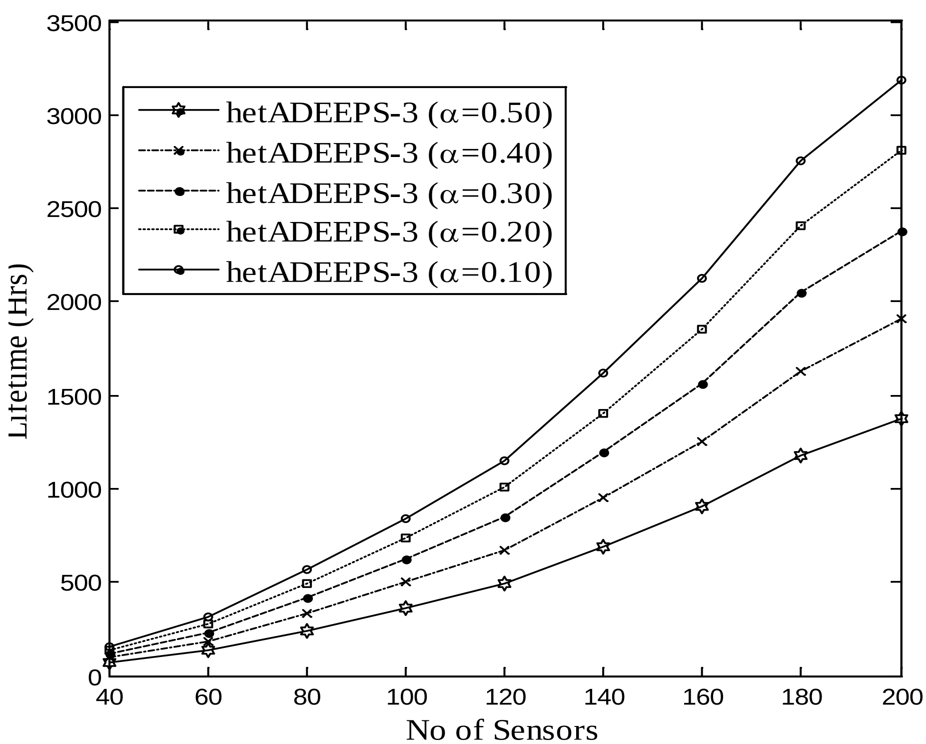

Figure 3. Lifetime vs. Number of Sensors for α = 0.10, 0.20, 0.30, 0.40, 0.50 in hetADEEPS-3 using Linear Energy Model

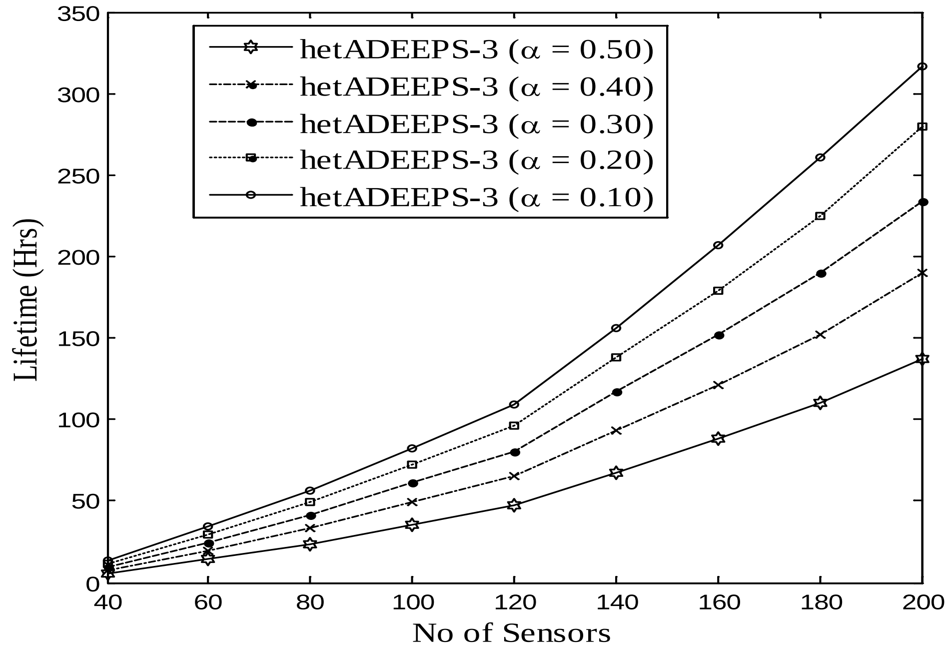

Figure 4. Lifetime vs. Number of Sensors for α = 0.10, 0.20, 0.30, 0.40, 0.50 in hetADEEPS-3 using Quadratic Energy Model

