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Implementation of EDEEC protocol for 4- Level Scalable HeterogeneousWireless Sensor Networks

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Abstract- Wireless Sensor Network consists of a large number of Sensor nodes, which firstly sense the data and then transmit the sensed data to the base station which is known as the Sink. Network lifetime is one of the key challenges for Wireless Sensor networks because of the limited battery life of the nodes. As we know sensor nodes are energy constrained devices and to increase the lifetime of the network it is very necessary to minimize the consumption of energy of nodes while sensing and transmitting the data. Clustering in Wireless networks is one of the pre-eminent ways to improve the lifetime ofthe network. In EDEEC, a clustering-based hierarchical model is used where data is aggregated in the cluster and sent to a higher-level cluster head where the cluster head is selected randomly on the basis of residual energy of the network. EDEEC works on 3-level heterogeneous wireless sensor networks in which there are three type of sensor nodes named as normal nodes, advanced nodes and super node, which still have scope of improvement because if the levels of heterogeneous wireless sensor networks are to be increased then more complexity will be there in the network and then a more stable behaviour of network is required. In this work it is proposed that performance of the network can be enhanced if the level of heterogeneity in the network increases because in the real world there can exist more than three types of nodes in the network. In this work EDEEC protocol has been implemented with four types of nodes that includes normal nodes, advance nodes, super nodes and ultra-super nodes and the nodes count varies from 100 to 1000 nodes to check the change in energy consumption and stability of the network.
Keywords: Clustering, Energy, Stability period, Heterogeneous, Wireless Sensor Networks.

I Introduction

A Wireless Sensor Network or WSN is supposed to be made up of a large number of sensors and at least one base station (sink) as shown in Figure 1. The sensors are autonomous small devices with several constraints like the battery power, computation capacity, communication range and memory. They also are supplied with transceivers to gather information from its environment and pass it on up to a certain base station, where the measured parameters can be stored and available for the end user. In wireless Sensor networks, each sensor node has a limited battery life, thus the network formed by these nodes is also energy constrained. These sensor nodes have limited range and energy in the network.

Sensor node is a tiny device that senses the data from the surrounding environment, processes it and then transmits it to the base station. Thus it includes three basic components: a sensing subsystem for data acquisition from the physical surrounding environment, a processing subsystem for local data sensing subsystem for data acquisition from the physical sensing subsystem for data acquisition from the physical surrounding environment processing and storage, and a wireless communication subsystem for data transmission.

Sink is the destination base station system that receives the data sent by all the sensor nodes. It can be considered as an interface between the sensor field and the user.

Thus Wireless Sensor Networks consist of a large number of small sensing nodes that monitor their environment, process data if necessary and send/receive processed data to/from other sensing nodes. These sensing nodes, distributed in the environment, are connected to a sink.

Wireless networks are used in a wide range of applications like area and environment monitoring,forest fire detection and greenhouse monitoring, landslide detection and machine health monitoring etc. In addition to these applications Wireless Sensor Networks are also used in various important areas like military, health-care and scientific research and infrastructure protection etc.

Mostly wireless sensor networks are used in those areas where continuous human intervention is impractical and it is unrealistic to remove a dead node and implant a new node in the network.

So there is a need to minimize the energy consumption of nodes during the transmission of data in the network. There are various routing protocols that are useful to achieve energy efficiency by using clustering.

There are many clustering based protocols like LEACH, SEP, PEGASIS and DEEC etc. EDEEC protocol is a variant of DEEC and EDEEC works on 3-level heterogeneous wireless sensor networks in which there are three types of sensor nodes named as normal nodes, advanced nodes and super nodes. This paper presents the behaviour analysis of EDEEC protocol for 4-level heterogeneous wireless sensor networks in which there are four types of nodes named as normal, advanced, super and ultra-super nodes.

Rest of the paper is organized as follows, section I contains introduction and applications of wireless sensor networks, importance of energy conservation in wireless sensor networks and motivation for the proposed work, section II contains the related work of clustering protocols used for energy conservations in heterogeneous wireless sensor networks, section III contains the motivation of work for implementing

EDEEC in a 4-level heterogeneous wireless sensor network, section IV represent the radio energy dissipation model that how the energy is consumed in sending and receiving the data packet, section V depicts the heterogeneous WSN model and introduced to the various levels in corresponding models, section VI contains the assumptions and properties of the network that are considered while doing simulation, section VII includes the methodology used for implementing the EDEEC protocol for 4-level heterogeneous wireless sensor network, section VIII includes the parameters used for performance evaluation, section IX describes the simulation results of EDEEC protocol for three and four types of nodes, section X concludes the research work.

II. Related Work

Clustering is the hierarchical method to extend the network lifetime through efficient resource utilization. In the clustering approach the Sensor network is divided into groups, called clusters. Nodes are grouped in clusters on the basis of some parameters and one node in each cluster that is selected by using some probability mechanism acts as cluster head which collects the data from its cluster and after aggregating and processing it sends it to the base station(sink). In a homogenous network it is assumed that the energy level of each node is equal, in this scenario the sensing, processing and communication capabilities of each node are the same. But in heterogeneous networks the level of energy varies. The energy level of nodes can be two-level, three-level and multilevel respectively.

Heinzelman, et al. [16] introduced a cluster- based protocol, named as LEACH (Low Energy aware clustering) protocol for homogeneous Wireless sensor networks to minimize the energy use in sensor networks by randomly choosing the sensor node as cluster heads. In Leach protocol there are two phases of data transmission namely setup and steady-state phases. In the setup phase, the nodes are randomly selected as cluster-heads using a cluster selection algorithm based on a certain probability. In the steady-phase, the nodes within the clusters transmit their data to the appropriate CH within a specific region, and then CH further aggregates and transfers the received data to the Sink. LEACH selects data transmission phases in each round based on their time and selects a random CH to balance the energy. However, this protocol does not guarantee the selection of an optimal number of CHs, and its performance does not improve in a heterogeneous environment. LEACH does not guarantee optimal number of CHs in each round and selection of CHs is random which makes cluster heads of different sizes.

The LEACH protocol is only suitable for homogeneous WSN. So to overcome this problem, G. Smaragdakis, et al. [19] proposed a protocol for two-level heterogeneous wireless sensor networks in which the network is composed of two types of nodes according to the initial energy. The advanced nodes are equipped with more energy than the normal nodes at the beginning. SEP prolongs the stability period, which is defined as the time interval before the death of the first node. SEP is not fit for the widely used multi-level heterogeneous wireless sensor networks, which include more than two types of nodes.

As SEP is not fit for widely used multi-level heterogeneous wireless sensor networks, L .Qing, et al. [13] proposed a protocol DEEC which is also fit for the multilevel heterogeneous networks and performs well. It selects the cluster heads with the help of probability based on the ratio between residual energy of each node and the average energy of the network. How long different nodes would be cluster heads, is decided according to the initial and residual energy. The authors assume that all the nodes of the wireless sensor network are equipped with different amounts of energy, which is a source of heterogeneity. CH selection is based on probability which depends upon the residual energy of nodes and average energy of the network.

DEEC always penalizes the advanced nodes, especially when their residual energy depletes and becomes in the range of the normal nodes. In this situation, the advanced nodes die more quickly than the others. B. Elbhiri, et al. [20] proposed a protocol, DDEEC, Developed Distributed Energy-Efficient Clustering, which permits to balance the cluster head selection of overall network nodes following their residual energy. This protocol is based on residual energy for CH selection to balance it over the entire network. So, the advanced nodes are more likely to be selected as CH for the first transmission rounds, and when their energy decreases, these nodes will have the same CH election probability like the normal nodes.

