Performance Investigation of Energy Efficient HetSEP for Prolonging Lifetime in WSNs

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Abstract. In this work, we investigate the performance of heterogeneous stable election protocol (HetSEP) for prolonging the network lifetime. An order-5 heterogeneous energy network model is proposed in this work that can defines the order-1, order-2, order-3, order-4, and order-5 heterogeneity. We consider the SEP protocol to calculate the lifetime of the network and consequently describe its accomplishments as HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5. The SEP protocol is HetSEP-1 in which all the sensor nodes have same amount of energy. The HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, contain two, three, four, and five orders of energy, respectively. The network lifetime increases as increasing the order of heterogeneity. The HetSEP-2, HetSEP-3, HetSEP-4, & HetSEP-5, prolong the lifetime of the network 100.39%, 126.12%, 186.56%, & 285.67%, in respect to the increase the energy of the network by 65.0%, 72.58%, 107.10%, & 208.40% with respect to the HetSEP-1.

Keywords: Network lifetime · Heterogeneity · Round
Stable election protocol

1 Introduction

Now a day, a wireless sensor networks (WSN) have turn out to be an attractive technology, where WSNs deployed easily without increasing the cost of the network in terms of communication infrastructures. These networks become popular because it takes very less time in installation where we want to perform monitoring task in the environment. Sensor networks are a network of network that includes a low size, low battery power, low memory, and low complex devices, known as sensor nodes. A WSN consists of thousands of thousand of sensor nodes installed with different communication, sensing, storing and computing abilities. In the monitoring environment, every sensor has the facility to capture the object in the monitoring environment of an activity and these sensor nodes perform calculation, and computations of the received data from the monitoring environment. Each node create communicates between the sensor nodes and its peers for collecting the monitored data and forward the sensed data to the base station (BS) with the help of other sensor nodes. A lot of

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protocol are exits for data collection from the monitoring environment, and these are energy aware for prolong the lifetime of the network because the substitution of the battery power of the nodes is a extremely complicated practice, once upon a time these sensor nodes have been installed in the monitoring environment. Sensor networks can efficiently utilized the battery power of sensor nodes by considering the different protocols for increasing the lifetime of wireless sensor networks [1]. There are two possible ways to deploy the sensor nodes in the monitoring area namely deterministically or randomly. The deployment of the sensor nodes in the deterministic fashion are additional favorable in different applications such as physically accessibility of the nodes are easy or nodes are placed manually in the monitoring locations. Example are as follows for the deterministic fashion deployment the line in sand for target tracking, city sense for urban monitoring, soil monitoring, etc. Another way of sensor node deployment is the random deployment where sensor nodes are not physically inaccessible in the monitoring area, for example, Mines, bird observation on Great Duck Island etc. In random deployment environment, the nodes are jumped down through an aircraft.

Longevity of the network for prolonging the lifetime of networks is the most important issue in wireless sensor networks, which is directly or indirectly influenced by the energy of network. There are two possible ways to increasing the lifetime of wireless sensor networks, firstly add some extra node in the monitoring environment, and secondly, increase the energy of the existing sensor nodes. Adding some extra node in the monitoring environment is the ten times costlier to increasing the energy of the exiting nodes. Therefore, increasing the energy of the existing nodes is the best way to increasing the lifetime of the networks. The categorizing the sensor nodes into groups are an efficient way for utilizing the network energy called clusters where each cluster has a master sensor node and it is also called the cluster head. This type of nodes has several member nodes and usually called member of the cluster. The cluster head generally performs the data fusion and data aggregation in order to have longer lifetime, the network should have good amount of energy. The wireless sensor networks with different energy levels are called heterogeneous WSNs [2]. In this paper, we propose a 5-order heterogeneous network model for wireless sensor networks to increasing the network lifetime. This model is capable to define order-1, order-2, order-3, order-4, and order-5 heterogeneity. The order-1 describes single type of nodes in a network in term of energy i.e., homogeneous network. The order-2, order-3, order-4, and order-5 describe two types, three types, four types, and five type sensor nodes, respectively. The election of cluster heads probabilities are weighted by the initial energy of a sensor relative to that of other sensors in the network.

The rest of the paper is organized as follows. Section 2 discusses the literature review based on clustering. Section 3 discusses the proposed heterogeneity network model for five order of heterogeneity. In Sect. 4, experimental results are discussed and finally in Sect. 5, the paper is concluded.

