Heterogeneous-Aware Optimization in WSN

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Abstract:

Enabling (Wireless Sensor Network) WSN to efficiently handling complex functions needs judicious design for the network routing protocol. Heterogeneous network was proved to be outperforming homogenous network in terms of life time. In this work, Particle Swarm Optimization (PSO) was employed to optimize the parameters that govern the heterogeneity levels (initial energy, number of advance and intermediate nodes,….) in order to increase network stability and life time under the constraint of the cost materialized by the overall network initial energy. The proposed algorithm simulation was tested for two and three levels of heterogeneity and for two scenarios; fixed network nodes density and fixed node initial energy. The optimization results show that, the maximum network stability was achieved by increasing the nodes' initial energy to (0.6J), even that was at the cost of decreasing the number of network nodes to (61) nodes only. On the other hand, longest network life time equals to (6357) rounds can be verified when configuring some nodes in two heterogeneity levels with the maximum bound of extra energy level proposed in this work. A significant enhancement especially in network life time is noticed compared to previous protocols under the same constraints. 65% and 101% of life time are achieved for first and second scenario respectively comparing to un-optimized SEP protocol, while 68% and 24% of life time are achieved for first and second scenario respectively comparing to un-optimized SEP-E protocol.

Keywords: **WSN; Heterogeneous; PSO; LEACH; SEP.**

امثلة وعي اللاتجانس في شبكات الاستشعار اللاسلكي

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المستخلص :

إن تمكيين شبكات الاستشعار اللاسلكية من معالجة الوظائف المعقدة يحتاج الى تصميم عادل للبروتوكول الذي يقوم بتوجيه البيانات عبر هذه الشبكات. الدراسات السابقة أثبتت أن الشبكات الهجينة قد تفوقت في أدائها عن الشبكات المتجانسة في إطالة عمر الشبكة. في هذا العمل وظفت خوارزمية سرب الطيور للأمثلة لغرض أمثلة المعاملات التي تحكم مستوى التهجين (الطاقة الأبتدائية للمستشعرات, عدد المستشعرات المتقدمة والوسطية......) لزيادة استقرار الشبكة واطالة عمرها تحت محدد الكلفة المتثمل بالطاقة الابتدائية الكلية للشبكة. أن محاكاة الخوارزمية المقترحة قد تم فحصها لمستويين وثلاثة مستويات من التهجين وبأفتراض حالتين: ثبوت العدد الكلي للمستشعرات وثبوت الطاقة الأبتدائية للمستشعرات. أن نتائج الأمثلة بينت أن أعلى قيمة للأستقرار يمكن الحصول عليها بزيادة الطاقة الأبتدائية للمستشعرات الى (0.6J) حتى لو كان على حساب تقليل عدد المستشعرات الكلي الى (٦١) مستشعر فقط. من جهة أخرى, أن أطول عمر للشبكة (مساوي الى ٦٣٥٧) يمكن أن يتحقق عند المستوي الثاني للتهجين وعند زيادة الطاقة الأبتدائية لبعض المستشعرات الى القيم العليا المفروضة في هذا العمل. كما يمكن ملاحظة تحسن كبير خصوصا في عمر الشبكة بالمقارنة مع البروتوكلات السابقة تحت المحددات نفسها. ٦٥% و ١٠١% زيادة في عمر الشبكة قد تحقق قي الحالة الأولى والثانية على التوالي بالمقارنة مع SEP بروتوكول الغير مأمثل, في حين أن ٦٨% و ٢٤% زيادة في عمر الشبكة قد تحقق قي الحالة الأولى والثانية على التوالي بالمقارنة مع SEP-E بروتوكول الغير مأمثل.

1. INTRODUCTION

The reliability and sensing accuracy of WSN is governed by its life time that is limited by their small batteries which are difficult to be recharged or replaced. Accordingly, the data link protocols must be designed carefully in order to conserve network energy efficiently and prolong the life time as long as possible [1].

The earliest data link protocol was materialized by a single hop followed by a multi-hop network topology [2]. In a single hop network all sensor nodes transmit simultaneously to the Base Station (BS) like in Direct Transmission (DT) protocol [2]. The disadvantage of this topology is that nodes which are far away from the BS would die first. A multi-hop topology was then implemented by Minimum Transmission Energy (MTE) protocol as in [3]. At the contrary of single-hop network, MTE scarify the nodes that are allocated near the BS first, where these nodes acts like relays in multi hope environment [3].

Later new hierarchical routing protocols were proposed to solve the problem of balancing the load between the nodes. By implementing those protocols, the network is divided into clusters and each cluster is constructed from a set of member nodes and one Cluster Head (CH). CHs take the responsibility of gathering the data from the clusters member nodes, processing and re-transmitting these data to the BS. This procedure is performed per each round and the CH can be elected from the set of member nodes based on specific criteria. Low Energy Adaptive Clustering Hierarchy (LEACH) was the first hierarchal protocol proposed in [4] LEACH rotates the CH uniformly among all nodes in order to conserve the nodes energy fairly and hence extending the network life time.

