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ANALYZING THE HETEROGENEOUS AND HOMOGENEOUS WSN_S IN THE TERM OF TOTAL ENERGY CONSUMPTION

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Abstract: Energy consumption is the most important issue in the design of Wireless Sensor Networks (WSNs). This paper analyzed the performance of Stable Election Protocol (SEP) and Extension of Stable Election Protocol (SEP-E), in term of total energy consumption as a heterogeneous networks. Based on the calculation of total energy for such protocols new equations are derived to calculate the average energy for each protocol. A homogeneous network with same parameters of SEP and SEP-E, equal number of nodes and the initial value of energy is equal to the calculated average value is proposed. Simulations are applied using Matlab Package to compare the performances of heterogeneous networks with the proposal homogeneous network. The results showed that the performance of proposed network is out performed each SEP and SEP-E by relative amount of rounds. On the other hand, the extra amount of total energy of heterogeneous networks is assumed as extra number of nodes for proposed network. The extra nodes are assumed as sleeping nodes for such network and simulation is applied. The results confirmed that relative improvements are obtained in the stable period of new network. In addition to the relative improvements, another benefit is to get rid of the limitations imposed by heterogeneous network like immobile nodes which give more flexibility for homogeneous network.

Keywords: *Wireless Sensor Networks, Energy Consumption, SEP, SEP-E.*

تحليل شبكات الاستشعار اللاسلكية المتجانسة وغير المتجانسة من مدى الطاقة الكلية المستهلكة

الخلاصة: استهلاك الطاقة هو من العوامل المهمة في شبكات الاستشعار اللاسلكية (WSNs). في هذا البحث تم تحليل اداء برتوكول الانتخاب المستقر (SEP) وكذلك بروتوكول الانتخاب المستقر المتمدد (SEP-E) من ناحية استهلاك الطاقة كشبكة غير متجانسة. واستنادا الى حساب الطاقة الكلية لهذين البروتوكولين تم اشتقاق معادلات لاحتساب معدل الطاقة الابتدائية لكل نقطة استشعار. تم اقتراح شبكة متجانسة باستخدام ذات العوامل في SEP و SEP-E ولعدد من المستشعرات مساوي لها ايضا مع استخدام معدل القيمة التي تم احتسابها. تم اجراء المحاكاة باستخدام الماتلاب لمقارنة اداء الشبكة الغير متجانسة مع الشبكة المتجانسة المقترحة. النتائج بينت ان الشبكة المقترحة تتقدم تلك الشبكتين الغير متجانستين اعلاه بعدد نسبي من الدورات. من ناحية اخرى تم اعتبار الزيادة في الطاقة للشبكة المقترحة كعدد زائد من نقاط الاستشعار للشبكة المقترحة واعتبارها كنقاط نائمة احتياطية وتم تطبيق المحاكاة لهذه الشبكة وبينت النتائج ان زيادة نسبية طرأت على فترة الاستقرار للشبكة المقترحة بالاضافة الى تحسن نسبي فانه تم تجاوز المحددات الخاصة بالشبكات اعلاه الغير متجانسة وهو يمكن ان تكون الحركة حرة للمستشعرات بالأضافة الى المرونة التي توفرها الشبكة المتجانسة.

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1. Introduction

Wireless Sensor Networks (WSNs) is one of the most important applications of wireless communications at present, which drew the attention of many researchers to develop multiple applications such as the monitoring of environments, health care, security, tracking and military applications. Any sensor node consists of transducer are used to transform the surrounding environment into electrical signal, Analog to Digital Converter (ADC), computing and store of data, radio system and power equipment. The major portion of energy consumed is called as the communication unit of WSNs [1]. The nodes are typically wireless transceiver and powered by non-recyclable battery making nodes as it lives until the battery dies out, so that it has limited energy. In other word, WSN are inherently resource constrain and have limited processing speed, communication bandwidth and storage capacity. In addition, WSNs are responsible for self-organizing infrastructure network; resulting in administrating development which is capable of observing and reacting to a phenomena in a particular environment. It is necessary during the node's applications that the energy consumption should be controlled knowingly and must be managed in an efficient manner [2].

WSNs need to pass their data to main location or sink through a network to enable user to observe and analyze. WSNs are an array of hundreds of thousands of sensor nodes that are interconnected by a communication network. The network is often unreliable, because there can be a node failure that leads to reconfiguration of the network and re-computation of the routing path resulting in delay when choosing long routs which leads to network lifetime [3]. The main goal of WSNs designer is to build an energy efficient routing protocol.

If each node starts to transmit its own data in the network consisting of huge number of nodes to a fixed or mobile base station directly or through a series of nodes. In WSNs the routing is very challenging because each one is differ from other due to its characteristics. In [4] the authors discuss routing algorithms for wireless networks with the goal of increasing the network and node life.

Numbers of various routing protocols have been previously proposed based on the network structure which can be classified into three main categories, flat, location-based and hierarchical [5]. Latter type brought great attention because of the results achieved in energy saving and minimize the energy dissipation in WSNs. Low-Energy Adaptive Clustering Hierarchy (LEACH) [6] is one of the famous Hierarchical network routing. A clustering-based routing protocol minimizes global energy usage by distributing the load to all nodes at different time. The idea is to use clustering for transmitting the data by elect Cluster Head (CH) to reduce the transmitting distances for most nodes to the base station and rotate CH to distribute the energy requirements of the system among all the nodes. In addition to achieving large reduction in the energy dissipation because each cluster can perform local computation. On the other hand, the main drawback of LEACH algorithm is a homogeneous distribution of sensor nodes in a given area and randomly choosing of CH which leads to unfair distribution of the number of cluster members, resulting in quick depletion of energy for cluster head nodes.