In order to increase the heterogeneity of the DEEC protocol, P. Saini, et al. [21] proposed EDEEC protocol which extended to three-level heterogeneity by adding an extra energy level. The nodes are categorized as normal, advanced, and super. However, the CHs selection probabilities are not adjusted according to nodes' energy levels.

III. Motivation

Many clustering based protocols like LEACH, SEP, DEEC and EDEEC etc. have been proposed for wireless sensor networks to increase the lifespan of the network by using the available energy in an efficient manner. LEACH is a clustering-based protocol that minimizes energy dissipation in sensor networks. It is suitable for homogeneous wireless sensor networks. The purpose of LEACH is to randomly select sensor nodes as cluster-heads, so the high energy dissipation in communicating with the base station is spread to all sensor nodes in the sensor network. The operation of LEACH is separated into two phases, the set-up phase and the steady phase. The duration of the steady phase is longer than the duration of the set-up phase in order to minimize the overhead. During the set-up phase, cluster-heads assign the time on which the sensor nodes can send data to the cluster-heads based on a TDMA approach. During the steady phase, the sensor nodes can begin sensing and transmitting data to the cluster heads. The cluster-heads also aggregate data from the nodes in their cluster before sending these data to the base station. SEP is a two-level heterogeneity based protocol in which the probability of an advanced node is higher than normal nodes. However in SEP, it is assumed that the energy of nodes is not properly utilized and it needs further improvement which is overcome by DEEC protocol. DEEC protocol is a heterogeneity based protocol that chooses the cluster heads on the basis of residual energy of the network. EDEEC is a variant of DEEC, it work on 3-level heterogeneity based wireless networks in which there are three type of sensor nodes named as normal nodes, advanced nodes and super node, which still have scope of improvement because if the levels of heterogeneous wireless sensor networks are to be increased then more complexity will be there in the network and then a more stable behaviour of network is required. This work aims to propose the implementation of EDEEC protocol for 4-level heterogeneous wireless sensor networks in which there are four types of nodes named as normal, advanced, super and ultra-super nodes to show that performance of the network can enhanced if the level of heterogeneity in the network increased because in real world there can exist more than three types of nodes in the network.

IV. Radio Energy Dissipation Model

We have assumed the same radio model which has been used in earlier works. For the radio hardware, the transmitter dissipates energy to run the transmitter radio electronics and power amplifier, and receiver dissipates energy to run the transmitter radio electronics as shown in Figure 2. For the scenarios described in the project work, both the free space (d2 power loss), and multipath fading (d4 power loss) channel model were used depending on the distance between the transmitter and receiver, if distance is less than a threshold, the free space model is used; otherwise, the multipath model is used.

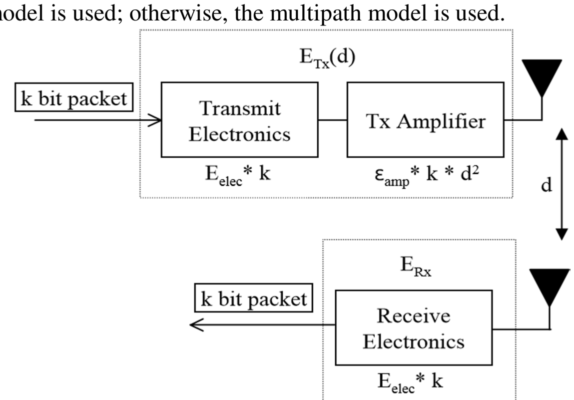

Figure 2 Wireless Sensor Network

V. Heterogeneous Wireless Sensor Networks

As we know basically there are two types of wireless sensor networks known as homogeneous and heterogeneous wireless sensor networks. Homogeneous network is the type of network in which the nodes are equipped with the same amount of communication, sensing and processing capabilities. While in Heterogeneous network, nodes are equipped with variable sensing, communication and processing capabilities. Heterogeneous WSNs contain two, three or multi types of nodes with respect to their energy levels and are termed as two, three and multi-level heterogeneous WSNs respectively.

Two -Level Heterogeneous WSN: Two level heterogeneous WSNs contain two energy levels of nodes: normal and advanced nodes. Where, E_o is the initial energy of normal node and $E_o(1 + a)$ is the initial energy of advanced nodes containing a times more energy as compared to normal nodes. Let N be the total number of nodes and m be the fraction of advanced nodes then the total number of advanced and normal nodes are:

$$N_{adv} = N.m \quad (1)$$

$$N_{nrm} = N.(1 - m) \quad (2)$$

The initial energy associated with total number of advanced and normal nodes is given as:

$$E_{adv} = N.m.(1 + a).E_o \quad (3)$$

$$E_{nrm} = N.(1 - m).E_o \quad (4)$$

The total initial energy of the network is the sum of energies of normal and advanced nodes:

$$E_{total} = N.(1 - m).E_o + m.N.(1 + a).E_o$$
$$= N.E_o.(1 - m + m + am)$$
$$= N.E_o.(1 + am) \quad (5)$$

The two level heterogeneous WSNs contain am times more energy as compared to homogeneous WSNs [13].

Three-Level Heterogeneous WSN: Three level heterogeneous WSNs contain three different energy levels of nodes i.e. normal, advanced and super nodes. Normal nodes contain initial energy of E_o, the advanced nodes of fraction m are having a times extra energy than normal nodes equal to $E_o(1 + a)$ whereas, super nodes of fraction m_o are having a factor of b times more energy than normal nodes so their energy is equal to $E_o(1 + b)$. Let N be the total number of nodes and m be the fraction of advanced and super nodes. Further that fraction m has m_o been the fraction of super nodes then the total number of advanced and normal nodes is:

$$N_{nrm} = N.(1 - m) \quad (6)$$

$$N_{adv} = N.m.(1 - \ )_o \quad (7)$$

$$N_{sup} = N.m.m_o \quad (8)$$

The initial energy associated with total number of advanced and normal nodes is given as:

$$E_{adv} = N.m.\left(1 - \ \right)_o.(1 + a).E_o \quad (9)$$

$$E_{nrm} = N.(1 - m).E_o \quad (10)$$

$$E_{sup} = N.m.m_o.(1 + b).E_o \quad (11)$$

The total initial energy of three level heterogeneous WSN is therefore given by:

$$E_{total} = N.(1 - m).E_o + m.N.\left(1 - m_o\right).($$
$$= N.E_o.(1 + m.\left(a + m_o.b\right)) \quad (12)$$

The three level heterogeneous WSNs contain $(a + m_o b)$ times more energy as compared to homogeneous WSNs [14].