2 Related Work

Now a day's WSNs have attracted several researchers due to their potential applications and challenges. Fruitful applications of the WSNs are as military, environmental, health, scientific exploration, area monitoring and structural health monitoring applications, etc. At the same point of time, WSNs have numerous challenges like efficient use of energy, fault-tolerance, connectivity, simplicity, coverage, robustness, scalability, security, etc. The main challenges in wireless networks are related to the improvement in network lifetime for longevity of the sensor networks. The lifetime of the network is an essentially related to the efficient use of energy of the network. Accordingly, lot of protocols have been developed for increasing the lifetime of wireless sensor networks by considering different deployment techniques, and heterogeneous networks models. Papers [6, 10] discuss an extremely first protocol for prolonging the lifetime in WSNs by Heinzelman et al. in 2000, and this protocol is known as low energy adaptive clustering hierarchy (LEACH) protocol. In this protocol, sensor nodes are divided into several groups called as cluster, and a cluster node in each cluster called cluster head that collects the information from its cluster members and sends that to the base station (BS), and all sensors don't send the data directly to the BS. They send their data through cluster heads that is why this protocol is called hierarchical protocol. In this protocol, the cluster heads may not be dispersed uniformly. The solution of this problem has been given in LEACH-C and fixed LEACH [10], by dispersing the cluster heads all over the network so that it can produce better performance in terms of network lifetime and energy consumption.

From the past few decades researcher mainly focuses on the homogeneous network technologies but recently researchers are shifted to the heterogeneous network technology because it become more popular due to its better performance. It has been proved by the researchers that lifetime in case of heterogeneous networks is large as compare to the homogeneous networks. Due to that region many researchers are shifted to heterogeneous networks and some works has been done the heterogeneous networks models. In paper [11], stable election protocol (SEP) is proposed by Smaragdakis et al. for heterogeneous networks, and it is an extension of LEACH and a very first protocol in the field of energy heterogeneity. The selection of cluster head in SEP is based on weighted election probability that can be calculated by the remaining energy of the nodes and node initial energy. SEP considers two level of heterogeneity, which contains two type of nodes namely normal and advance nodes. In this protocol, advanced node energy is higher than that of the normal nodes. In paper [13], a distributed energy efficient clustering (DEEC) protocol is discussed by Qing et al. using 2-level and multilevel heterogeneity. The 2-level heterogeneity network model is precisely identical as discussed in [12] and multilevel heterogeneous model, the energy of each node is arbitrarily to be paid from a given energy interval. Therefore, in this network levels of energy can be infinite due to random allocation of the energy. This model is hardly of any use because each node has different amount energy level and designing of such type of nodes may not be practically feasible. In paper [12], an EEHC protocol for heterogeneous WSNs is discussed by Mao et al. and it considers 3-levels of heterogeneity is discussed by using 3 types of nodes namely: normal nodes, advanced nodes, and super nodes. Advanced node energy is higher than normal node energy and the super node energy is higher than advanced node energy. The selection of cluster head is based on the weighted election probability so that the sensor nodes energy is efficiently utilized. In [14] authors discuss a balanced energy efficient network integrated super heterogeneous (BEENISH) protocol to compute lifetime of the network on the basis of its average energy and its residual energy of nodes. In [15–22] authors discuss a modified HEED protocol for heterogeneous WSNs. It describes 1-level heterogeneity, 2-level heterogeneity, and 3-level heterogeneity by considering level or order of energies. It considers one additional parameter for fuzzy clustering called distance between the sensor node and the cluster head to determine the cluster heads.

In paper [20] a novel energy-efficient clustering protocol (NEECP) for increasing the network lifetime in wireless sensor networks is proposed. It selects the cluster heads in an effective way with an adjustable sensing range and performs data aggregation using chaining approach. It also avoids transmission of redundant data by using a redundancy check function for improving the network lifetime. It is implemented by considering the data with aggregation and without aggregation. In paper [21, 22] a 3-level heterogeneous network model for WSNs to enhance the network lifetime, which is characterized by a single parameter is proposed. Depending upon the value of the model parameter, it can describe 1-level, 2-level, and 3-level heterogeneity. The proposed heterogeneous network model also helps to select effective active sensor nodes for scheduling and compute the network lifetime by implementing two protocols for our network model, which include ALBP and ADEEPS. The ALBP and ADEEPS protocols are implemented for the existing 1-level, 2-level, and 3-level heterogeneous network models, and for the proposed 3-level heterogeneous network model, the ALBP implementations. The simulation results indicate that heterogeneous protocols prolong the network lifetime as compared to the homogeneous protocols. Furthermore, as the level of heterogeneity increases, the lifetime of the network also increases.