There are several improvements for LEACH protocol to overcome its drawback like. The authors in [7], proposed a new protocol, called Stable Election Protocol (SEP), for electing cluster heads in a distributed fashion in two-level hierarchical wireless sensor networks, and they assume fixed uniformly distribution nodes. Their contribution is to prolong the time interval before the death of the first node; this interval is called the "stability period". An extension of SEP (SEP-E) proposed in [5] considers three types of nodes, normal nodes, intermediate nodes and advance nodes. The advance nodes have additional energy which is in a fraction of total nodes, while intermediate nodes have extra energy greater than normal nodes and less than advance nodes. On the other hand authors in [8] are evaluated the performance of LEACH protocol with 802.15.4 and CBRP protocols in term of Quality of Service (QoS). Their results show that 802.15.4 and CBRP protocols are better than LEACH network.

This paper attempts to evaluate LEACH, SEP and SEP-E to show the amount of each lifetime. A comparison between homogeneous and heterogeneous will be presented and calculated to the overall dissipated and average energy for each protocol. Then the performance of a homogeneous network with initial energy equal to the average energy of SEP and SEP-E will be shown. Finally a proposed dimension of homogeneous network with a number of nodes equal to the sum of overall energy of SEP-E network divided by initial energy of LEACH network and considers the percentage increases of nodes as a sleeping percentage.

2. Energy Dissipation for wireless Transceiver

Fig. 1 illustrates a simple transceiver scheme to clear out the dissipation of energy in this part of sensor node.

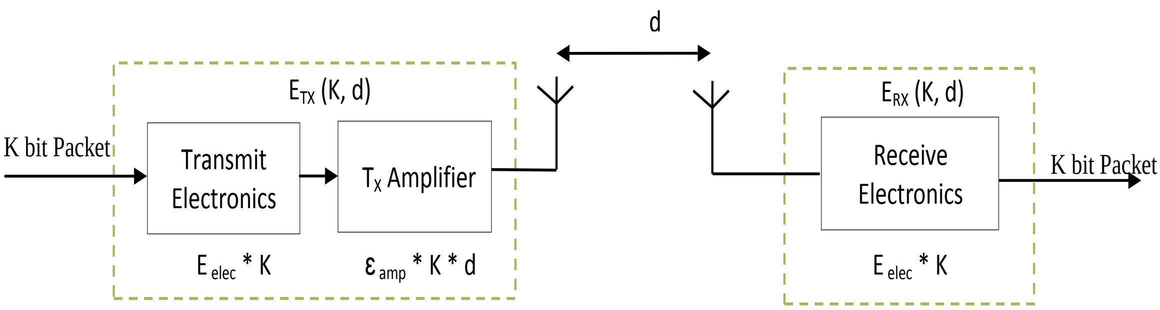


Figure 1: Radio energy dissipated model.

To transmit a data of k bits over a distance (d), the energy expanded is [6]:

$$E_{Tx}(k,d) = E_{elec} \times k + E_{fs} \times k \times d^2 \quad (1)$$

Where E_{elec} the energy dissipated per bit in the circuit of transmitter or receiver and E_{amp} is the transmit amplifier. If the distance is more than threshold value which determined by the designer thus equation (1) becomes:

$$E_{Tx}(k,d) = E_{elec} \times k + E_{amp} \times k \times d^4 \quad (2)$$

Assuming that the radio channel is symmetric and the amount of required energy to transmit *k* bits from node *n* to node *n+1* and vice versa is same. So, the receiver end the energy dissipated is:

$$E_{Rx}(k) = E_{elec} \times k \quad (3)$$

2.1 Homogeneous Network

For such network the total energy dissipated in the network will be calculated with assumption of hierarchy which divides the network into clusters forms. To elect CH it is assumed that the optimal number of clusters c in each round. The probability of any node to becomes CH is P_{opt}, each node will be CH every $1/P_{opt}$ rounds, so we have $(n\, P_{opt})\ CHs/round$. First is to calculate the total energy dissipated by each CH is [8]:

$$E_{CH} = kE_{elec}\left(\frac{n}{c} - 1\right) + kE_{da}\frac{n}{c} + E_{Tx}(k, d_s) \quad (4)$$

Where $\frac{n}{c}$ is all number of nodes per cluster, $\left(\frac{n}{c} - 1\right)$ is non- CH nodes per cluster, E_{da} is energy dissipated for data aggregation per bit and d_s is the distance from CH to sink. The energy dissipated by each non- CH nodes is:

$$E_{non-CH} = kE_{elec} + E_{fs}(d_C)^2 \quad (5)$$

Where d_C is the distance from each node to their respective CH and its average value can be estimated as [10]:

$$d_C = \frac{M}{\sqrt{2\pi c}} \quad (6)$$

The overall energy dissipated in the cluster is:

$$E_C = E_{CH} + \left(\frac{n}{c} - 1\right)E_{non-CH} \quad (7)$$

And the total energy of the network is:

$$E_T = cE_C \quad (8)$$

In this research it has been assumed that the distance between CH and the sink is equal or less than threshold value so, with the help of equations (1-8) the total energy becomes:

$$E_T = k\left[2nE_{elec} + nE_{da} + E_{fs}\{c(d_s)^2 + n(d_c)^2\}\right] \quad (9)$$

2.2 Heterogeneous Network

Two and three levels of heterogeneous network will be addressed in this research which are SEP and SEP-E that have been discussed in [7] and [5] respectively. In SEP, some nodes have extra energy called advance nodes and the rest with normal initial energy. The election probabilities of CHs in SEP are based on the initial energy of each node and by assigning a weight for each node. The weight is equal to initial energy of node divided by initial energy of the normal nodes.
The weight probability of normal nodes and advanced node are P_{nrm} and P_{adv} respectively which are given by [8]:

$$P_{nrm} = \frac{P_{opt}}{1 + m\beta} \tag{10}$$

$$P_{adv} = \frac{P_{opt}(1 + \beta)}{1 + m\beta} \tag{11}$$

Where *m* is the proportion of advanced nodes and $\beta$is the rate of increased energy.
In SEP-E network an additional node has been introduced which is called the "intermediate nodes" and its initial energy level between that of the advanced nodes and the normal nodes. The probability of (10) and (11) becoming P_{nrm}, P_{intr} and P_{adv} for normal, intermediate and advanced respectively as follow:

$$P_{nrm} = \frac{P_{opt}}{1 + m\beta + b\mu} \tag{12}$$

$$P_{intr} = \frac{P_{opt}(1 + \mu)}{1 + m\beta + b\mu} \tag{13}$$

$$P_{adv} = \frac{P_{opt}(1 + \beta)}{1 + m\beta + b\mu} \tag{14}$$

Where b is the proportion of intermediate nodes and μ is the rate of intermediate energy increases. For simplicity [9] assume that $\mu = \beta/2$ which is adopted in this research.