Four-Level Heterogeneous WSN: Four level heterogeneous WSNs contain four different energy levels of nodes i.e. normal, advanced and super and ultra-super nodes. Normal nodes contain initial energy of E_o, the advanced nodes of fraction m are having a times extra energy than normal nodes equal to $E_o(1 + a)$ whereas, super nodes of fraction m_o are having a factor of b times more energy than normal nodes so their energy is equal to $E_o(1 + b)$ and ultra-super nodes of fraction m_1 are having a factor of c times more energy than normal nodes so their energy is equal to $E_o(1 + c)$. Let N be the total number of nodes and m be the fraction of advanced, super nodes and ultra-super nodes. Further that fraction $m1$ has m_o been the fraction of ultra-super nodes and super nodes then the total number of advanced and normal nodes is:

$$N_{nrm} = N.(1 - m) \quad (13)$$

$$N_{adv} = N.m.(1 - \ )_o \quad (14)$$

$$N_{sup} = N.m(1 - m_o)(1 - \ )_1$$

$$N_{ultra} = N.m.m_o m_1 \quad (15)$$

The initial energy associated with total number of advanced and normal nodes is given as:

$$E_{adv} = N.m.\left(1 - \ \right)_o.(1 + a).E_o \quad (16)$$

$$E_{nrm} = N.(1 - m).E_o \quad (17)$$

$$E_{sup} = N.m.\left(1 - \ \right)_o(1 - \ )_1(1 + b).E_o$$

$$E_{ultra} = N.m.m_o.m_1(1 + c).E_o \quad (18)$$

The total initial energy of three level heterogeneous WSN is therefore given by:

$$E_{total} = N.(1 - m).E_o + m.N.\left(1 - m_o\right).(1 \quad (19)$$

Multi-level Heterogeneous WSN: Multi level heterogeneous WSN is a network that contains nodes of multiple energy levels. Most of the recent research has been made considering the WSN model to be two level or three level heterogeneous WSN. CH nodes consume more energy as compared to member nodes so after some rounds the energy level of all the nodes becomes different as compared to each other. Therefore, heterogeneity is introduced in homogeneous WSNs and the networks that contain heterogeneity are more important than homogeneous networks.

VI. Assumptions and Properties of the Network

The heterogeneous WSN is provided with different energy levels. Some nodes have more energy than the normal nodes at the time of initialization. Some assumptions have been made for the network as well as sensor nodes in the network as well as sensor network model described above. Those assumptions are:

- Sensor nodes are uniformly distributed and randomly placed in the wireless sensor network.
- At the centre of the sensing field, there is a base station also called a sink which is placed in the centre of the field.
- Sensor nodes are always provided with data to transmit to sink.
- Sensor nodes are not aware of each other's locations.
- All nodes have similar processing and communication capabilities and of equal significance.
- All the nodes are considered to be either fixed or micro-mobile, so their energy loss due to collision and interference between signals of different nodes are ignored.

VII. Methodology

EDEEC with 4-level of heterogeneous nodes (proposed protocol) is implemented the same way as that of EDEEC, but it improves simply by increasing the level of heterogeneity in the network. Below are the steps which are involved in implementing EDEEC with 4-level of heterogeneous nodes:

a. **Create Network:** Consider a network of 100*100 meters and 100 nodes are randomly deployed on it and a sink node is located at the centre of the field.
b. **Add Heterogeneity of the Nodes:** Based on the fractional division calculate the number of normal, advanced, super and advanced nodes. For this thesis work, the fraction parameters m, mo and m1 are considered to be 0.8, 0.5 and 0.4 respectively. Therefore, number of normal, advanced, super and ultra-super nodes are 20, 40, 24 and 16 respectively by calculating using equations 13,14 and 15
c. **Energy initialization:** Initialize the energy to each type of nodes using equation 16, 17 and 18 for normal, advanced, super and ultra-super nodes. For this scenario, the initial energy appears to be 0.5, 1.25, 1.5 and 2.5 Joules for each normal, advanced, super and ultra-super node. Thus the total energy of the network is 124 Joules.
d. **Cluster Head Selection:** The cluster head selection is performed on the basis of residual energy of each node and average network energy using cluster head selection algorithm. This algorithm will be executed for 10000 rounds so as to evaluate the network stability.

VIII. Parameters Used for Performance Evaluation

To study and evaluate the clustering protocols, various performance metrics are used such as stability period, number of alive nodes, throughput, energy dissipation and number of data packets received at base station and cluster head.

Stability Period: The time interval of network from the start of network operation until the death of the first sensor node.

Instability Period: The time interval from the death of the first node until the death of the last sensor node.

Number of alive nodes: This instantaneous measure reflects the total number of nodes and that of each type that has not yet expended all of their energy.

Data Packets Received at Base Station: The total number of messages or data packets that sink receives.

Data Packets Received at Cluster Head: The total number of messages or data packets that cluster head receives from other cluster members.

Energy Dissipation: The energy consumed in the network, measured at each transmission round.

Throughput: The number of data packets received at Base Station and at Cluster Head is termed as throughput.

Table 1. Simulation Parameters

Parameters	Value
Network area	100*100
Number of nodes	100 to 1000
Location of Sink	50,50
Initial Energy	0.5J
E_{TX}	50nJ
E_{RX}	50nJ
E_{amp}	0.0013Pj/bit/m^2
Efs	10pJ/bit/m^2
E_{DA}	5nJ/bit/signal
Message Size	4000Bits
d_o	70m
p_{opt}	0.1
E_{total}	124J
E_{nrm}(per node)	0.5J
E_{adv}(per node)	1.25J
E_{sup}(per node)	1.5J
E_{ultra}(per node)	1.75J
Number of rounds	10000

Radio parameters used in heterogeneous WSN are mentioned in Table 1.

IX. Simulation and Results

This section includes the implementation of EDEEC for 3-level and 4-level heterogeneous wireless sensor networks.

In this work the behaviour of EDEEC which is a three-level protocol which has three type of nodes such as normal, advanced and super nodes, is compared with the behaviour of EDEEC which is a four-level heterogeneous protocol (proposed work), which has four types of nodes such as normal, advanced, super nodes and ultra-super nodes.

5.1. Results and Analysis

For the simulation, a network is created of N=100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 nodes which are randomly deployed in a field of dimension 100m * 100m with a centrally located sink. These nodes are divided into four types based on their energy. Using the fraction of advanced nodes (m) be 0.8, super nodes (m_o) be 0.5 and ultra-super (m_1) be 0.4 the number of normal, advanced, super and ultra-super nodes are calculated using the equations 13, 14 and 15.

Normal nodes contain initial energy of $_o$, the advanced nodes of fraction m are having a times extra energy than normal nodes equal to $E_o(1 + a)$ whereas, super nodes of fraction m_o are having a factor of b times more energy than normal nodes so their energy is equal to $E_o(1 + b)$ and ultra-super nodes of fraction m_1 are having a factor of c times more energy than normal nodes so their energy is equal to $E_o(1 + c)$.

5.1.1 Stability Period

The time interval of the network until the death of the first node is called the stability period. Figure 3 depicts the number of dead nodes during each round. For N=100 (When the number of nodes are 100 in wireless sensor network), first node for EDEEC and EDEEC for four-level heterogeneous dies in 964th and 1462th round respectively. At this stage the number of nodes alive in EDEEC for four-level heterogeneous nodes is quite larger than EDEEC.