We have already seen in Figures 1 and 2 that the hetADEEPS-3 provides longest lifetime of the network for both linear and quadratic energy models. We now study the effect of the model parameter α on the network lifetime for hetADEEPS-3 protocol. Figs. 3 and 4 show the network lifetime for the hetADEEPS-3 protocol by taking α = 0.1, 0.2, 0.3, 0.4, 0.5 using linear and quadratic models, respectively, with respect to number of sensor nodes. The values of α = 0.1, 0.2, 0.3, 0.4, 0.5 correspond to the values of n = 12, 6, 4, 3, 2, respectively, for $E_1 = 2J$, $E_2 = 2.5J$, $E_3 = 6.5J$. As the value of α decreases, the network lifetime increases in both energy models. It is logically justified because as the value of α decreases, the contribution of type-3 nodes, which have maximum energy, increases and hence the network lifetime.

Another important parameter for network lifetime is the number of rounds when the first or/and last sensor node becomes dead. Table II shows the number of rounds when the first and last nodes become dead for linear and quadratic energy models. It is evident from this table that the first and last nodes become dead in more number of rounds using hetADEEPS-2 than that of the homogeneous ADEEPS and they become dead in more number of rounds using hetADEEPS-3 than that of the hetADEEPS-2 for both the linear as well as quadratic energy models.