3. Network Model

In this research, LEACH, SEP and SEP-E protocol has been adopted to evaluate each performance while focusing on the total energy of each network and to calculate the average energy of node. The idea is to sum the overall energy of heterogeneous networks and divide the total number of nodes as follow:

a- For SEP there are two levels which are normal and advanced nodes, the total initial energy for such network is:

$$E_{Tsep} = nE_0(1 - m) + nmE_0(1 + \beta)$$
$$= nE_0(1 + m\beta) \tag{15}$$

WhereE_0, is the initial energy of each normal node.

b- For SEP-E there are three levels which are normal, intermediate and advanced nodes, it is expected that the initial energy is larger than SEP as shown in the following equation:

$$E_{Tesep} = nE_0(1 - m - b) + nmE_0(1 + \beta) + nbE_0(1 + \mu)$$
$$= nE_0(1 + m\beta + b\mu) \qquad (16)$$

From (15) and (16), it has been possible to calculate the average initial node for SEP and SEP-E networks as follow:

$$E_{av-sep} = \frac{E_{Tsep}}{n} = E_0(1 + m\beta) \qquad (17),$$

$$E_{av-esep} = \frac{E_{Tsepe}}{n} = E_0(1 + m\beta + b\mu) \qquad (18)$$

It is clear that the average initial energy of SEP and SEP-E networks is more that initial energy of normal node by the factor of $(1 + m\beta)$ and $(1 + m\beta + b\mu)$ respectively.

Now lets assume that the initial energy of homogeneous network with the same number of nodes for SEP or SEP-E, but with initial energy equal to the average energy of equations (17) and (18). The expected performance as compared with homogeneous network as in LEACH, is improved by the same factor as mentioned above.

On the other hand, if we keep the same value of initial energy for normal nodeE_0, and calculate the possible number of nodes. In this case, the extension energy which has been added to heterogeneous is considered as additional nodes. In this case the new number of nodes will increase by the same factors of (17) and (18) as follow:

$$n_{h1} = \frac{E_{Tsep}}{E_0} = n(1 + m\beta) \qquad (19)$$

$$n_{h2} = \frac{E_{Tsepe}}{E_0} = n(1 + m\beta + b\mu) \qquad (20)$$

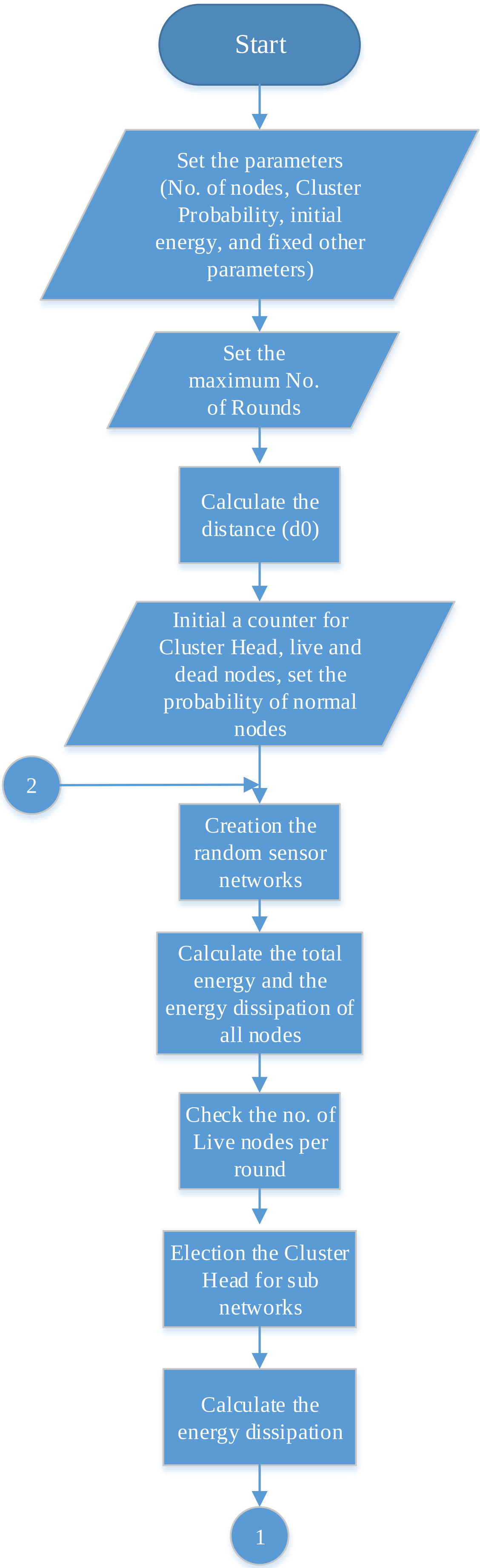
Finally, if homogeneous network with fixed node and same function is adopted, it can be considered that the increases number of nodes in the equations (19) and (20) as a sleep nodes to improve the stable period which is from 0 round until the death of the first node. The expected performance is improved by the same factors mentioned above. The mechanism of homogeneous WSNs protocol with sleep protocol was illustrated in Fig. (2).