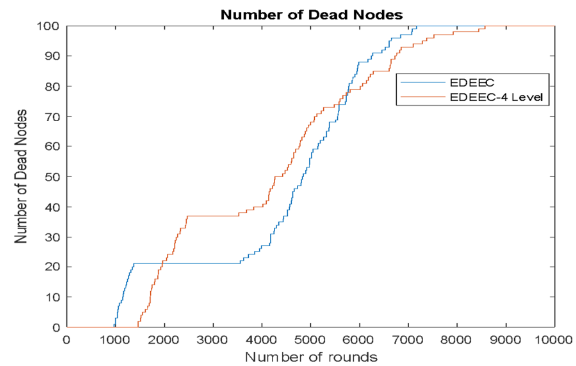

Figure 3 Performance Comparison for Stability Period for 100 nodes

When the total number of nodes are 200 then there are 40 normal, 80advance, 48 super and 32 ultra- super nodes that are calculated using the same equations that are used above for 100 nodes. For N=200 (When the number of nodes are 200 in wireless sensor network), first node for EDEEC and EDEEC for four-level heterogeneous dies in 526th and 1388th round respectively as shown in Figure 4 Again the stability period is improved in this network scenario.

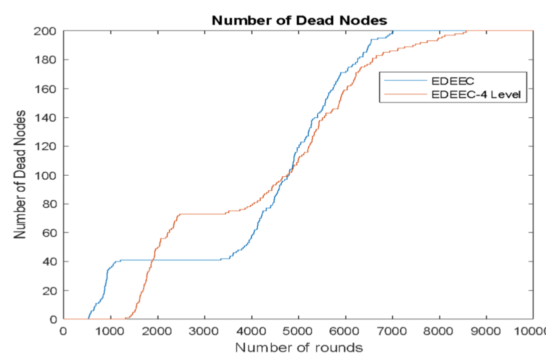

Figure 4 Performance comparison for stability period for 200 nodes

When the numbers of nodes (N) in WSN are 300, then 60 nodes are normal nodes, 120 are advanced, 72 are super and 48 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 428th and 1373th round respectively as shown in Figure 5.

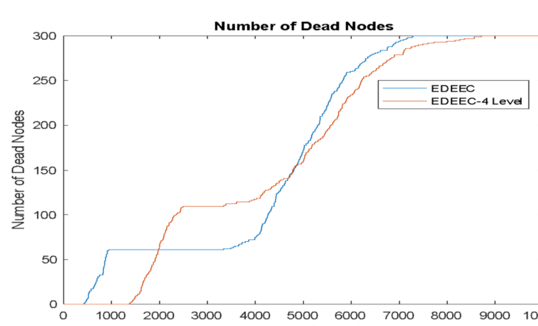

Figure 5 Performance comparison for stability period for 300 nodes

When the numbers of nodes (N) in WSN are 400, then 80 nodes are normal nodes, 160 are advanced, 96 are super and 64 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 422th and 1346th round respectively as shown in Figure 6.

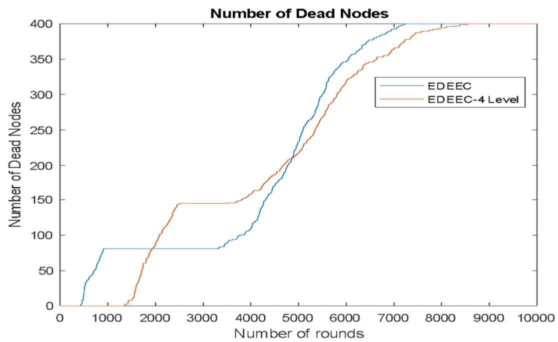

Figure 6 Performance comparison for stability period for 400 nodes

When the numbers of nodes (N) in WSN are 500, the 100 nodes are normal nodes, 200 are advanced, 120 are super and 80 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 338th and 1342th round respectively as shown in Figure 7.

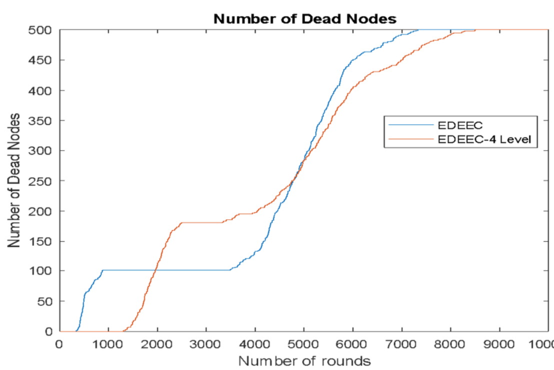

Figure 7 Performance comparison for stability period for 500 nodes

When the numbers of nodes (N) in WSN are 600, then 120 are normal nodes, 240 are advanced, 144 are super and 96 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies in at 21th and 1336th round respectively as shown in Figure 8.

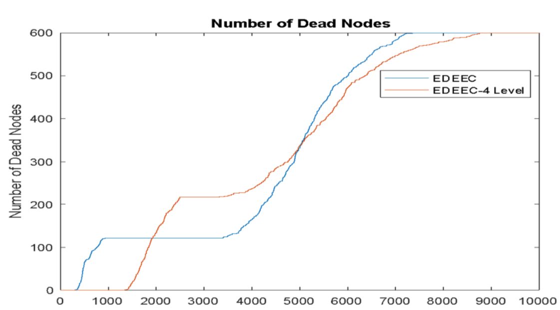

Figure 8 Performance comparison for stability period for 600 nodes

When the numbers of nodes (N) in WSN are 700, then 140 nodes are normal nodes, 280 are advanced, 168 are super and 112 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 314th and 1332th round respectively as shown in Figure 8.

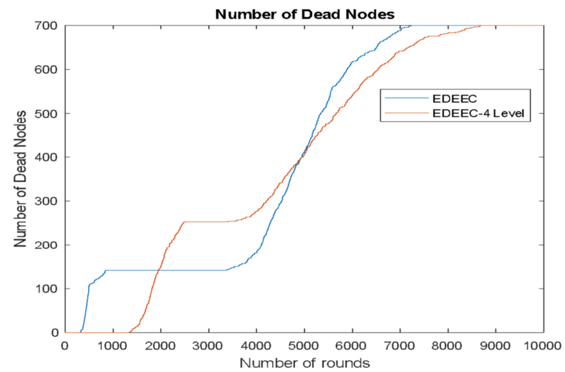

Figure 8 Performance comparison for stability period for 700 nodes

When the numbers of nodes (N) in WSN are 800, then 160 are normal nodes, 320 are advanced, 192 are super and 128 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 303th and 1281th round respectively as shown in Figure 9..

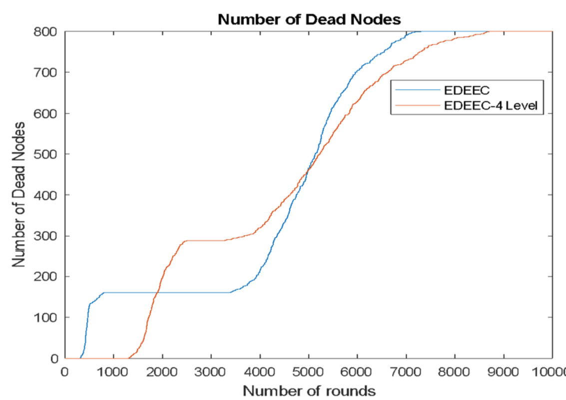

Figure 9 Performance comparison for stability period for 800 nodes

When the numbers of nodes (N) in WSN are 900, then 180 are normal nodes, 360 are advanced, 216 are super and 144 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 288th and 1274th round respectively as shown in Figure 10.