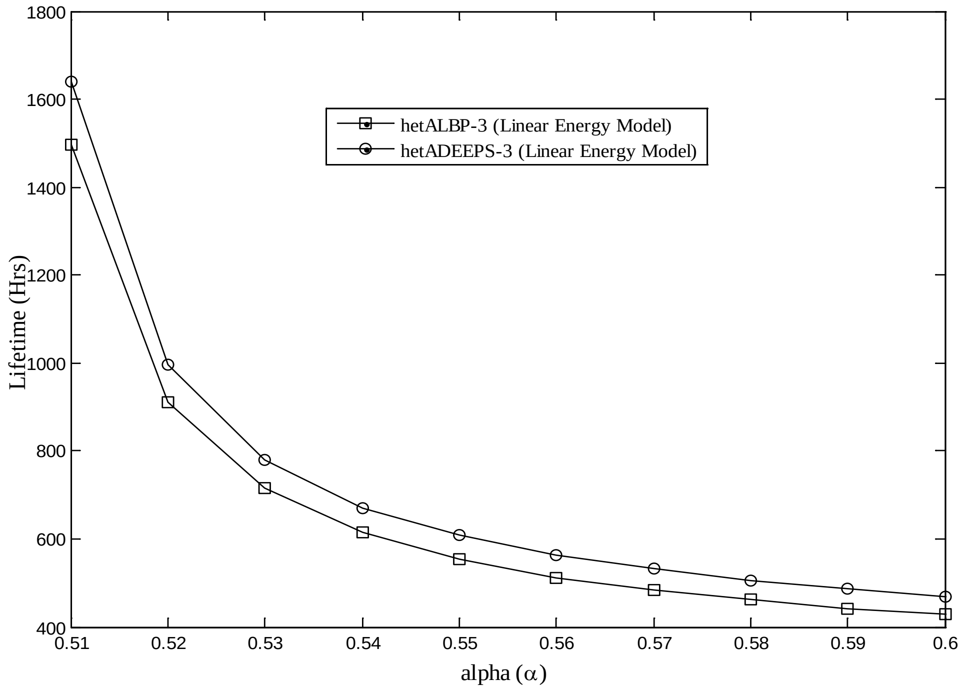

Figure 5. Lifetime vs. Model Parameter α using Linear Energy Model

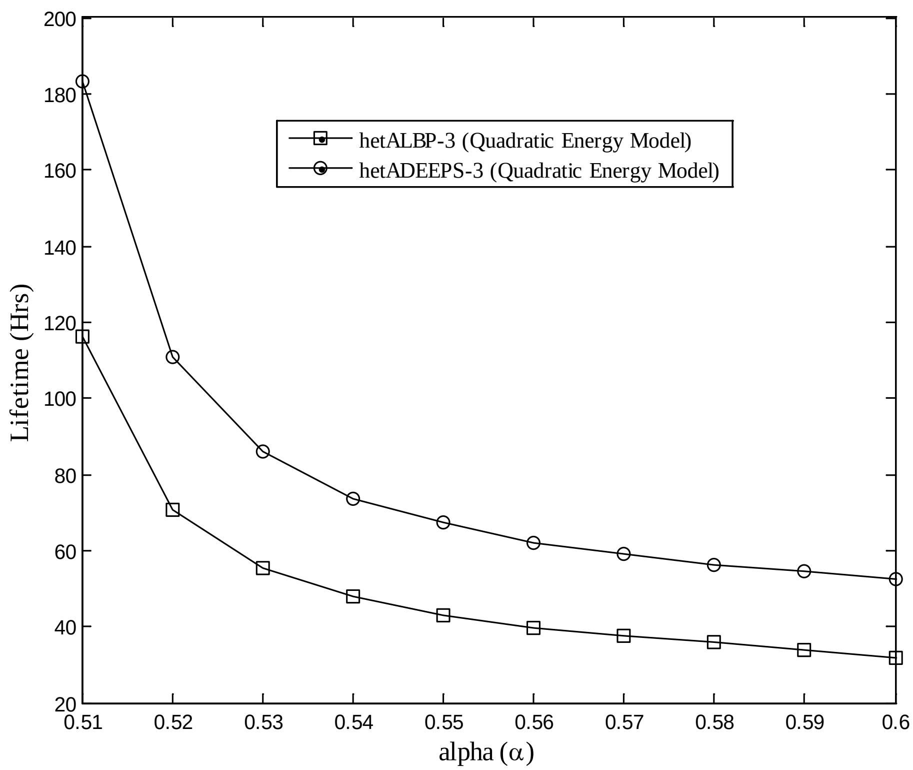

Figure 6. Lifetime vs. Model Parameter α using Quadratic Energy Model

Table II. Round Number when First and Last Nodes are Dead using Linear and Quadratic Energy Models in Homogeneous ADEEPS and Hetadeeps for 60M Sensing Range, 50 Targets, and 200 Sensors in 100x100m2

Sensing range: 60M, targets: 50, number of sensors: 200				
Cases	Linear energy model		Quadratic energy model	
	First node dead	Last node dead	First node dead	Last node dead
homogeneous ADEEPS	467	591	33	105
hetADEEPS-2	471	595	34	190
hetADEEPS-3	648	772	53	206

We have compared the results of hetADEEPS with that of the hetALBP protocol. The hetALBP protocol is nothing but the implementation of ALBP protocol using our heterogeneity model of the network. The homogeneous ADEEPS and homogeneous ALBP are simply ADEEPS and ALBP protocols. For the comparative performance of the ADEEPS and ALBP, one may refer [9]. The comparative results of the hetADEEPS-2 and hetALBP-2 protocols can be obtained when $\alpha = (\sqrt{5}-1)/2$. Though we have plotted the graphs for the network lifetime by varying the value of parameter α up to 0.6 using hetADEEPS and hetALBP protocols, yet it can be inferred from these figures that for $\alpha = (\sqrt{5}-1)/2$, the hetADEEPS-2 provides longer lifetime than the hetALBP protocol. As far as the hetADEEPS-3 is concerned, it gives longer lifetime than that of the hetALBP protocol as is evident from Figures 5 and 6 for linear as well as quadratic energy models.

5. Conclusion

In this paper, we have proposed hetADEEPS, an implementation of ADEEPS using the heterogeneity model of 3-level for wireless sensor networks. The model has been characterized by a single parameter, whose values help to describe 1-level, 2-level and 3-level heterogeneity of the network and accordingly the hetADEEPS of level-1, -2 and -3 has been discussed. The zero and $(\sqrt{5}-1)/2$ values of the parameter signify 1-level and 2-level heterogeneity, respectively. The 3-level heterogeneity is signified for the values of the parameter in the interval $\left(\frac{1}{n}, \frac{\sqrt{5}-1}{2}\right)$. The hetADEEPS provides longer network lifetime than the hetALBP - an implementation of the ALBP protocol using the same heterogeneity model for all levels of heterogeneity. It has also been observed that increasing the level of heterogeneity increases the network lifetime. Similar behavior has been obtained for decreasing the model parameter in the interval $\left(\frac{1}{n}, \frac{\sqrt{5}-1}{2}\right)$ in case of hetADEEPS-3.

References

[1] T. Arampatzis, J. Lygeros and S. Manesis, "A Survey of Applications of Wireless Sensors and Wireless Sensor Networks", Proceedings of the 13th Mediterranean Conf. on Control and Automation, Limassol, Cyprus, **(2005)** June 27-29, pp. 719-724.