4. Simulations and Results

In this section, the simulation is applied to evaluate the ideas that have been already presented in section 3. All simulations are applied using Matlab version R2013a and for the purpose of simplifying the simulation, the following parameters listed in table 1 are adopted for the network model:

Table 1: some of parameters of network model

parameter	*Value*
No. of nodes	100
Initial Energy	Eo=0.5 joule
Packet size	4000 bits
Probability of mode to become cluster head	P=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


Start
Set the parameters (No. of nodes, Cluster Probability, initial energy, and fixed other parameters)
Set the maximum No. of Rounds
Calculate the distance (d0)
Initial a counter for Cluster Head, live and dead nodes, set the probability of normal nodes
2
Creation the random sensor networks
Calculate the total energy and the energy dissipation of all nodes
Check the no. of Live nodes per round
Election the Cluster Head for sub networks
Calculate the energy dissipation
1

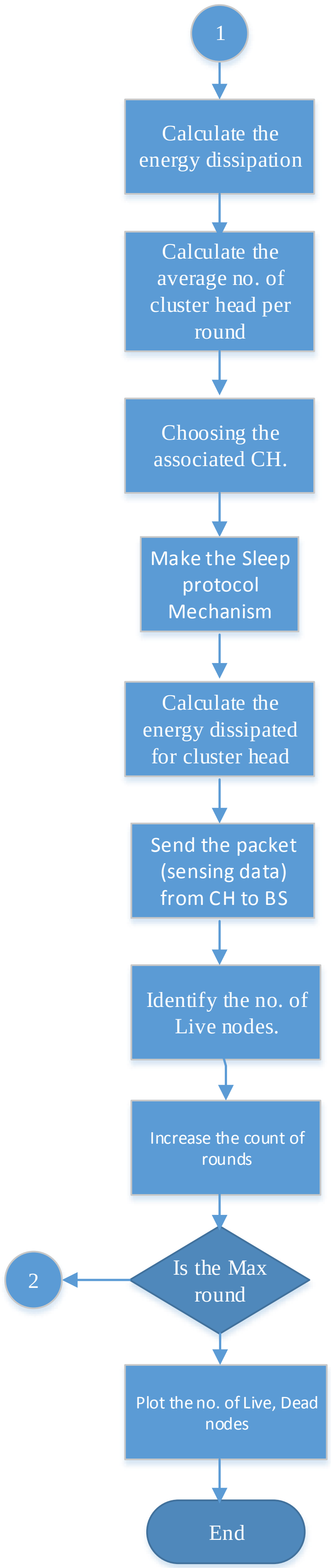


Figure (2): Shows the flowchart of WSNs homogeneous network with sleep protocol.

4.1 Heterogeneous Versus Homogeneous

The first step of simulation is applied over heterogeneous network (SEP & SEP-E). The comparison is based on the total energy of those network at it is assumed to be the total energy of homogeneous network with the same parameters. This means that the initial energy of each node for such network increases by the factors described in equations (17) and (18).

For SEP network, assume that the energy increases to $\beta = 1$ and the proportion of advanced nodes *m=0.3*, therefore the initial energy will increase from $E_0 = 0.5J$ to $\bar{E}_0 = 0.5(1 + 0.3 \times 1) = 0.65J$. Now the simulation is applied over homogeneous network with the same parameters and the total energy of heterogeneous and homogeneous are equal. Fig. 3 shows the results of previous assumptions.

It is clear that the homogeneous is slightly ahead of SEP network in the first 1500 rounds, but then the opposite happens after the remaining number of nodes is 30 which are the advanced nodes with high level of energy in heterogeneous. While in homogeneous all nodes have equal energy so when it begins to weary, the remaining will not resist for more rounds.

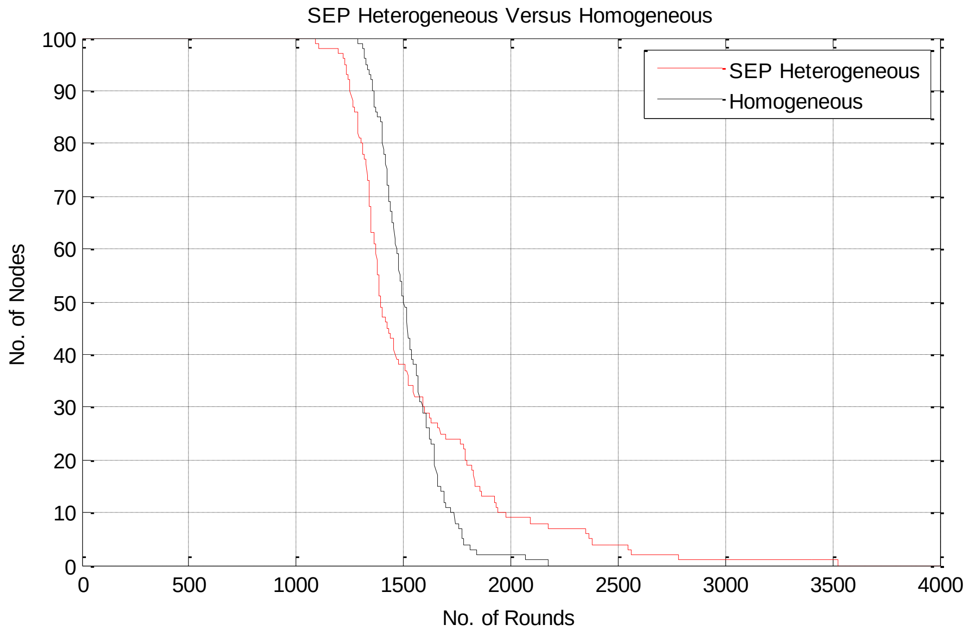


Figure 3: Performance of homogeneous and SEP heterogeneous.