Paper [23] discusses a cluster based approach is proposed to increase the network lifetime and throughput of the heterogeneous wireless sensor networks. This approach combined the direct data transmission to base station with the cluster head transmission of data in wireless sensor networks. It uses the twice energy for advanced nodes in comparison to normal nodes. It is observed that results are found good with the use of 10% of advanced nodes along with normal nodes in the network in this approach. However, on further increasing the advanced node deployment beyond deployment 30%, network lifetime and throughput of network start degrading. So, the proposed solution with 10% advanced node may be considered as the best suitable and acceptable solution for better network throughput and life time in WSNs. This paper [24] gives a new reputation based OR metric and some rules, in which the next hop selection is based on its reputation. This metric considers the reputation level as a primary selection parameter for next-hop. A new OR metric relies on energy efficiency and packet delivery ratio of next-hop. This OR protocol selects all middle position neighbors as next-hop and potential forwarder will be decided on the basis of new OR metric. Energy consumption is considered to be dynamic. It has been compared with Middle Position Dynamic Energy Opportunistic Routing (MDOR), and Trust and Location Aware Routing Protocol (TLAR). Paper [25] discusses a data aggregation approach for analyzing in wireless sensor network. This approach minimizes the traffic between the clusters and the sensor nodes by removing the duplicate data at the cluster heads.

In this work, we discuss an order-5 energy network model for increasing the lifetime of a wireless sensor networks. We consider SEP implementations for performance evaluation of the proposed model and accordingly the implementation of SEP is denoted as HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5. The variants of HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5 are one, two, three, four, and five order of nodes, respectively. The heterogeneity is beneficial in networks because increasing the network energy by adding more sensors is much costlier than by increasing the energy of some of the nodes. In next section, we will discuss network assumptions and propose our heterogeneous network model.

3 Proposed Method

We assume the following for the WSNs.

- All the nodes have similar abilities such as its memory, processing power, communication range and having equal significance.
- Sink is stationary in our networks and situated in middle in the networks.
- Sensor nodes have capabilities of data fusion and aggregation.
- The categorization of sensor and their energies depends on the order of heterogeneity.
- All the sensor nodes are randomly deployed.
- All the nodes have same capability such as link, memory, sensing range and microprocessor except energy.

We propose an order-5 heterogeneity or non homogeneous network energy model i.e., capable to describe the order-1, order-2, order-3, order-4, and order-5 heterogeneity. Let N be the total number of nodes in the network. The numbers of nodes for all five order of heterogeneity in the network are denoted as N_1, N_2, N_3, N_4, N_5 and they necessity assure the inequality $N_5 < N_4 < N_3 < N_2 < N_1$. The sum of energy/battery power of the heterogeneous networks is denoted by E_{total} and given by

$$E_{total} = E_0 * \beta * N + E_1 * \beta^2 * N + E_2 * \beta^3 * N + E_3 * \beta^4 * N + E_4 * \beta^5 * N \tag{1}$$

where, β is a parameter and E_0, E_1, E_2, E_3 and E_4 are the energies of order-1, order-2, order-3, order-4, and order-5 nodes that necessity assure the inequality $E_4 > E_3 > E_2 > E_1 > E_0$. The battery power of order-*i* sensor nodes is related to the battery power of order-1 sensors is give by

$$E_j = E_0 + \mu_j \tag{2}$$

Using (1), (2) can be written as

$$E_{total} = E_0 * \beta * N + (E_0 + \mu_1) * \beta^2 * N + (E_0 + \mu_2) * \beta^3 * N + (E_0 + \mu_3) * \beta^4 * N + (E_0 + \mu_4) * \beta^5 * N$$

$\mu_1, \mu_2, \mu_3,$ and μ_4 are the new model parameters. E_{total} can be simplified as follows:

$$E_{total} = N * \left(E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right) \tag{3}$$

Order-1 Heterogeneity: For $\mu_1 = \mu_2 = \mu_3 = \mu_4 = 0$, the model defined in (3) described one non zero term or one type of nodes (order-1) i.e., called order-1 heterogeneity. The total network energy of order-1 is as follows:

$$\mathrm{E}_{\mathrm{order}-1} = \mathrm{E}_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right)$$

The total no. of sensor nodes in order-1 heterogeneity is defined as

$$N_1 = \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right)$$

With the following condition

$$\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5 = 1.$$

Order-2 Heterogeneity: For $\mu_2 = \mu_3 = \mu_4 = 0$, the model defined in (3) contains two non zero. It defines order-2 heterogeneity and contains order-1 and order-2 nodes. The total network energy of order-2 is as follows:

$$\mathrm{E}_{\mathrm{order}-2} = \mathrm{E}_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \beta^2 * \mu_1$$

The total no. of order-1 and order-2 nodes in order-2 heterogeneity, denoted by N_1 and N_2, respectively, are given as

$$N_1 = \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right),$$
$$\text{and } N_2 = \mathrm{N} * \beta^2 * \mu_1$$

With the following conditions

$$\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1 \text{ and, } \beta^2 * \mu_1 = \mathrm{N} - N_1.$$