[2] J. Yick, B. Mukherjee and D. Ghosal, "Wireless Sensor Network survey," Computer Networks, vol. 52, no. 12, **(2008)**, pp. 2292-2330.

[3] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless Sensor Networks: a Survey", Computer Networks, vol. 38, **(2002)**, pp. 393-422.

[4] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "A Survey on Sensor Networks", IEEE Communications Magazine, vol. 40, no. 8, **(2002)**, pp. 102-114.
[5] M. Cardei, J. Wu and M. Lu, "Improving network lifetime using sensors with adjustable sensing ranges", International Jour. of Sensor Networks, (IJSNET), vol. 1, no. 1-2, **(2006)**, pp. 41-49.
[6] P. Berman, G. Calinescu, C. Shah and A. Zelikovsky, "Power Efficient Monitoring Management in Sensor Networks", Proceedings of the IEEE Wireless Communication and Networking Conference (WCNC'04), Atlanta, **(2004)**, pp. 2329-2334.
[7] D. Brinza and A. Zelikovsky, "DEEPS: Deterministic Energy-Efficient Protocol for Sensor networks, Proc. of ACIS International Workshop on Self-Assembling Wireless Networks (SAWN'06), **(2006)**, pp. 261-266.
[8] A. Dhawan and S. K. Prasad, "A Distributed Algorithmic Framework for Coverage Problems in Wireless Sensor Networks", International Journal of Parallel, Emergent and Distributed Systems (IJPEDS), vol. 24, no. 4, **(2009)**, pp. 331.
[9] A. Dhawan, A. Aung and S. K. Prasad, "Distributed Scheduling of a Network of Adjustable Range Sensors for Coverage Problems", Proceedings of the International Conf. on Information Systems, Technology and Management (ICISTM'2010), vol. 54, **(2010)**, pp. 123-132.
[10] A. Dhawan and S. K. Prasad, "Energy Efficient Distributed Algorithms for Sensor Target Coverage based on Properties of an Optimal Schedule", Proceedings of the 15th Int. Conf. on High Performance Computing, HiPC'08, Springer, **(2008)**, pp. 269-281.
[11] W. R. Heinzelman, A. P. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", Proc. of 33rd Hawaii Int. Conf. on System Sciences, vol. 8, no. 8020, **(2000)**.
[12] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Transactions on Wireless Communications, vol. 1, no. 4, **(2002)**, pp. 660-670.
[13] G. Smaragdakis, I. Matta and A. Bestavros, "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks", Proceedings of the 2nd International Workshop on Sensor and Actor Network Protocols and Applications, **(2004)**.
[14] Q. Li, Z. Qingxin and W. Mingwen, "Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks", Computer Communications, vol. 29, **(2006)**, pp. 2230-7.
[15] R. B. Patel and D. Kumar, "HCEE: Hierarchical clustered energy efficient protocol for HWSNs", International Journal of Electronics Engineering, vol. 1, no. 01, pp. 123-126, **(2009)**.
[16] O. Younis and S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks", IEEE Transactions on Mobile Computing, vol. 3, no. 4, **(2004)**, pp. 660-669.
[17] Y. Mao, Z. Liu, L. Zhang and X. Li, "An Effective Data Gathering Scheme in Heterogeneous Energy Wireless Sensor Networks", Proceedings of the International Conf. on Computational Science and Engineering, **(2009)**, pp. 338-343.
[18] R. B. Patel, T. S. Aseri and D. Kumar, "Prolonging Network Lifetime and Data Accumulation in Heterogeneous Sensor Networks", International Arab Journal of Information Technology (IAJIT), Jordan, vol. 7, no. 3, **(2010)**, pp. 302-309.
[19] M. Bala and L. Awasthi, "Proficient D-SEP protocol with heterogeneity for maximizing the lifetime of wireless sensor networks", International Journal of Intelligent systems and applications, vol. 7, **(2012)**, pp. 1-15.
[20] L. Seghal and V. Choudhary, "REEH: Residual Energy Efficient Heterogeneous Clustered Hierarchy Protocol for wireless sensor networks", International Journal of Scientific and Engineering Research, vol. 2, no. 12, **(2011)**, pp. 1-5.

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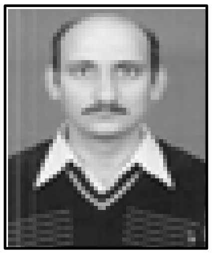

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