Now the same simulation will apply for SEP-E heterogeneous network. By reference to the equation (20), the parameters of such network are assumed as follow:

$\beta = 1, m = 0.2, b = 0.3 \; and \; \mu = 0.5,$

So that the resulted initial energy for homogeneous will be:

$$\bar{\bar{E}}_0 = 0.5(1 + 0.2 \times 1 + 0.3 \times 0.5) = 0.675J$$

Note that for SEP-E network there will be 50 nodes which are normal with initial energy of 0.5J and while the rest 50 nodes are intermediate and advanced nodes. Fig. 4 shows the performance of SEP-E heterogeneous network with the above assumed parameters compared with homogeneous network with the initial energy which is calculated above. As expected the homogeneous is outperformed heterogeneous network at a number of rounds between 1250 to1500. When all normal nodes of SEP-E network are dead after 1500 rounds the nodes of high energy level will stay for more rounds.

Based on the results depicted above, if we take into account the cost spent for SEP and SEP-E networks on the basis of the total energy expended and those costs were paid for homogeneous the results will be better. On the other hand, the authors of [7] and [9] have assumed that all nodes are immobile while in homogeneous it is possible fixed or mobile, giving more flexibility to the network. Accordingly, the homogeneous network gives better performance if the initial nodes energy were the same average energy of heterogeneous networks.

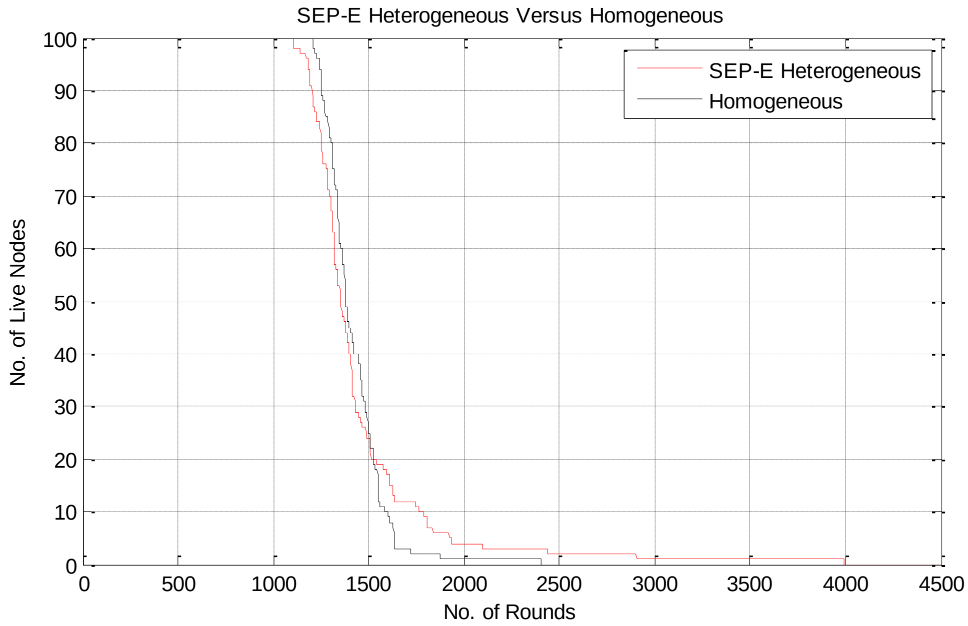


Figure 4: Performance of homogeneous and SEP-E heterogeneous networks.

4.2 Heterogeneous versus Homogeneous with sleeping nodes

This subsection used the additional energy of SEP and SEP-E networks over homogeneous which; can be exploited as extra nodes. Return to equations (19) and (20), the new number of nodes can be calculated as follow:

- For SEP, assume the same values used in subsection 4.1, the total energy is:

$$E_{Tsep} = 100 \times 0.5(1 + 0.3 \times 1) = 65\, joul$$

The new number of nodes according to equation (19):

$$n_{h1} = 100(1 + 0.3 \times 1) = 130\, nodes$$

- For SEP-E, also using same previous values and equation (20):

$$E_{Tesep} = 100 \times 0.5(1 + 0.2 \times 1 + 0.3 \times 0.5) = 67.5\, joul$$

$$n_{h2} = 100(1 + 0.2 \times 1 + 0.3 \times 0.5) = 135\, nodes$$

In SEP network it has been assumed that the total number of nodes is 100 nodes with two levels of initial energy. In the later calculation it is clear that 30 nodes is possible to be added to the network in the case of homogeneous network with the same total energy. Fig. 5 shows the result of such assumption and use the extra addition as sleeping nodes.

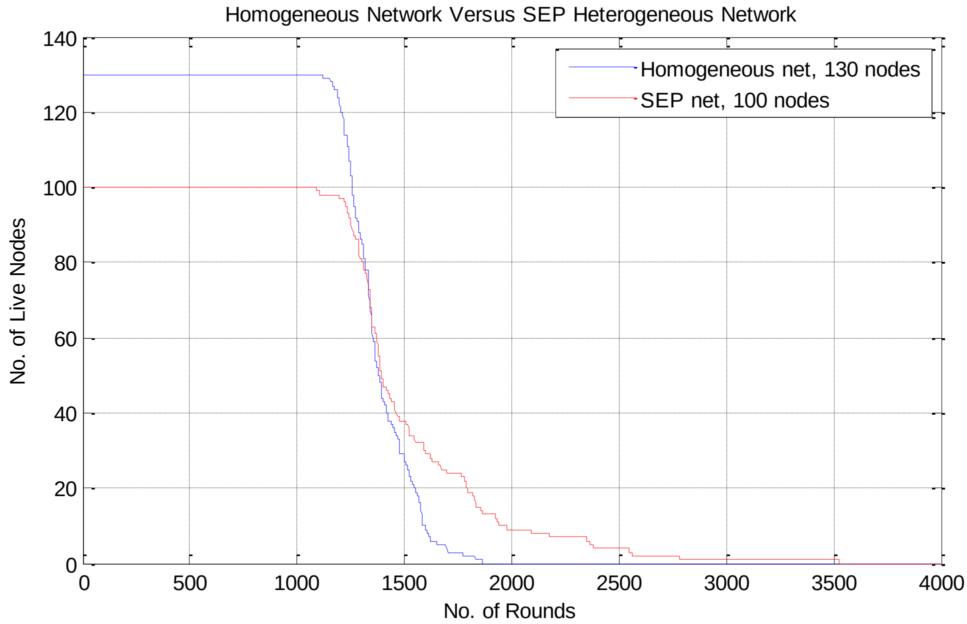


Figure 5: The results of sleeping technique of extra nodes compared with SEP.