Although LEACH protocol outperforms the single and multi-hop protocols in terms of network life time by balancing the energy usage and hence achieving better performance, it considers only homogenous network, where all nodes have the same energy. In reality not, all nodes experience the same energy consumption. For example, the nodes would be prone to different radio channel characteristics due to the random deployment. Also in some applications, it is valuable to re-energize the node's battery rather than employing extra nodes. Accordingly, a new Stable Election Protocol (SEP protocol) was introduced for heterogeneous network [5]. SEP implements heterogeneity by proposing two groups of sensor nodes (advance and normal nodes) with different densities and energy levels. By applying SEP, CHs are elected based on weighted election probabilities according to the remaining energy in each node. Compared to LEACH, SEP increases the stability period, which is the period before the first node die and it is critical period for many applications. Later, SEP is extended to SEP-E [6] in order to introduce more robust performance in terms of network life time. SEP-E introduces three levels of heterogeneity by deploying intermediate nodes with different density and energy level between normal and advance nodes. The effect of heterogeneity on the network performance is determined by the density and energy levels of the three types of nodes, which is to the best of the author knowledge has not been discussed yet. Accordingly this will be the first objective of this work to introduce a comprehensive study to investigate the role of these parameters in enhancing the network performance.

Many researchers' efforts were employed for analyzing and evaluating the homogenous and heterogeneous WSN protocols. In [7], the network performance according to different hierarchal protocols was compared in terms of life time and stability. The effect of heterogeneity with three levels of energy was discussed in [8], and the network performance for different routing protocols was analyzed. A comparison between homogenous and heterogeneous WSN for different hierarchical routing protocols was done in [1], the network performance was analyzed in terms of stability period and throughput. In [9], the WSN under different network area dimension was simulated and the network's alive nodes, Anumber of packets received by the BS and the energy consumption were based to evaluate the network performance when implementing LEACH and SEP protocols. The researcher in [10] showed that homogenous WSN can outperform heterogeneous WSN by translating the residual energy of heterogeneous WSN into extra node density in homogenous WSN for the same initial parameters.

All the above mentioned research investigated the role of hierarchal protocols and heterogeneity in prolong the network life time. A comparison between different classical routing protocols was done in order to evaluate the network performance under employing these protocols. At the same time, none of these research investigated the effect of protocols parameters' variation, or the limits of these parameters. [7] and [8] simulated the network under different levels of initial energy, while [1] discussed only the effect of heterogonous nodes density and the node priority to be a CH. The researcher in [9] was taken into account only two cases of advance nodes density and energy. For [10], the contribution was based only on the relationship between normal nodes density and average energy regardless the effects of other parameters.

This work aims to enhance the WSN performance by optimizing the heterogeneity parameters which are taken place over two dimensions; nodes density and nodes energy levels. Since these parameters values are hardly be decided and for seeking the network to best performance, PSO algorithm will be employed to optimize these parameters values in order to achieve more balancing for energy consumption which is materialized by network life time and stability.

The organization of this paper is as follows; section two reviews the theoretical aspects of homogenous and heterogeneous WSN protocols besides PSO algorithm that used for enhancing the performance. The system model is discussed in section three including the optimization procedure. In section four, the network simulation results is investigated and analyzed. Finally, section five summarizes the conclusion.

2. THEORETICAL BACKGROUND

In this section, the concept of homogeneity and heterogeneity and all important aspects which are related to them will be introduced. Also, PSO algorithm will be explained.

II.A Homogenous WSN

Heinzelman et.al introduced LEACH as the first hierarchal routing protocol for homogenous WSN, where each node is embedded by the same battery initial energy (Eo). They proposed that a WSN can be virtually divided into local clusters, where each cluster is composed from a set of member nodes and one node acts like CH. Each member node consumes a specific amount of its energy to transmit the data to the CH proportional to the data packet size and the distance, while the CH receives, processes and retransmits the packets to the BS at the cost of much intensive energy consumption. LEACH prolongs the network life time energy by randomly rotating the function of CH between nodes through many rounds, and hence evenly distributes the energy between the nodes [11]. The CH election decision is determined by comparing a random number r (between 0 and 1) to a threshold value $T(n)$ as in equation (1) [11]:

$$T(n) = \begin{cases} \frac{P_{pot}}{1-P_{pot}(r \bmod \frac{1}{P_{pot}})} & if\ n \in G \\ 0 & otherwise \end{cases} \qquad (1)$$

where, P_{pot} is the optimal probability of a node to become a cluster head, n is the number of total nodes. $T(n)$ ensures that nodes which are employed as CH in the last 1/ P_{pot} rounds will not be selected in the current round. It can be noticed that, even LEACH rotates the CH's randomly, but the election of CH is governed by two criteria; the predefined CH percentage and the number of rounds that the node has been a CH so far.