Order-3 Heterogeneity: For $\mu_3 = \mu_4 = 0$, the model defined in (3) contains three non zero terms and define three types of nodes as called order-1, order-2, and, order-3 nodes. The total network energy of 3-order is as follows:

$$\mathrm{E}_{\mathrm{order}-3} = \mathrm{E}_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \beta^2 * \mu_1 + \beta^3 * \mu_2$$

The total no. of order-1, order-2 and order-3 nodes in 3-order heterogeneity, denoted by N_1, N_2 and N_3, are respectively, given as

$$N_1 = \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), N_2 = \mathrm{N} * \beta^2 * \mu_1, \text{and } N_3 = \mathrm{N} * \beta^3 * \mu_2.$$

With the following conditions

$$\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1, \text{and } \beta^2 * \mu_1 + \beta^3 * \mu_2 = \mathrm{N} - N_1.$$

Order-4 Heterogeneity: For $\mu_4 = 0$, the model defined in (3) contains four non zero terms and define four types of nodes as order-1, order-2, order-3, and order-4 nodes. The total network energy of order-4 heterogeneity is as follows:

$$E_{tire-4} = \left(E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3\right)\right)$$

The total no. of order-1, order-2, order-3, and order-4 nodes in *order-4* heterogeneity denoted by N_1, N_2, N_3, and N_4, are respectively, given as

$$\begin{aligned} N_1 &= \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), \\ N_2 &= N * \beta^2 * \mu_1, \\ N_3 &= \mathrm{N} * \beta^3 * \mu_2, \text{ and} \\ N_4 &= \mathrm{N} * \beta^4 * \mu_3. \end{aligned}$$

With the following conditions

$$\begin{aligned} &\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1, \text{ and} \\ &\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 = \mathrm{N} - N_1. \end{aligned}$$

Order-5 Heterogeneity: the model defined in (3) contains all non zero terms and define five order heterogeneity. The five typ of are as order-1, order-2, order-3, order-4, and order-5 nodes. The total network energy of order-5 heterogeneity is as follows:

$$E_{tire-5} = \left(E_0 * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right)$$

The total no. of order-1, order-2, order-3, order-4, and order-5 nodes in order-5 heterogeneity denoted by $N_1, N_2, N_3, N_4,$ and N_5, are respectively, given as

$$\begin{gathered} N_1 = \mathrm{N} * \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right), \\ N_2 = N * \beta^2 * \mu_1, \\ N_3 = \mathrm{N} * \beta^3 * \mu_2, \\ N_4 = \mathrm{N} * \beta^4 * \mu_3, \text{ and} \\ N_5 = \mathrm{N} * \beta^5 * \mu_4 \end{gathered}$$

With the following conditions

$$\begin{gathered} \left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) * 100 = N_1, \text{ and} \\ \beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4 = \mathrm{N} - N_1. \end{gathered}$$

The selection of master node or cluster head is depends on the probability of nodes. We determine the probability of order-5 heterogeneity nodes i.e., order-1, order-2, order-3, order-4, and order-5 nodes as follows:

$$\left.\begin{aligned} p_{order-1} &= \frac{p_{opt}}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right.} \\ p_{order-2} &= \frac{p_{opt} * (\mu_1)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right.} \\ p_{order-3} &= \frac{p_{opt} * (\mu_2)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right.} \\ p_{order-4} &= \frac{p_{opt} * (\mu_3)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right.} \\ p_{order-5} &= \frac{p_{opt} * (\mu_4)}{\left(\left(\beta + \beta^2 + \beta^3 + \beta^4 + \beta^5\right) + \left(\beta^2 * \mu_1 + \beta^3 * \mu_2 + \beta^4 * \mu_3 + \beta^5 * \mu_4\right)\right.} \end{aligned}\right\} \quad (4)$$

In Eq. (1), replace the value of p_{opt} by the weighted probability for the threshold i.e., applied to select the master node in each and every round. The threshold of order-1, order-2, order-3, order-4, and order-5 nodes are define as $\mathrm{T}(s_{order-1})$, $\mathrm{T}(s_{order-2})$, $\mathrm{T}(s_{order-3})$, $\mathrm{T}(s_{order-4})$, and $\mathrm{T}(s_{order-5})$, respectively, as in (5).