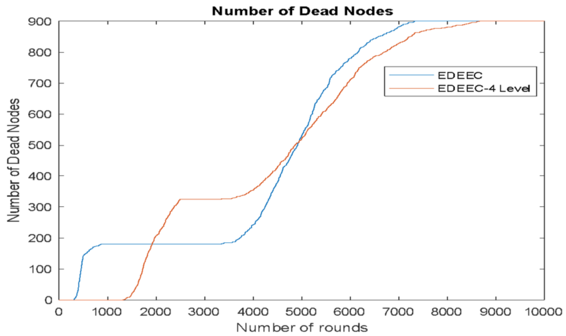

Figure 10 Performance comparison for stability period for 900 nodes

When N=1000 i.e. the numbers of nodes are 1000, then 200 nodes are normal nodes, 400 are advanced, 240 are super and 160 are ultra-super nodes. Then in this network scenario the first node for EDEEC and EDEEC for four-level heterogeneous dies at 281th and 1260th round respectively as shown in Figure 11.

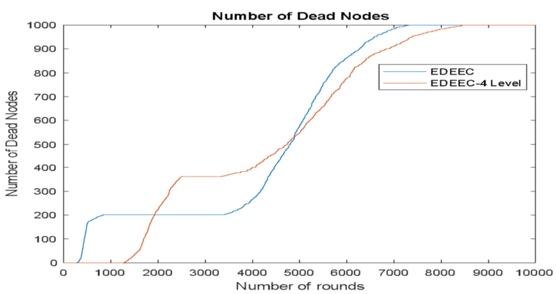

Figure 11 Performance comparison for stability period for 1000 node

The following graph (Figure 12) shows the comparative behaviour analysis of stability period of EDEEC for 3-level and 4-level heterogeneity for varying number of nodes (n) in the network where the value of n is 100,200,300,400,500,600,700,800,900 and 1000 respectively.

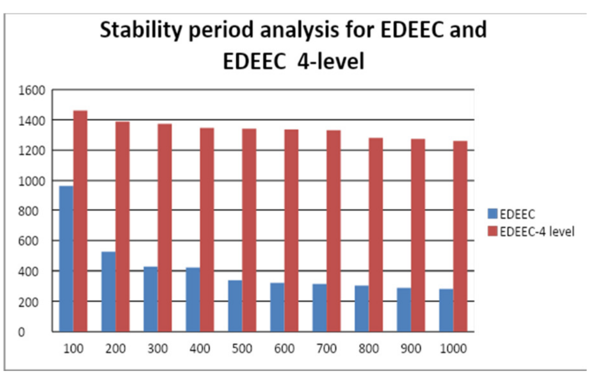

Figure 12 Stability period comparison chart for EDEEC an 4-Level EDEEC

5.1.2 Number of Alive Nodes

As the nodes communicate with cluster heads and sink, some of the energy associated with those particular nodes is utilized. After some number of nodes, as the nodes lose their energy, nodes start to die out. The measure of total number of all types of nodes that have not yet dissipated all of their energy is termed as number of nodes alive.

Figure 13 depicts the number of alive nodes during each round. All the nodes are alive till round number 963th and 1461th for EDEEC for four-level heterogeneous nodes respectively. There are 20 normal nodes out of 100 total nodes in the network. Normal nodes have least energy amongst all other types. Advanced nodes have energy more than normal nodes but less than super and ultra-super nodes. Ultra-Super nodes have higher energy amongst other types of nodes.

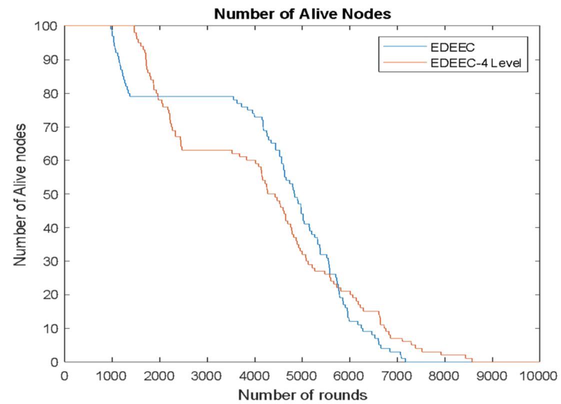

Figure 13 Performance comparison for number of nodes alive for 100 nodes

Figure 14 shows the number of nodes alive for a total 200 numbers of nodes in the network. When we have a total 200 nodes in the network then there are 40 normal nodes and energy given to them is minimal as compared to other nodes.

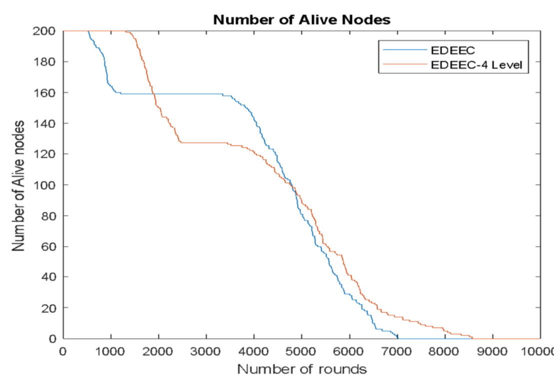

Figure 14 Performance comparison for number of nodes alive for 200 nodes

When n=300, i.e. there are a total 300 nodes in the WSN network then the number of alive nodes in the network is shown in Figure 15, given below.

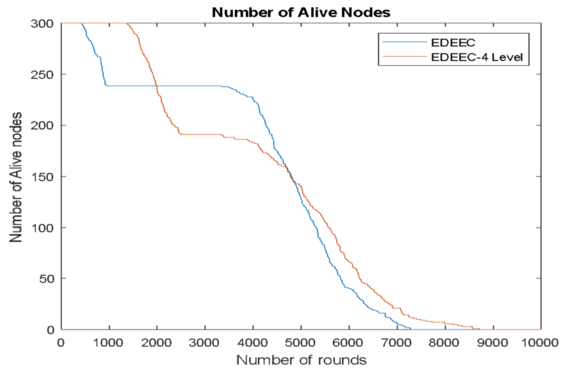

Figure 15 Performance comparison for number of nodes alive for 300 nodes

When n=400, i.e. there are a total 400 nodes in the WSN network then the number of alive nodes in the network is shown in Figure 16 given below.

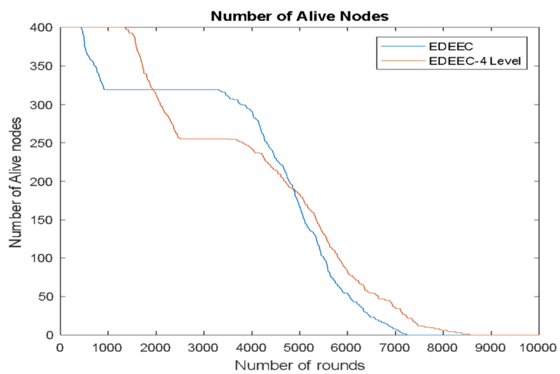

Figure 16 Performance comparison for number of nodes alive for 400 nodes

When n=500, i.e. there are a total of 500 nodes in the WSN network then the number of alive nodes in the network is shown in Figure 17, given below.