II.B Heterogeneous WSN

Heterogeneous WSN is two or three level of nodes' energy as introduced by SEP and SEP-E protocols in this paper [5] and [6]. By implementing SEP, two level of heterogeneity are verified by identifying some nodes as advance nodes with m% density and extra α% energy more than of the rest normal nodes. The probability for normal and advance node to be a CH are P_{nrm} and P_{adv} respectively which are given by [12] as below:

$$P_{nrm} = \frac{P_{pot}}{1+\alpha.m} \qquad (2)$$

$$P_{adv} = \frac{P_{pot}}{1+\alpha.m} \times (1+\alpha) \qquad (3)$$

It can be noticed that, CH is elected due to the node initial energy to the normal node initial energy. As a result advance nodes have higher probability to be CH more than normal nodes and this leads to increase the stability period.

For further energy efficiency usage, SEP-E considers three levels of energy, where b% nodes identified as "intermediate nodes" are equipped with μ% extra energy and it acts as intermediate level between advance nodes and normal nodes. The CH election probability is modified to be convenient with the three types of nodes to be respectively as given by [6]:

$$P_{nrm} = \frac{P_{pot}}{1+\alpha.m+b.u} \qquad (4)$$

$$P_{adv} = \frac{P_{pot}}{1+\alpha.m+b.u} \times (1+\alpha) \qquad (5)$$

$$P_{int} = \frac{P_{pot}}{1+\alpha.m+b.u} \times (1+u) \qquad (6)$$

II.C Particle Swarm Optimization

Kennedy and Eberhart in 1995 proposed a self-organized system inspired by the behavior of bird flocking identified as Particle Swarm Optimization (PSO). The algorithm based on multiple interactions, where information is interchanged between the neighbor particles and then spread all over the swarm. Each particle moves and changes its direction towards the optimal solution based on its previously best position has been visited ($pbest$) and the global best position has been visited by the swarm ($gbest$) as below [13] and [14]:

$$pbest(i,t) = \arg min\left[f\left(P_i(k)\right)\right], \quad i \in \{1,2,\ldots\ldots,N_P\}, \quad k = 1\ldots t \tag{7}$$

$$gbest(t) = \arg min\left[f\left(P_i(k)\right)\right], \quad k = 1 \ldots t, \quad i = 1 \ldots N_P \tag{8}$$

where i is the particle index, N_P the total number of particles, t the current iteration number, f the fitness function and P the position. Each particle updates its position according to its velocity which can be determined as in equation (9) and (10) below:

$$V_i(t+1) = wV_i(t) + c_1 r_1\left(pbest(i,t) - P_i(t)\right) + \quad c_2 r_2\left(gbest(t) - P_i(t)\right) \tag{9}$$

$$P_i(t+1) = \ P_i(t) + V_i(t+1) \tag{10}$$

where V denotes the velocity, ω is the inertia weight used to balance the global exploration and local exploitation, r_1 and r_2 are uniformly distributed random variables within range [0, 1], and c_1 and c_2 are positive constant parameters called “acceleration coefficients.” This process will be repeated till seek the optimal solution.

PSO has been widely used in optimizing different parameters in wireless communication network due to its flexibility and robustness. It can easily deal with non-differentiable fitness functions. Also it has implied parallelism so that it will be less liable to getting trapped on local minima besides having fast convergence. Accordingly PSO will be used for optimizing heterogeneity in order to seek the longest network life time as possible.

3. SYSTEM MODEL

In order to enhance the network performance, the system model is proposed based on optimizing different parameters that affect the heterogeneity. Different levels and heterogeneity degrees can be achieved by varying the density and the initial energy of different nodes.

The main assumption of this work is to maintain the overall network energy at fixed value which is depicted the network cost. The initial total energy mathematical model ($ET_{initial}$) for three heterogeneity levels is as below:-

$$ET_{initial} = N_T E_O \; [\; K_a \; (1 + L_a \;) + K_i \; (1 + L_i \;) + (K_n)]$$

where N_T is the total network node and Eo is the initial energy of normal nodes. L_a and L_i are the extra energy level for advance and intermediate nodes respectively, while K_a and K_i are the deployment density percentage of advance and intermediate nodes respectively. K_n represents normal nodes density percentage and equals to $(1 - K_a - Ki)$. The terms $K_a \; (1 + L_a)$ and $K_i \; (1 + L_i)$ have the dominate role in modifying the weight as will be discussed through next sections. Equation (11) can be rearranged as below:-

$$ET_{initial} = N_T E_O \; [\; 1 + K_a \; L_a \; + K_i \; L_i \;] \qquad (12)$$

III.A Heterogeneity with Various Energy Levels

In this case, L_a and L_i are varied in order to achieve different levels of heterogeneity, while K_a and K_i are assumed to be constant values as explained in cases below. Also, under the consideration of fixed network number of nodes (N_T), initial energy must be determined for all cases.