$$\left.\begin{array}{l}
T(s_{order-1}) = \begin{cases} \dfrac{p_{order-1}}{1-p_{order-1}\cdot\left(r \bmod \frac{1}{p_{order-1}}\right)} & \text{if } s_{order-1}G^1 \\ 0 & \textit{Otherwise} \end{cases} \\
T(s_{order-2}) = \begin{cases} \dfrac{p_{order-2}}{1-p_{order-2}\cdot\left(r \bmod \frac{1}{p_{order-2}}\right)} & \text{if } s_{order-2}G^2 \\ 0 & \textit{Otherwise} \end{cases} \\
T(s_{order-3}) = \begin{cases} \dfrac{p_{order-3}}{1-p_{order-3}\cdot\left(r \bmod \frac{1}{p_{order-3}}\right)} & \text{if } s_{order-3}G^3 \\ 0 & \textit{Otherwise} \end{cases} \\
T(s_{order-4}) = \begin{cases} \dfrac{p_{order-4}}{1-p_{order-4}\cdot\left(r \bmod \frac{1}{p_{order-4}}\right)} & \text{if } s_{order-4}G^4 \\ 0 & \textit{Otherwise} \end{cases} \\
T(s_{order-5}) = \begin{cases} \dfrac{p_{order-5}}{1-p_{order-5}\cdot\left(r \bmod \frac{1}{p_{order-5}}\right)} & \text{if } s_{order-4}G^5 \\ 0 & \textit{Otherwise} \end{cases}
\end{array}\right\} \tag{5}$$

where, r is the current round, G^1, G^2, G^3, G^4, and G^5, are the set of order-1, order-2, order-3, order-4, and, order-5 nodes that have not yet turn into master node in last $\left\{\frac{1}{p_{order-1}}, \frac{1}{p_{order-2}}, \frac{1}{p_{order-3}}, \frac{1}{p_{order-4}} \text{and} \frac{1}{p_{order-5}}\right\}$ rounds, and $T(s_{order-1})$, $T(s_{order-2})$, $T(s_{order-3})$, $T(s_{order-4})$, and $T(s_{order-5})$ are the thresholds applied to the population of order-1, order-2, order-3, order-4, and order-5 nodes, respectively.

In the next section, we will discuss the simulation of the exiting SEP i.e., HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5 protocols.

4 Simulation Results

In this section, we present the simulation results for our proposed heterogeneous network model by considering SEP protocol and the implementation of SEP protocol over our proposed model is called HetSEP. Section 3 has discussed a proposed model and it can define order-1 (original SEP), order-2, order-3, order-4, and order-5 heterogeneity of the WSNs. On the bases of heterogeneity, we call the implementations as HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5 heterogeneity. In this work, we compute the network lifetime, no. of alive nodes, no. of dead nodes, no. of packets sent at the sink and total energy consumption for the proposed heterogeneous network model. In this work, we have randomly deployed 100 no. of nodes in an area of size 100 M × 100 M. The energy dissipation model is used in this work as same given in [2, 6, 10]. Table 1 shows the input parameters which are used in our simulations.

For different order of heterogeneity, the proposed model has characterized by different parameters $\beta, \mu_1, \mu_2, \mu_3$ and μ_4. For order-1 heterogeneity (HetSEP-1), we assume the total no. of sensor nodes are 100 with initial energy 0.5 J. For order-1 heterogeneity (HetSEP-2), we compute the no. of order-1 and order-2 nodes are 75 and 25 and the energies of order-1 & order 2 are as 0.5 J and 1.80 J, respectively. For order-3 heterogeneity (HetSEP-3), we compute the no. of order-1, order-2, and order-3 nodes are 70, 20 and 10 and the energies are 0.5 J, 1.64 J and 1.85 J, respectively. For order-3 heterogeneity (HetSEP-4), the no. of order-1, order-2, order-3, and order-4 nodes are 65, 20, 10 & 5 and the energies are 0.5 J, 1.75 J, 2.06 J & 2.45 J, respectively. For order-5 (HetSEP-5), we compute the no. of order-1, order-2, order-3, order-4, and order-5 nodes are 60, 15, 12, 8 & 5, and the energies are 0.5 J, 1.54 J, 2.69 J, 4.34 J & 6.82 J, respectively.

Table 1. Simulation parameters

Heterogeneity	No. of Nodes	β	μ_1	μ_2	μ_3	μ_4	E_0	E_1	E_2	E_3	E_4	E_{total}	Lifetime
Order-1	100	NA	NA	NA	NA	NA	0.5	NA	NA	NA	NA	50.00	1815
Order-2	75 + 25	0.44	1.31	NA	NA	NA	0.5	1.80	NA	NA	NA	82.50	3637
Order-3	70 + 20 + 10	0.42	1.14	1.35	NA	NA	0.5	1.64	1.85	NA	NA	86.29	5201
Order-4	65 + 20 + 10 + 5	0.40	1.25	1.56	1.95	NA	0.5	1.75	2.06	2.45	NA	103.55	4104
Order-5	60 + 15 + 12 + 8 + 5	0.38	1.04	2.19	3.84	6.31	0.5	1.54	2.69	4.34	6.82	154.20	7000

NA- not applicable

In Fig. 1, we have work out for different orders of heterogeneity by considering the no. of alive nodes with respect to the number of rounds. It is evident from the analysis of simulation of results, as the order of heterogeneity increases, the network lifetime of the network increases. It is also clear from the Fig. 1 that the last sensor nodes dead come about in 1815th, 3637th, 5204th, 4104th and 7000th no. of rounds for all five variants of HetSEP protocols, respectively. The HetSEP-5 performs the better than among all others in terms of no. of alive sensor nodes. We also computed the no. of dead nodes in Fig. 2 for different orders of heterogeneity with respect to the number of rounds.