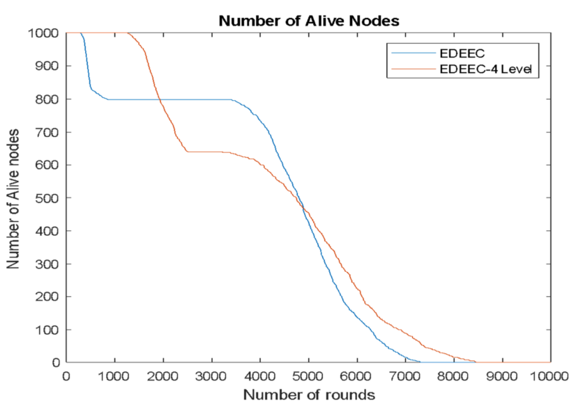

Figure 17 Performance comparison for number of nodes alive for 500 nodes

When n=600, i.e. there are a total 600 nodes in the WSN network then the number of alive nodes in the network is shown in Figure18, given below.

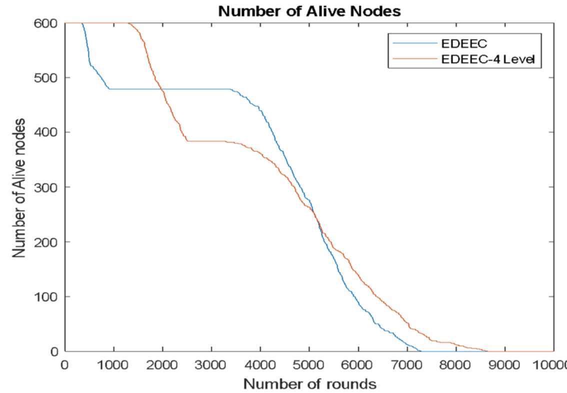

Figure18 Performance comparison for number of nodes alive for 600 nodes

When n=700, i.e. there are a total 700 nodes in the WSN network then the number of alive nodes in the network is shown in Figure 19, given below.

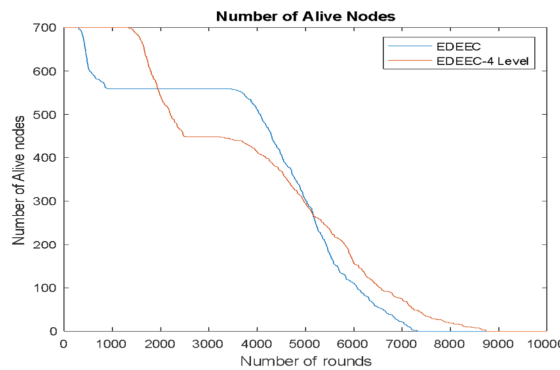

Figure 19 Performance comparison for number of nodes alive for 700 nodes

When n=800, i.e. there are a total 800 nodes in the WSN network then the number of alive nodes in the network is shown in Figure 20.

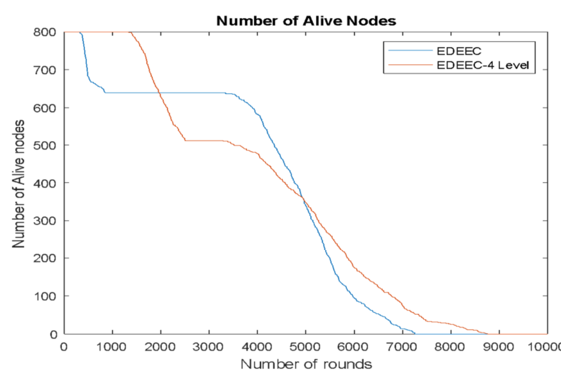

Figure 20 Performance comparison for number of nodes alive for 800 nodes

When n=900, i.e. there are a total of 500 nodes in the WSN network then the number of alive nodes in the network is shown in Figure 21.

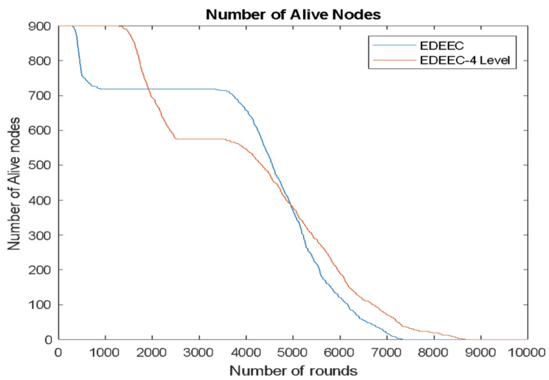

Figure 21 Performance comparison for number of nodes alive for 900 nodes

When n=1000, i.e. there are a total 1000 nodes in the WSN network then the number of alive nodes in the network is shown in the Figure22, given below.

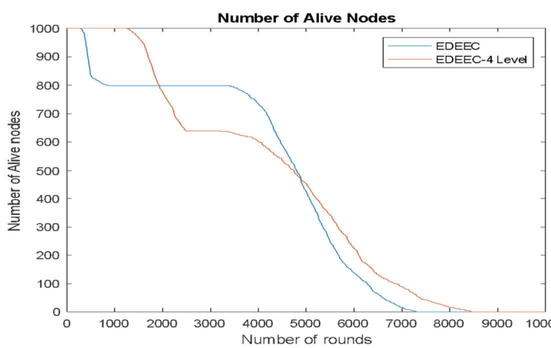

Figure 22 Performance comparison for number of nodes alive for 1000 nodes

5.1.3 Number of Packets Sent to Base Station

After collecting the data from cluster members, cluster heads aggregate the data and send it to the base station. The following figure depict the data sent to the base station/sink for 100, 200,300,400,500,600,700,800,900 and 1000 nodes wireless sensor networks The packet sent to the base station is slightly better more in EDEEC 4- level heterogeneity protocol as compare to existing EDEEC with 3-level heterogeneity protocol for all WSNs.

As shown in Figure 23 when there are 100 nodes in the wireless sensor network, the total number of packets sent to base station for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols are 399851 and 412661 respectively

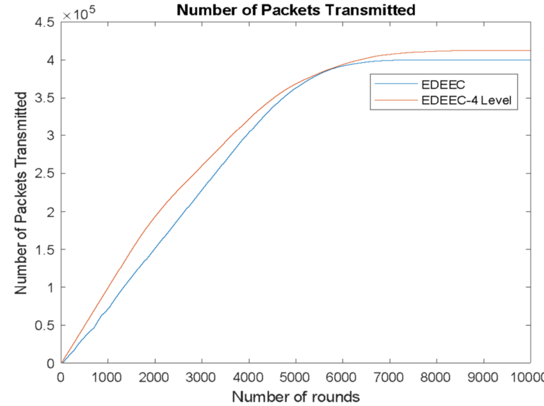

Figure 23 Performance comparison for number of packets sent to base station for 100 nodes

Figure 24 shows the packets sent to the base station for 200 nodes wireless sensor network. In this the number of packets sent to the base station is 746664 and 850285 for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols respectively.

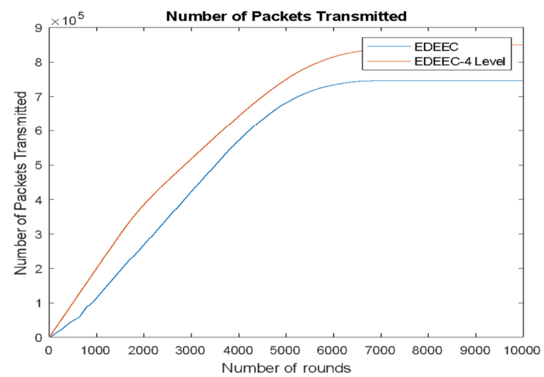

Figure 24 Performance comparison for number of packets sent to base station for 200 nodes

As shown in Figure 25 when there are 300 nodes in the wireless sensor network, the total number of packets sent to base station for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols are 1111215 and 850285 respectively.