Case 1: Three levels of heterogeneity with different degrees can be verified when L_a and L_i are varied in the range [L_{min}, L_{max}] and $L_a \neq L_i$. The initial energy is determined as below:-

$$E_O = \frac{ET_{initial}}{N_T[1 + \; K_a \; L_a \; + K_i \; L_i \;]} \qquad (13)$$

Case 2: Two level of energy is implemented when L_a equals to L_i. Accordingly, two types of nodes will be identified normal nodes with initial energy (E_O) and advance nodes with extra energy (L_a) as adopted by SEP protocol. In this case (E_O) is determined as below:-

$$E_O = \frac{ET_{initial}}{N_T[1 + L_a \ (K_a \ + K_i \ )]} \qquad (14)$$

Case 3: Homogenous network (One level of heterogeneity) can be achieved when $L_a = L_i = zero$. In this case all nodes will have the same energy levels and considered as normal nodes with initial energy (E_O) as adopted by LEACH protocol below:

$$E_O = \frac{ET_{initial}}{N_T} \qquad (15)$$

III.B Heterogeneity with Different nodes density

In this case, K_a and K_i are varied in order to adjust different heterogeneity weight, while L_a and L_i are assumed to be constant values and ($L_a \neq L_i$) as explained in cases below. In all cases the initial energy (E_O) is assumed to be fixed, accordingly the total number of nodes (N_T) must be determined.

Case 1: Three levels of heterogeneity with different density degrees (SEP-E protocol) can be verified when K_a and K_i are varied in the range [$Kmin$, $Kmax$]. In this case n is determined as below:-

$$N_T = \frac{ET_{initial}}{E_O \ [1 + \ K_a \ L_a \ + K_i \ L_i \ ]} \qquad (16)$$

Case 2: Two levels of heterogeneity (SEP protocol) can be verified if $k_a \ or \ k_i$ equals to zero. In this case two types of nodes will be identified normal nodes and advance nodes. Accordingly, the total number of nodes (n) is determined as in below:-

$$N_T = \begin{cases} ET_{initial}/E_O \ [1 + k_a \ L_a], & if \ k_i \ = 0 \\ ET_{initial}/E_O \ [1 + k_i \ L_i \ ], & if \ k_a \ = 0 \end{cases} \qquad (17)$$

Case 3: Homogenous network (One level of heterogeneity) can be achieved when $k_a = k_i = zero$. In this case (n) will be equals to total number of normal nodes with initial energy (E_O) as adopted in LEACH protocol and can be determined as below:

$$N_T = \frac{ET_{initial}}{E_O} \tag{18}$$

Heterogeneity – Aware Optimization Model

Enhancing of network life time is materialized by optimizing the heterogeneity level and degree based on PSO algorithm. The solution is specified by two sets of variables d and e; the optimal node density (d_i^*) which is determined by the set $i \in K|\ K_{min} \leq\ d_i\ \leq\ K_{max}\}$and the optimal extra energy (e_i^*) which is determined by the set $\{i \in L|\ L_{min} \leq\ e_i\ \leq\ L_{max}\}$. The objective function depicts maximizing the network life time in terms of node's residual energy per each round (Er) as below:-

$$max\ \sum_r^R [\sum_x^{N_a} E_{r,x} + \sum_y^{N_i} E_{r,y} + \sum_z^{N_n} E_{r,z}] \tag{19}$$

$$\text{s.t}\quad \sum_x^{N_a} E_0(1+e_x) + \sum_y^{N_i} E_0(1+e_y) + \sum_z^{N_n} E_0 = ETinitail, \quad \forall r=1 \tag{19-a}$$

$$0 \leq\ \sum_x^{N_a} d_x\ \leq \frac{NT}{2} \tag{19-b}$$

$$0 \leq\ \sum_y^{N_i} d_y\ \leq \frac{NT}{2} \tag{19-c}$$

$$0 \leq\ \sum_x^{N_a} e_x\ \leq 1 \tag{19-d}$$

$$0 \leq\ \sum_y^{N_i} e_y\ \leq 1 \tag{19-e}$$

where, $E_{r,x}, E_{r,y}, E_{r,z}$ are the energy of advance, intermediate and normal nodes respectively in the rth round. N_a, N_i and N_n are the total number of advance, intermediate and normal nodes respectively. R is the maximum number of rounds such that :-

$$\begin{cases} \sum N_{dead} = 1 & for\ stability \\ \sum N_{dead} = N_T & for\ life\ time \end{cases} \tag{20}$$

where N_{dead} is the number of dead nodes. The condition in (19-b) ensures that the total initial energy of three types of nodes will maintain the predefined overall network initial energy. Equations (19-c---19-e) determine the minimum and maximum limits of K and L set respectively.