In Fig. 2, the first nodes dead become 402th, 662th, 843th, 1020th, and 1602th in no. of rounds for HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, respectively.

In Fig. 3, we have computed the no. of packets delivered to the sink with respect to the no. of rounds for different orders of heterogeneity. The no. of packets transferred to the sink in HetSEP-1, HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, has been obtained as 1.51×10^4, 2.51×10^4, 2.72×10^4, 3.33×10^4 and 4.73×10^4, respectively, with respect to the no. of rounds. It is also evident that the HetSEP-5 has more no. of data packets delivered to the sink than the HetSEP-1, HetSEP-2, HetSEP-3, and HetSEP-4. In this work, we have also computed the total energy consumption with respect to the number of rounds as shown in Fig. 4. The five order of heterogeneity (HetSEP-5) performs better among all orders of heterogeneity of the HetSEP variants. However, the rate of energy consumption is much slower in case the HetSEP-5 (five order of heterogeneity) than the all other orders of heterogeneity. The HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, increase the network lifetime 100.39%, 126.12%, 186.56%, and 285.67%, corresponding to the increase in the network energy by 65.0%, 72.58%, 107.10%, and 208.40% with respect to the HetSEP-1.

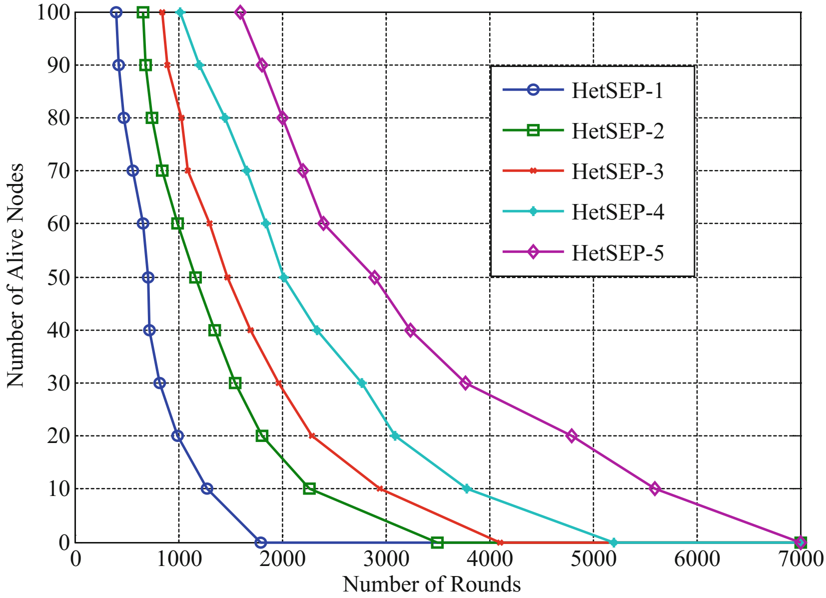

Fig. 1. No. of nodes alive vs. number of rounds

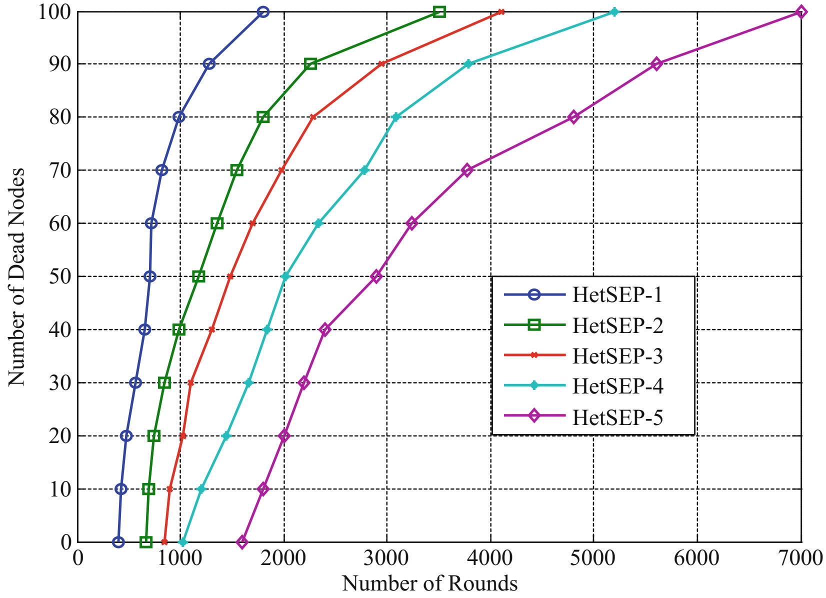

Fig. 2. No. of dead nodes vs. number of rounds

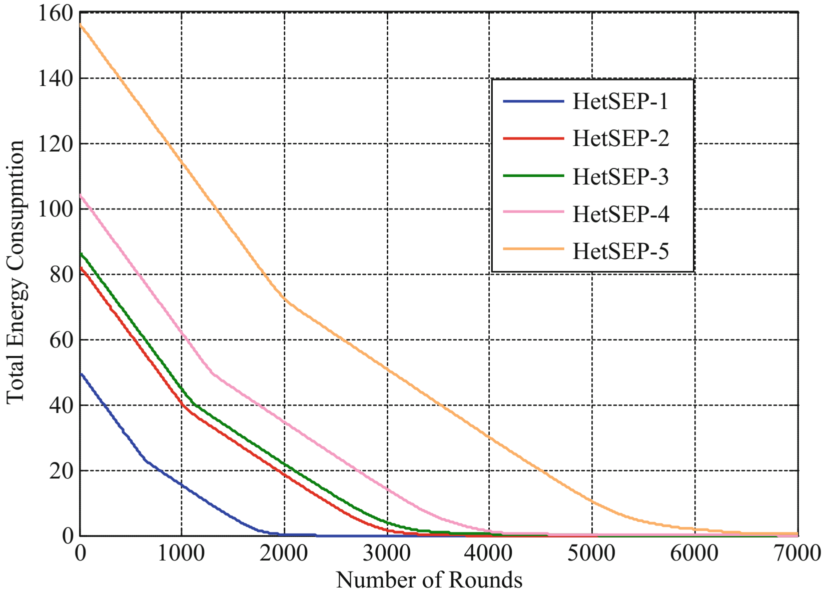

Fig. 3. Total energy consumption vs. number of rounds

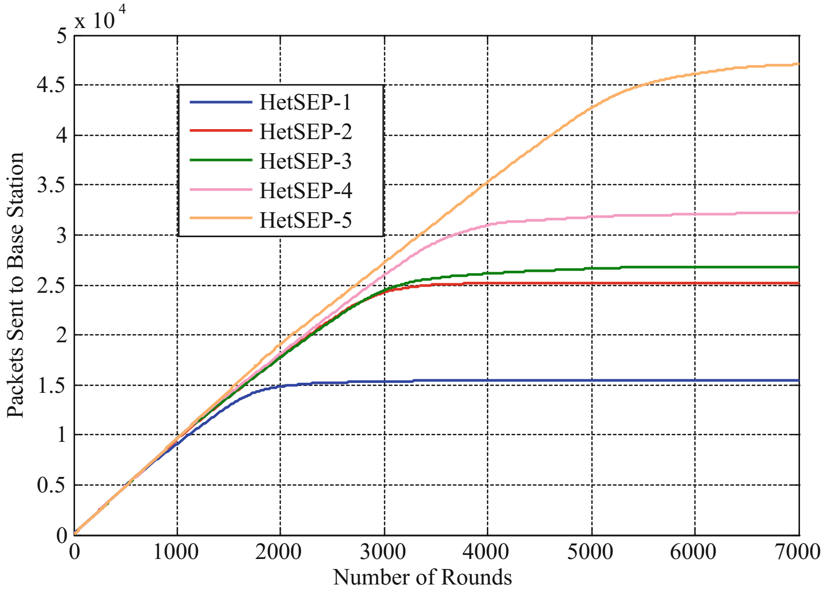

Fig. 4. No. of packets sent to the sink vs. number of rounds

5 Conclusions

In this work, an order-5 heterogeneity network model has been proposed for WSNs, namely: order-1, order-2, order-3, order-4, and order-5 heterogeneity in terms of energy. As the analysis of simulation of results, prolonging heterogeneity order prolongs the network lifetime in much proportion as compared to prolong in the network energy. However, the HetSEP-2, HetSEP-3, HetSEP-4, and HetSEP-5, prolong the network lifetime 100.39%, 126.12%, 186.56%, and 285.67% corresponding to the prolong in the network energy by 65.0%, 72.58%, 107.10%, and 208.40% with respect to the HetSEP-1. The HetSEP-5 performs better than the HetSEP-1, HetSEP-2, HetSEP-3, and HetSEP-4.