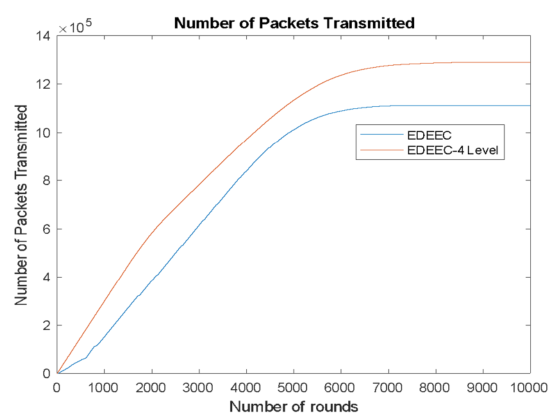

Figure 25 Performance comparison for number of packets sent to base station for 300 nodes

As shown in Figure 26 when there are 400 nodes in the wireless sensor network, the total number of packets sent to the base station for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols are 1449207 and 1713973 respectively.

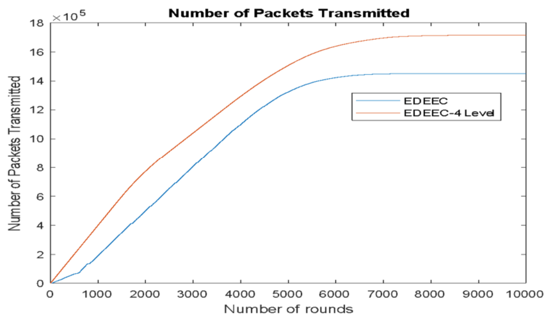

Figure 26 Performance comparison for number of packets sent to base station for 400 nodes

As shown in Figure 27 when there are 500 nodes in the wireless sensor network, the total number of packets sent to the base station for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols are 1793308 and 2137803respectively.

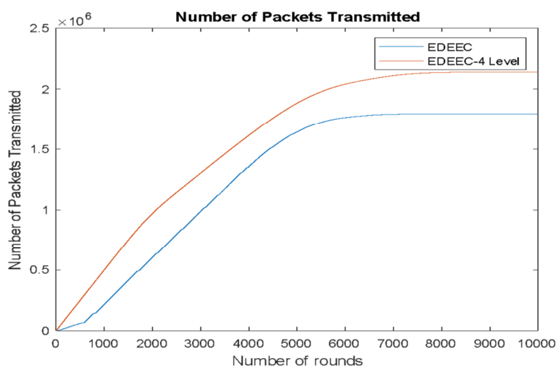

Figure 27 Performance comparison for number of packets sent to base station for 500 nodes

Figure 28 shows the packets sent to the base station for 600 nodes wireless sensor network. In this the number of packets sent to the base station is 2191405 and 2590446 for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols respectively.

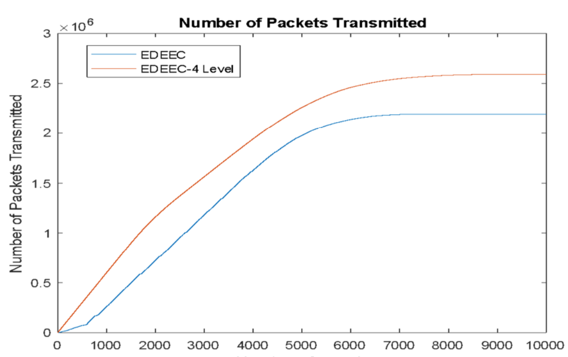

Figure 28 Performance comparison for number of packets sent to base station for 600 nodes

Figure 29 shows the packets sent to the base station for 700 nodes wireless sensor network. In this the number of packets sent to the base station is 2516465 and 3013981 for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols respectively.

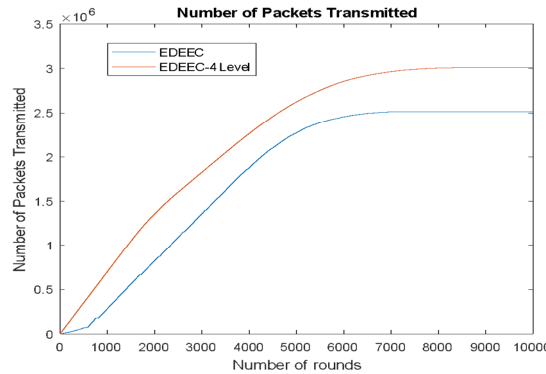

Figure 29 Performance comparison for number of packets sent to base station for 700 nodes

Figure 30 shows the packets sent to the base station for 800 nodes wireless sensor network. In this the number of packets sent to the base station is 2836134 and 3437305 for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols respectively.

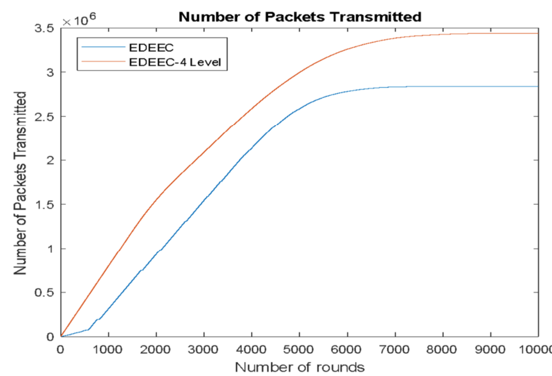

Figure 30 Performance comparison for number of packets sent to base station for 800 nodes

Figure 31 shows the packets sent to the base station for 900 nodes wireless sensor network. In this the number of packets sent to the base station is 3175576 and 3828800 for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols respectively.

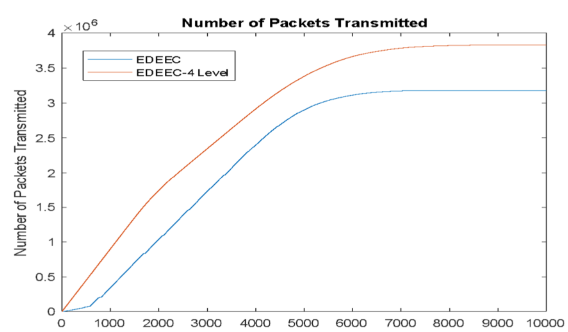

Figure 31 Performance comparison for number of packets sent to base station for 600 nodes

Figure 32 shows the packets sent to the base station for 1000 nodes wireless sensor network. In this the number of packets sent to the base station is 3542360 and 4292254 for EDEEC with 3-level heterogeneity and 4 level heterogeneity protocols respectively.

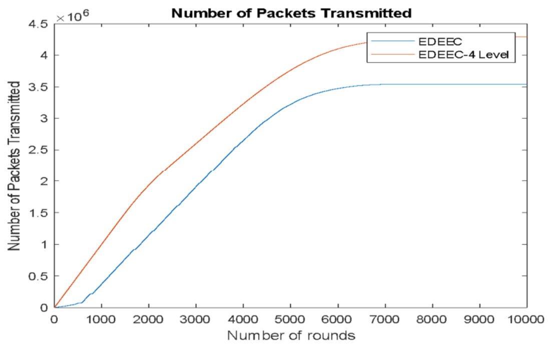

Figure 32 Performance comparison for number of packets sent to base station for 1000 nodes

The following graph (Figure 33) shows the comparative behaviour analysis of total packets sent to base station for EDEEC for 3-level and 4-level heterogeneity for varying number of nodes (n) in the network where the value of n is 100 to 1000 nodes respectively.