The results show the nodes with high energy levels stay for more rounds over normal nodes. Therefore, the nodes of homogeneous network fall quickly after the death of the first nodes.

Now the same experiment is applied for the network with 135 homogeneous nodes and compared with SEP-E heterogeneous network of 100 nodes. Fig. 6 illustrates the results. Since 50% of SEP-E network is intermediate and advanced nodes with three levels of energy, more nodes stay in live compared to homogeneous.

Arrangements of parameters values are applied to SEP and SEP-E networks to increase the total energy to 75 Joule for each. If this value is used for homogeneous network with initial value of 0.5 Joule which is same the value of normal nodes for heterogeneous networks, this means that the total number of homogeneous network will be about 150 nodes. Hence, the simulation runs with the assumption that the total energy of the three networks (SEP, SEP-E and homogeneous) are equal. Fig. 7 clears out the results of such virtual networks. The stable period of homogeneous network here is better than other networks. The stable period means the time between first round and first death of nodes.

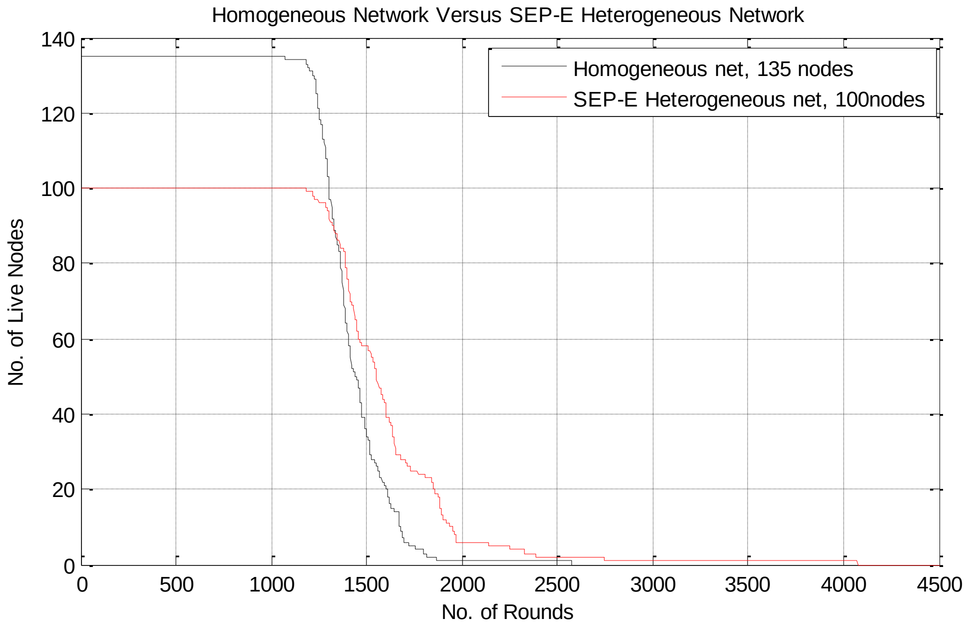


Figure 6: The results of sleeping technique of extra nodes compared with SEP-E.

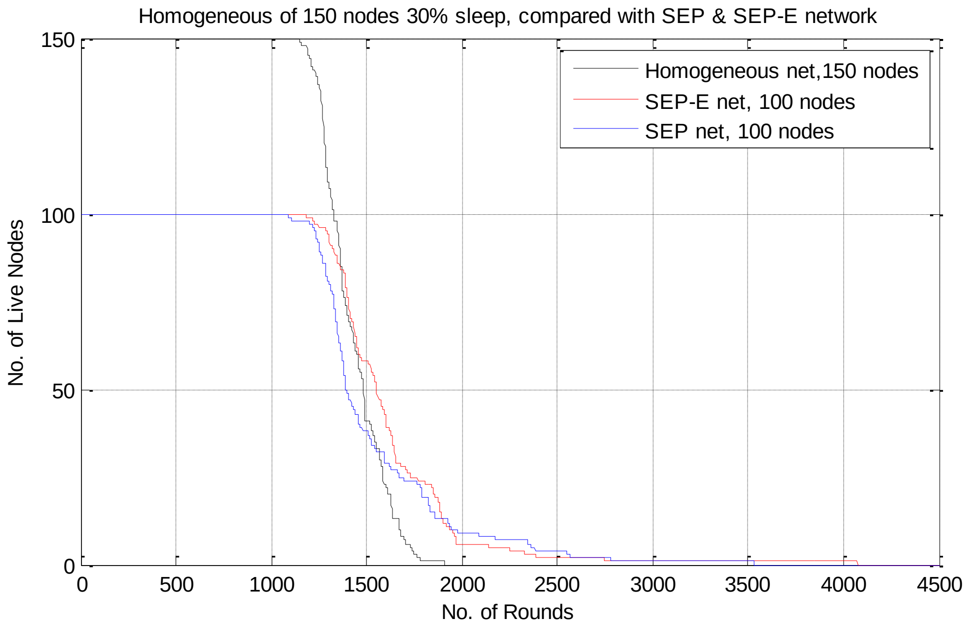


Figure 7: Performance of 150 nodes of homogeneous using sleeping technique compared with SEP and SEP-E networks.