4. SIMULATION RESULTS AND DISCUSSION

The simulation is implemented for 100 nodes deployed randomly within 100m×100m square area. The BS is located at the center of the network area. All simulations are applied using Matlab version R2016b based on network's parameters that are illustrated in table (1) under the assumption of maintaining the overall network initial energy to 60J.

Table 1: some of parameters of network model

parameter	*value*
Packet size	4000 bits
Probability of mode to become cluster head	0.1
Transmit/Receive Energy	Eele= 50nJ/bit
Data Aggregation Energy	EDA=5nJ/bit
Transmitter Amplification d <= Threshold distance	Efs = 10pJ/bit/m2
Transmitter Amplification d> Threshold distance	Emp = 0.0013pJ/bit/m2

IV.A Heterogeneity Test Results for Various Energy Levels

In order to investigate the effect of various energy levels, La and Li are varied from (0) to (1) in step (0.1). Nodes deployment density assumed to be fixed (Ka equals to 0.1 and Ki equals to 0.2). The network is simulated as explained in section (III-A) and the simulation results are depicted in figures (1-3).

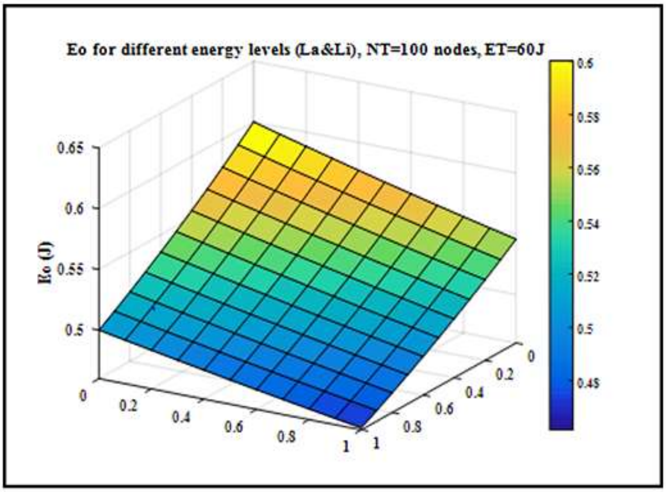


Figure 1: Eo for different energy levels

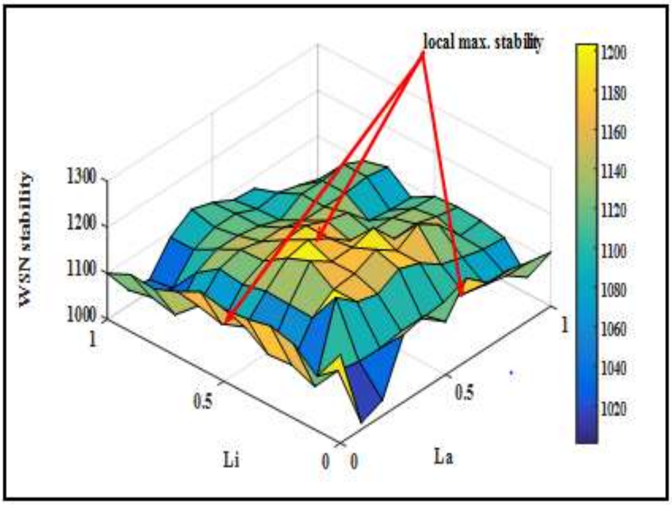


Figure 2: Network stability vs. different energy levels

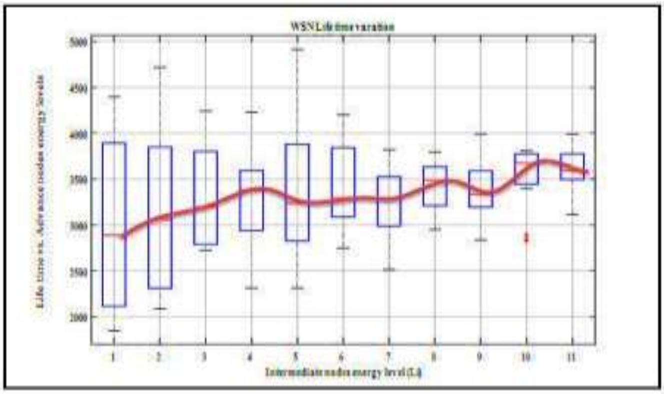


Figure 3-a: Network life time vs. intermediate node energy levels

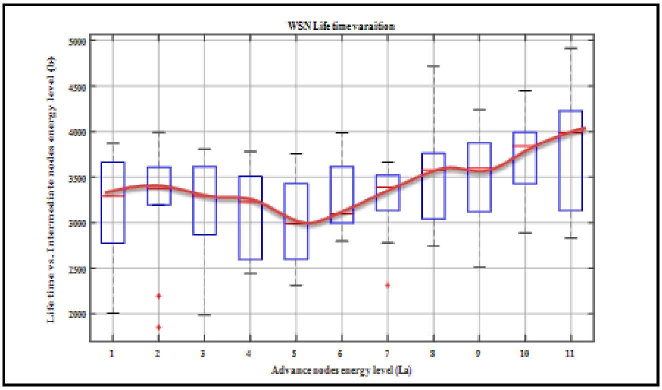


Figure 3-b: Network life time vs. advance node energy levels

Figure (1) shows that increasing heterogeneity degree by increasing the variance of energy between nodes would be at the cost of decreasing the normal nodes energy under the condition of maintaining the overall energy to a predefined value. Figure (2) represents the network stability period while varying the extra energy for advance and intermediate nodes. In general, it can be noticed the maximum stability period can be achieved almost when La equals to Li, also when La and/or Li equals to zero. That means low heterogeneity level produces long stability. In general, figures (3-a,b) show that, the average life time can be increased by increasing intermediate nodes and advance nodes energy levels. Also it can be noticed that, as Li increases, the effect of La would be restricted. At the contrary, at maximum La the variation in life time according to various Li are noticed.

IV.B- Heterogeneity Test Results for Different Nodes Density

In order to investigate the effect of different nodes deployment density, Ka and Ki are varied from (0) to (50%) in step of (5%). Nodes extra energy level assumed to be fixed (La equals to 1 and Li equals to 0.5). Figures (4-6) depicts the simulation results of this step.

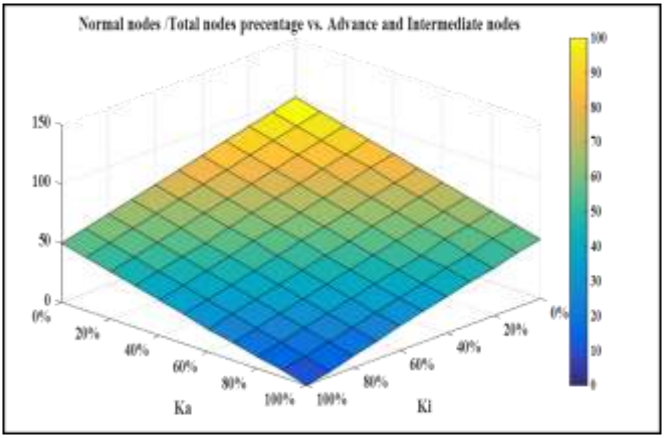


Fig. (4) The percentage of normal nodes vs. advance and intermediate nodes density