References

1. Akyildiz, I.F., Su, W., Sankarasubramaniam, Y., Cayirci, E.: WSNs: a survey. Comput. Netw. **38**, 393–422 (2002)
2. Heinzelman, W.R., Kulik, J., Balakrishnan, H.: Adaptive protocols for information dissemination in wireless sensor networks. In: Proceedings of ACM/IEEE International Conference on Mobile Computing and Networking MobiCom 1999, Seattle, WA (1999)
3. Intanagonwiwat, C., Govindan, R., Estrin, D.: Directed diffusion: a scalable and robust communication paradigm for sensor networks. In: Proceedings of ACM MobiCom 2000, Boston, MA, pp. 56–67 (2000)
4. Braginsky, D., Estrin, D.: Rumor routing algorithm for sensor networks. In: Proceedings of the First Workshop on Sensor Networks and Applications (WSNA), Atlanta, GA (2002)
5. Madiraju, S., Mallanda, C., Kannan, R., Durresi, A., Iyengar, S.S.: EBRP: energy band based routing protocol for wireless sensor networks. Department of Computer Science, Louisiana State University, 298 Coates Hall, LA 70803, USA (2004)
6. Heinzelman, W., Chandrakasan, A., Balakrishnan, H.: Energy-efficient communication protocol for wireless microsensor networks. In: Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS 2000) (2000)
7. Lindsey, S., Raghavendra, C.S.: PEGASIS: power efficient gathering in sensor information systems. In: Proceedings of the IEEE Aerospace Conference, Big Sky, Montana (2002)
8. Manjeshwar, A., Agarwal, D.P.: TEEN: a protocol for enhanced efficiency in wireless sensor networks. In: Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA (2001)
9. Manjeshwar, A., Agarwal, D.P.: APTEEN: a hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks. In: Proceedings of the International Parallel and Distributed Processing Symposium, IPDPS 2002, pp. 195–202 (2002)
10. Heinzelman, W.B., et al.: An application-specific protocol architecture for wireless microsensor networks. IEEE Trans. Wireless Commun. **1**(4), 660–670 (2002)
11. Smaragdakis, G., Matta, I., and Bestavros, A.: SEP: a stable election protocol for clustered heterogeneous WSNs. In: Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004) (2004)
12. Kumar, D., Aseri, T.C., Patel, R.B.: EEHC: energy efficient heterogeneous clustered scheme for WSNs. Comput. Commun. **32**, 662–667 (2009)

13. Qing, L., Zhu, Q., Wang, M.: Design of a distributed energy efficient clustering algorithm for heterogeneous WSNs. Comput. Commun. **29**, 2230–2237 (2006)
14. Qureshi, T.N., et al.: BEENISH: balanced energy efficient network integrated super heterogeneous protocol for wireless sensor networks. In: International Workshop on Body Area Sensor Networks (BASNet-2013) (2013). Procedia Comput. Sci. **00**, 1–6
15. Chand, S., Singh, S., Kumar, B.: Heterogeneous HEED protocol for wireless sensor networks. Wirel. Pers. Commun. **77**(3), 2117–2139 (2014)
16. Singh, S., Malik, A.: hetDEEC: heterogeneous DEEC protocol for prolonging lifetime in wireless sensor networks. J. Inf. Optim. Sci. **38**(5), 699–720 (2017)
17. Singh, S., Malik, A., Kumar, R.: Energy efficient heterogeneous DEEC protocol for enhancing lifetime in WSNs. Int. J. Eng. Sci. Technol. **20**(1), 345–353 (2017)
18. Singh, S.: Energy efficient multilevel network model for heterogeneous WSNs. Int. J. Eng. Sci. Technol. **20**(1), 105–115 (2017)
19. Singh, S., Chand, S., Kumar, B.: Multilevel heterogeneous network model for wireless sensor networks. Telecommun. Syst. **64**(2), 259–277 (2016)
20. Singh, S., Chand, S., Kumar, R., Malik, A., Kumar, B.: NEECP: a novel energy efficient clustering protocol for prolonging lifetime of WSNs. IET Wirel. Sens. Syst. **6**(5), 151–157 (2016)
21. Singh, S., Malik, A.: Energy efficient scheduling protocols for heterogeneous WSNs. Int. J. Forensic Comput. Sci. **11**(1), 8–29 (2016)
22. Chand, S., Singh, S., Kumar, B.: hetADEEPS: ADEEPS for heterogeneous wireless sensor networks. Int. J. Future Gener. Commun. Netw. **6**(5), 21–32 (2013)
23. Kumar, H., Singh, P.K.: Node energy based approach to improve network lifetime and throughput in wireless sensor networks. J. Telecommun., Electron. Comput. Eng. **9**(3), 83–88 (2017)
24. Kumar, N., Singh, Y., Singh, P.K.: Reputation-based energy efficient opportunistic routing for wireless sensor networks. J. Telecommun., Electron. Comput. Eng. **9**(3), 29–33 (2017)
25. Kumar, H., Singh, P.K.: Analyzing data aggregation in wireless sensor network. In: Proceedings of the INDIACom-2017, 01–03 March 2017, pp. 4024–4029 (2017)