Another experiments are applied for the network with (200, 500 and 1000) homogeneous nodes. The results in Fig. (8) to Fig.(9) are compared with different nodes for SEP & SEP-E to achieve the sleep protocol. In addition, the result, show that the homogeneous network longer life time but fall quickly after the death of the first nodes.

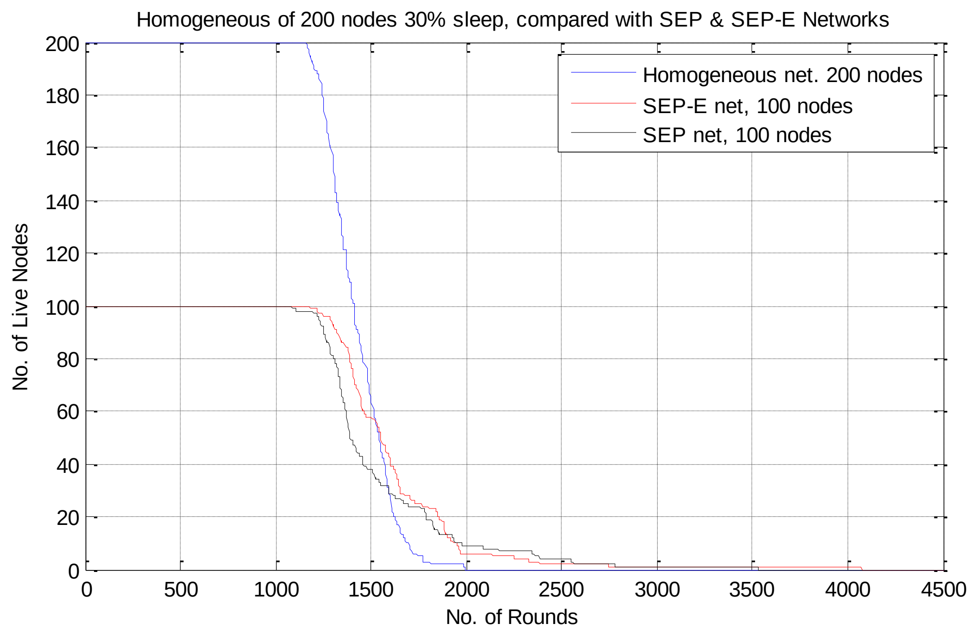


Figure 8: Performance of 200 nodes of homogeneous using sleep technique compared with SEP and SEP-E networks.

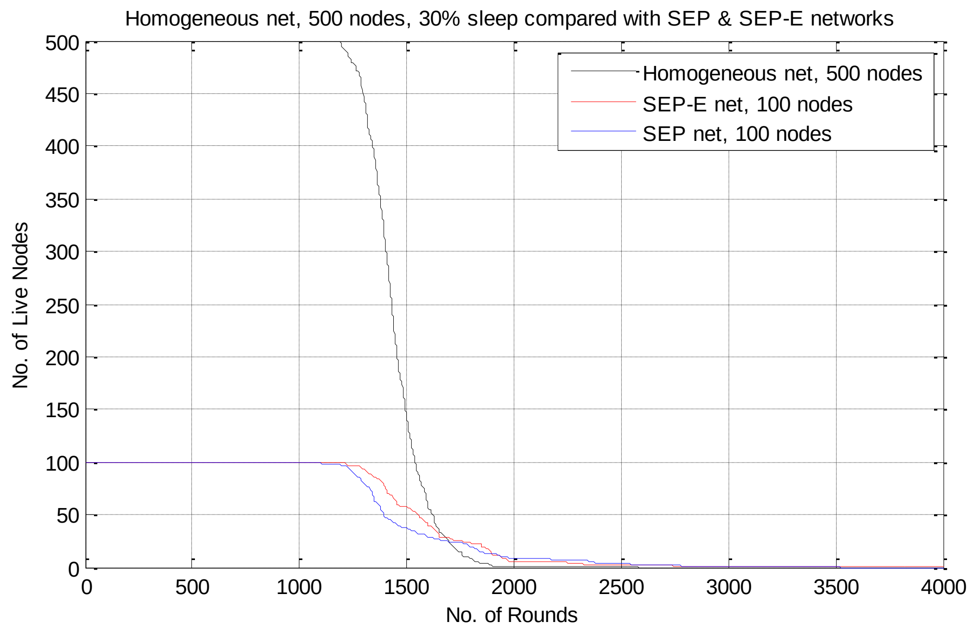


Figure 9: Performance of 500 nodes of homogeneous using sleep technique compared with SEP and SEP-E networks.

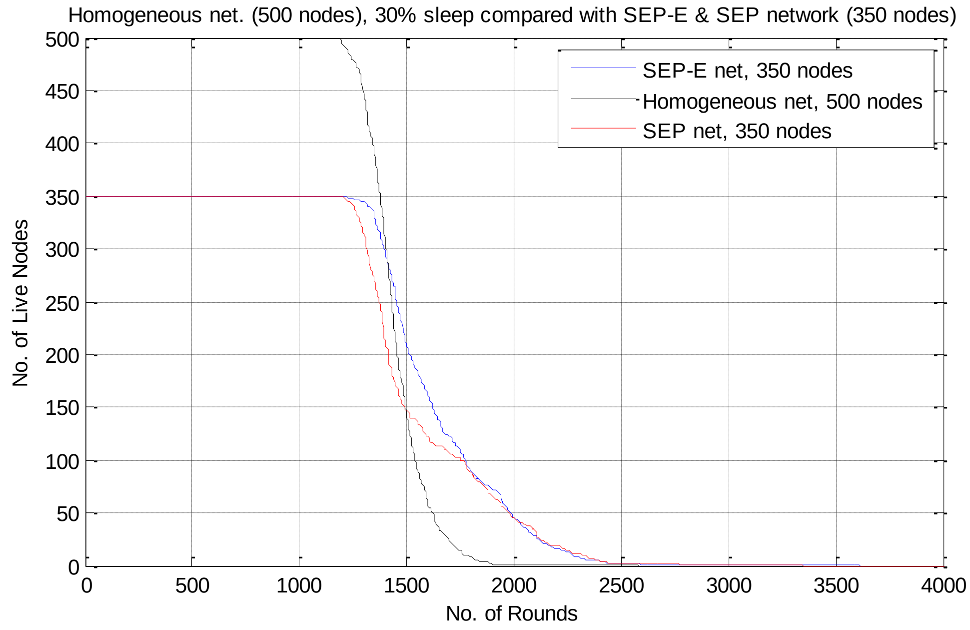


Figure 10: Performance of 500 nodes of homogeneous using sleep technique compared with SEP-E & SEP networks (350 nodes).