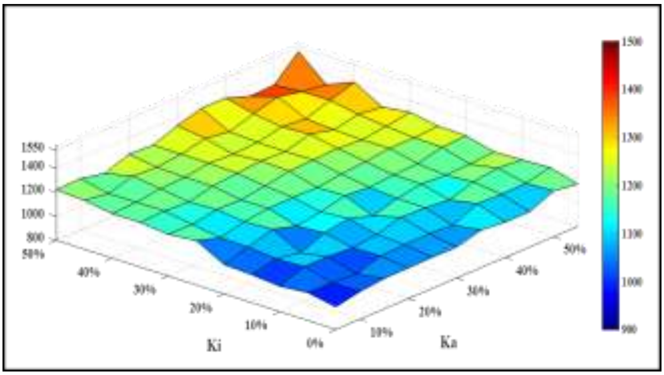


Fig (5) Network stability vs. advance and intermediate nodes density

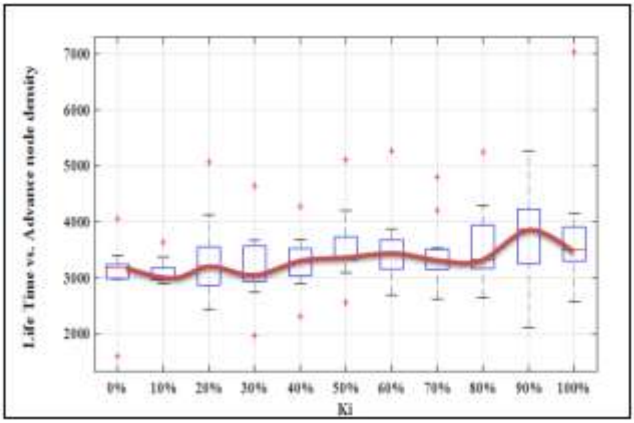


Fig. (6-a) Network life time vs. intermediate nodes density

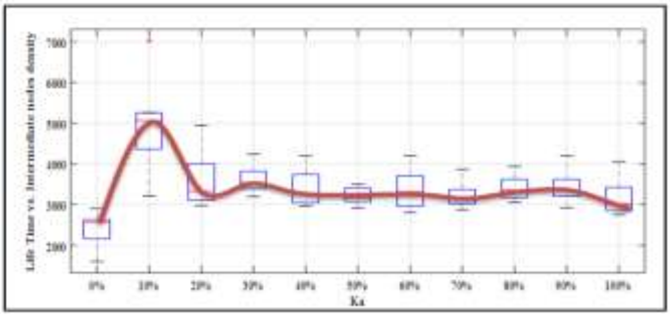


Fig. (6-b) Network life time vs. advance nodes density

Figure (4) depicts the ratio of normal nodes density to the total network nodes. Also, with constrained initial energy ($ET_{initial}$ and E_o), the maximum number of normal nodes is achieved with homogeneity (1-level of heterogeneity) and equals to total number of nodes (120). Figure (5) shows that the network stability is increased as heterogeneity approaches two levels (advance and intermediate nodes only). The results show that the stability is increased as the nodes energy increased, which results in decreasing the number of nodes to (69) under the condition of preserving the overall initial network energy. In general, it can be notice from figure (6-a and b) that the average network life time almost stay stable with the variation of both advance and intermediate nodes respectively. Under this simulation constraints, the maximum life time can be achieved at higher variation between advance and intermediate nodes density as the peaks in figure (6-a and b) are show.

IV. C. Heterogeneity Parameters Optimization Results

The network performance was investigated also when PSO was implemented. Two metrics were used for evaluation; life time and stability. Two scenarios were proposed for testing the network performance by simulated the proposed optimized algorithm; fixed network nodes density (N_T=100 nodes) and fixed node initial energy (Eo=0.5J). Some penalties were imposed to ensure the simulation at two and three heterogeneity levels.