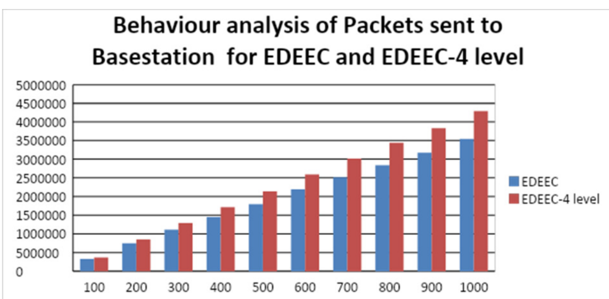

Figure 33 Packets sent to base station comparison chart for EDEEC and 4-Level EDEEC

5.1.4. Energy consumption

The energy consumption is the total energy consumed by normal, advanced, super and ultra-super nodes in the normal. The comparison chart of energy consumption for EDEEC and 4-level EDEEC 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 nodes is shown below in Figure 34. Here the y-axis represents the energy consumption in joules (J) and the x-axis represents the number of nodes. By using the equation 12 and 19 the total initial energy given to the network is calculated. When there are 100 nodes in the network then energy given to EDEEC with 3-level heterogeneity is 120J and to EDEEC with 4-level heterogeneity given energy is 124J and for 200 nodes energy given for EDEEC and 4-level EDEEC is 240J and 248J respectively. For 500 nodes in WSN, the energy given is 600J and 1240J for EDEEC and 4-level EDEEC. When there are 1000 nodes in the network the energy given for EDEEC and 4-level EDEEC is 1200J and 1240J respectively. By using the same equation energy given for 300,400,600,700,800 and 900 can be calculated

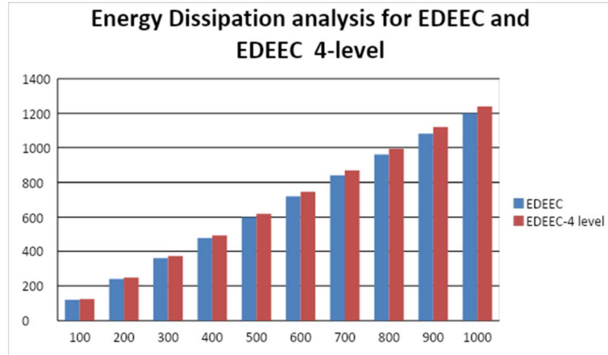

Figure 34 Energy Dissipation comparison chart for EDEEC and 4-Level EDEEC

REFERENCES

[1] D. L. Reddy, V. Aran, A. V. Paramkusam and N. Nagaraju, "Wireless sensor networks algorithms to improve energy efficiency: Review," *2017 International Conference on Intelligent Sustainable Systems (ICISS)*, 2017, pp. 1164-1166, doi: 10.1109/ISS1.2017.8389369.

[2] C. Yu, D. Yao, L. T. Yang and H. Jin, "Energy Conservation in Progressive Decentralized Single-Hop Wireless Sensor Networks for Pervasive Computing Environment," in *IEEE Systems Journal*, vol. 11, no. 2, pp. 823-834, June 2017, doi: 10.1109/JSYST.2014.2339311.

[3] D. Garg, "Performance Analysis on Energy Efficient Protocols in Wireless Sensor Networks," vol. 8, no. 5, pp. 1862–1869, 2017.

[4] J. Yan, M. Zhou, and Z. Ding, "Recent Advances in Energy-Efficient Routing Protocols for Wireless Sensor Networks," Middle-East J. Sci. Res., vol. 4, pp. 5673–5686, 2016.

[5] S. Mahajan and P. K. Dhiman, "Clustering in Wireless Sensor Networks: A Review Shilpa," Int. J. Adv. Res. Comput. Sci., vol. 7, no. 3, pp. 198–201, 2016.

[6] Z. Han, J. Wu, J. Zhang, L. Liu, and K. Tian, "A General Self-Organized Tree-Based Energy-Balance Routing Protocol for Wireless Sensor Network," vol. 61, no. 2, pp. 732–740, 2014.

[7] A. Braman and G. R. Umapathi, "A Comparative Study on Advances in LEACH Routing Protocol for Wireless Sensor Networks : A survey," Int. J. Adv. Res. Comput. Commun.Eng., vol. 3, no. 2, pp. 5683–5690, 2014.

[8] G. M. Shafiullah, S. A. Azad, and A. B. M. S. Ali, "Energy-efficient wireless mac protocols for railway monitoring applications," *IEEE Trans. Intell.Transp. Syst.*, vol. 14, no. 2, pp. 649–659, 2013.

[9] H. Yoo, M. Shim, and D. Kim, "Dynamic duty-cycle scheduling schemes for energy-harvesting wireless sensor networks," *IEEE Commun. Lett.*, vol. 16, no. 2, pp. 202–204, 2012.

[9] B. Tong, G. Wang, W. Zhang, and C. Wang,

"Node reclamation and replacement for long-lived sensor networks," *IEEE Trans. Parallel Distrib.Syst.*, vol. 22, no. 9, pp. 1550–1563, 2011.

[10] S. Sudevalayam and P. Kulkarni, "Energy harvesting sensor nodes: Survey and implications," *IEEE Commun. Surv.Tutorials*, vol. 13, no. 3, pp. 443–461, 2011.

[11] B. Tong, G. Wang, W. Zhang, and C. Wang, "Node reclamation and replacement for long-lived sensor networks," *IEEE Trans. Parallel Distrib.Syst.*, vol. 22, no. 9, pp. 1550–1563, 2011.

[12] P. Saini and A. K. Sharma, "E-DEEC - Enhanced distributed energy efficient clustering scheme for heterogeneous WSN," *2010 1st Int. Conf. Parallel, Distrib.Grid Comput.PDGC - 2010*, pp. 205–210, 2010.

[13] P. Saini and A. K. Sharma, "Energy Efficient Scheme for Clustering Protocol Prolonging the Lifetime of Heterogeneous Wireless Sensor Networks," *Int. J. Comput.Appl.*, vol. 6, no. 2, pp. 975–8887, 2010.

[14] B. Elbhiri, S. Rachid, S. El Fkihi, and D. Aboutajdine, "Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks," *2010 5th Int. Symp.I/V Commun.Mob.Networks, ISIVC 2010*, pp. 1–4, 2010.

[15] D. Kumar, T. C. Aseri, and R. B. Patel, "EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks," *Comput. Commun.*, vol. 32, no. 4, pp. 662–667, 2009.

[17] G. Anastasi, M. Conti, M. D. Francesco and A. Passarella, "Energy conservation in wireless sensor networks: A survey," Elsevier, 2008.

[18] L. Qing, Q. Zhu, and M. Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks," Comput.Commun., vol. 29, no. 12, pp. 2230–2237, 2006.

[19] G. Smaragdakis, I. Matta, and a.Bestavros, "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks," Second Int. Work. Sens. Actor Netw.Protoc.Appl. (SANPA 2004), pp. 1–11, 2004.

[20] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Trans. Wirel.Commun.*, vol. 1, no. 4, pp. 660–670, 2002.

[21] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," *Proc. 33rd Annu. Hawaii Int. Conf. Syst. Sci.*, vol. vol.1, no. c, p. 10, 2000.