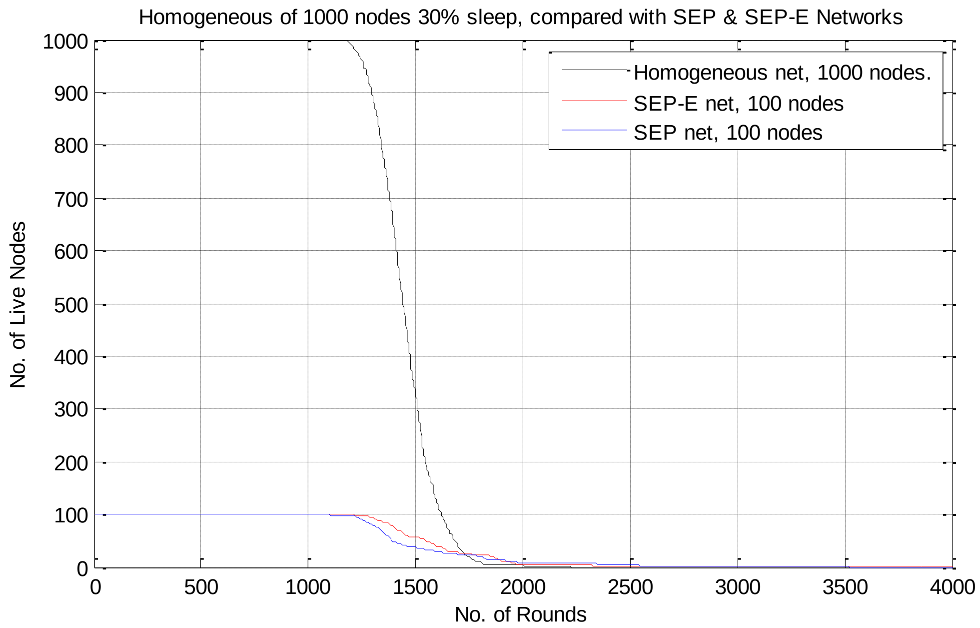


Figure 11: Performance of 500 nodes of homogeneous using sleep technique compared with SEP and SEP-E networks.

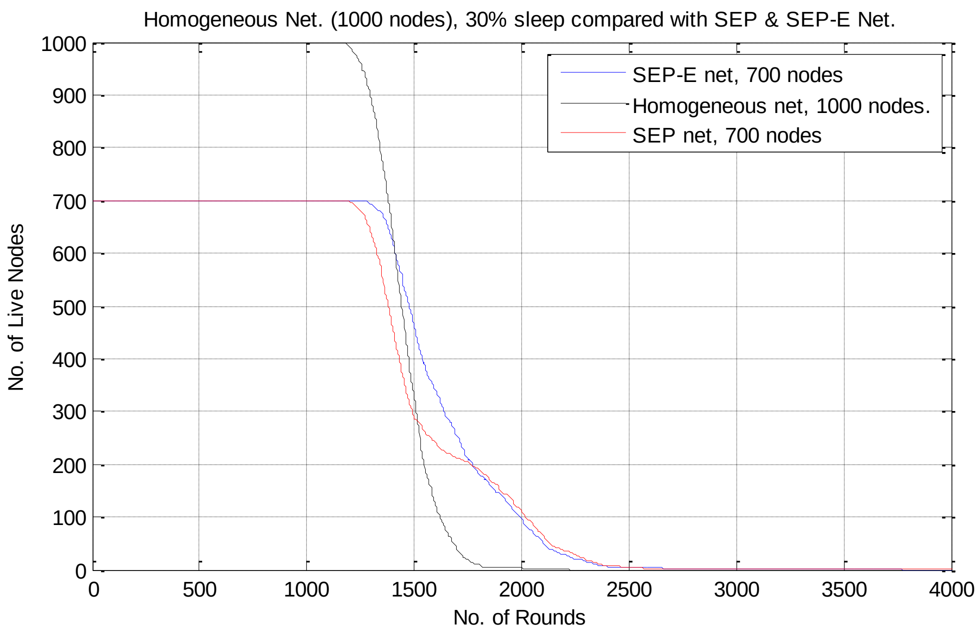


Figure 12: Performance of 500 nodes of homogeneous using sleep technique compared with SEP-E & SEP networks (350 nodes).

5. Conclusions

This paper has analyzed the SEP and SEP-E wireless sensor networks in term of the total energy dissipated. According to the calculation given by the researches [5-10], it has derived an equations to calculate the average energy value for SEP and SEP-E heterogeneous networks. This value is adopted as initial value for homogeneous network with same parameters of heterogeneous networks listed in table 1. From the results it can be drawn the following conclusions:

1- The performance of homogeneous is outperforming heterogeneous networks.
2- But there are some limitations of heterogeneous networks must be taken into account, which are assumes fixed nodes instead of mobility given in homogeneous.
3- If the value of initial energy for homogeneous is assumed to be the same value of normal nodes as in heterogeneous and the extra energy is taken as extra nodes. Then the extra nodes are considered as sleeping nodes for homogeneous network. The simulation of such assumptions confirmed that the homogeneous network is slightly better than heterogeneous taking into account the drawback of the later.

6. References

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