Figure (7) depicts the network stability, while the numerical results are illustrated in tables (2) and (3). It can be noticed that the stability is increased as the heterogeneity levels decreases. Even that three levels of heterogeneity of the second scenario looks like scored the maximum stability, but when comparing the numerical results, it can be found that La approximately equals to Li which again return the network near two heterogeneity levels configuration. Also, scenario two simulation results indicate better network stability. This because the proposed algorithm optimizes the extra energy level of advance and intermediate nodes in such a way that the initial energy of these nodes might be maximized even at the cost of total number of nodes. Also, generally the three levels of heterogeneity converged slower than two levels of heterogeneity due to the time required to optimize more parameters.

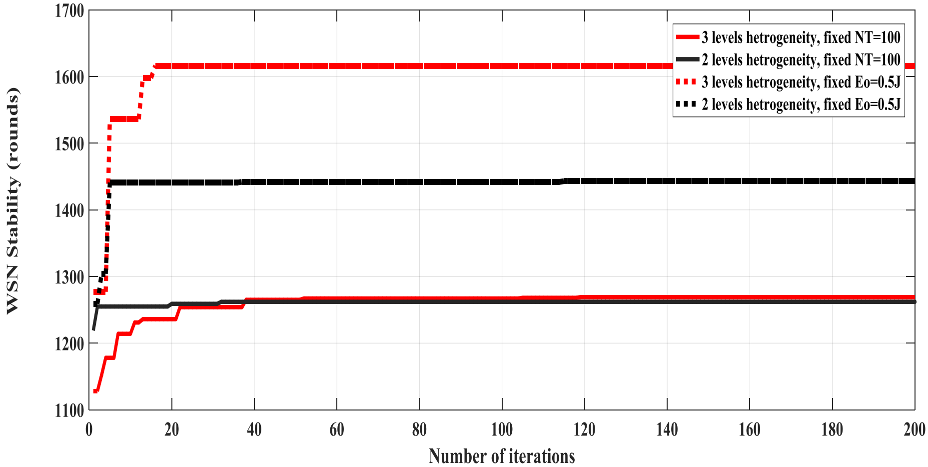


Fig. (7) Network stability vs. PSO algorithm iterations

Figure (8) depicts the network performance in terms of life time, which increases through progressing of the optimization procedure iterations till it converged after 200 iterations to the numerical results illustrated in tables (2) and (3) for two and three levels.

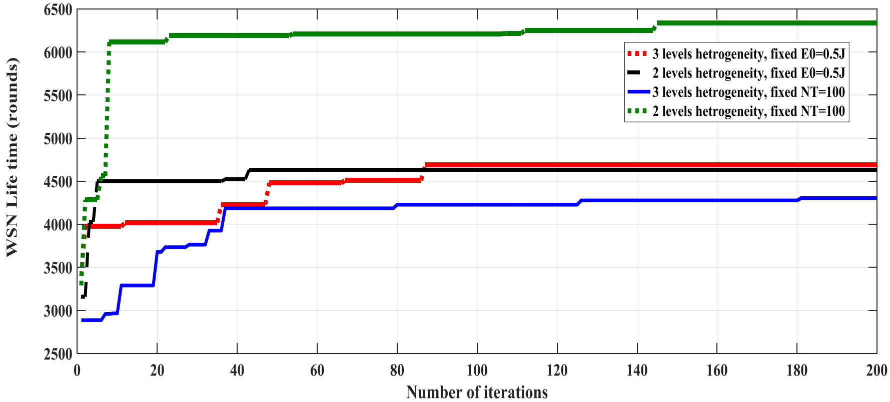


Fig. (8) Network life time vs. PSO algorithm iterations

In the first scenario, network with two levels outperforms network with three levels of heterogeneity in terms of life time. The results show that only one advance node with double initial energy is required to achieve 6339 rouds for life time. For the second scenario, the network life time achieved by both two and three levels are almost equal. It can be noticed that, the intermediate nodes approaches the normal nodes initial energy level. This indicates that, under the constraint of this scenario, the network may perform better with two levels of heterogeneity.

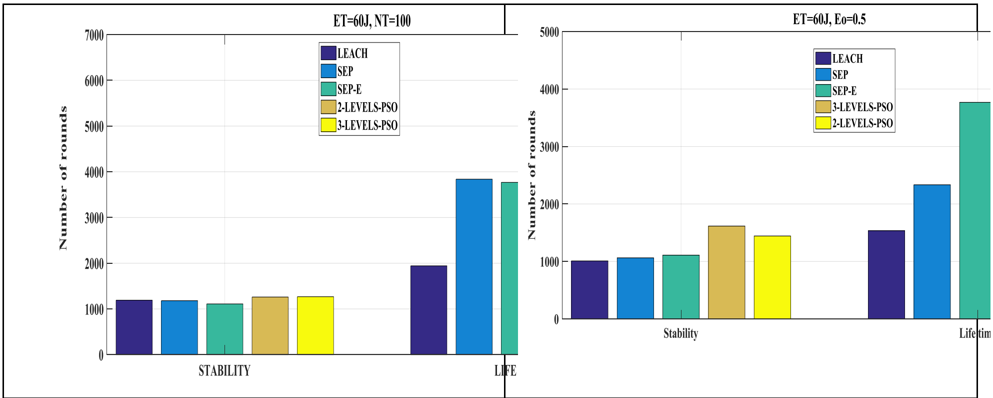
Table (2) optimized parameters for a fixed NT scenario

Heterogeneity levels	Stability						Life time					
	Ka	La	Ki	Li	Eo	Rounds	Ka	La	Ki	Li	Eo	Rounds
Two	10 %	0.609	0	0	0.567	1261	1%	0.999	0	0	0.595	6357
Three	34 %	0.2	27 %	0.178	0.540	1268	23 %	0.8009	29 %	0.0842	0.494	4303

Table (3) optimized parameters for a fixed Eo scenario

Heterogeneity levels	Stability						Life time					
	Ka	La	Ki	Li	NT	Rounds	Ka	La	Ki	Li	NT	Rounds
Two	86%	0.995	0	0	65	1443	74%	1	0	0	88	4633
Three	26%	0.937	73%	1	61	1616	19%	0.87	29%	0.0911	100	4688

In figure (9), a comparison has been performed to evaluate the network performance in terms of stability and life time between LEACH,SEP and SEP-E protocols (based on predefined parameters values (as proposed in [4],[5] and [6]) with the proposed optimized protocol. It can be noticed that the enhancement is significant in the network life time.



9-A FIRST SCENARIO | 9-AB SECOND SCENARIO

Fig. (9) Network stability and life time comparison

5. Conclusion

From the all above mentioned simulation results, it can be concluded that the network stability and life time are governed by many effective parameters which may be varied according to practitioners needs. In this work, an exhaustive research was first performed to evaluate the network performance under the conditions of fixed network density and overall initial energy respectively. It can be concluded that the network configurations that seeks to the required performance cannot be determined unless implementing an optimization algorithm in order to reduce the complexity and conserving time as well as efforts. Accordingly, PSO algorithm was used to prolong the network stability and life time. For both implemented scenarios (with their constraints), the results show that the node initial energy is the major factor that affects the network stability. This achieved in the first scenario by either increasing the extra energy for intermediate nodes, where 1268 rounds indicate the maximum stability achieved when the initial energy for intermediate nodes are doubled. Also, increasing the initial energy level of normal nodes will results in increasing the stability, where 0.56J of normal nodes energy even with low advance node density increasing the stability to 1261 rounds. In the second scenario, increasing the node initial energy was implemented at the cost of total network nodes, where maximum stability is achieved (1616 rounds) when doubling the initial advance and intermediate nodes energy.

For network life time and for both scenarios, it can be concluded that, a significant enhancement can be achieved by dedicating an extra energy level to some network nodes. In general, under this work's constraints, two levels outperform and three levels of heterogeneity are noticed. The maximum life time equals to 6357 rounds is achieved when increasing Eo to almost 0.6 J.

A significant enhancement especially in network life time is achieved equals to 226%, 65% and 68% compared to LEACH, SEP and SEP-E respectively for the first scenario, while 205%, 101% and 24% are achieved compared to the same mentioned protocols for the second scenario.

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