Node Energy Based Approach to Improve Network Lifetime and Throughput in Wireless Sensor Networks

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***Abstract*—Energy consumption is the one of the most important issue in wireless sensor networks. To improve the network lifetime energy consumption in the network must be less. In this paper, a cluster based approach is proposed to increase the network lifetime and throughput of the heterogeneous wireless sensor networks. The proposed approach combined the direct data transmission to base station with the cluster head transmission of data in wireless sensor networks. The proposed scheme uses the twice energy for advanced nodes in comparison to normal nodes. In the proposed approach, it is observed that results are found good with the use of 10 % of advanced nodes along with normal nodes in the network. 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.**

***Index Terms*—Wireless Sensor Networks (WSNs); Network Lifetime; Network Throughput; Network Performance**

I. Introduction

Wireless sensor networks composed by a number of nodes; those having some sensing, communication and computing capabilities. It is always in demand that nodes designed in such a manner so that the energy consumption should be less in WSNs. In some of the studies, it has been discussed that the overall network energy consumption may be reduced by making clusters in the wireless sensor networks [1]. In the modern era, wireless sensor networks widely used in so many applications like surveillance, environmental monitoring, internet of things and machine failure detection, etc. thousands sensor nodes deployed to monitor and report the target area. Energy consumption minimization is very important in wireless sensor network because of recharge of a sensor node is almost impossible in number circumstances [2]. Wireless sensor networks designed for sensing the environmental parameters in so many applications like humidity, gas, pressure, temperature, etc. Sometimes it happens that same information reaches at the base station by two or more nodes lead to data redundancy that further make the network inefficient. To overcome data redundancy problem in WSNs, data aggregation is suggested as one of the key areas in wireless sensor networks [3]. In this paper, the proposed work is limited to the heterogeneous wireless sensor networks. Heterogeneous wireless sensor networks consist of different types of nodes and these nodes are randomly deployed in the network. One of the key challenges for heterogeneous networks is to use appropriate energy consumption and to extend the network lifetime. Reduction of energy consumption in the network may be achieved by different topology creation technique. Clustering topology is found to be one of the most popular topology to reduce the energy consumption in wireless sensor networks [4]. Data aggregation is a technique in which aggregates the data at a particular node. Mainly data aggregation applied at the routing level. Data aggregation uses some function like SUM, AVERAGE, MAX and MIN etc. [5]. In clustering technique, a special node called as cluster head work as a leader in the cluster. All cluster members send the data to cluster head and further cluster head forward it to the base station node or sink node. In homogenous network all nodes have same initial energy level while heterogenous network has different-different initial energy levels [6].

In data aggregation, sometimes information may not be accurate means data accuracy may be degraded. So this is the main concern to maintain the correct information system regarding the network while applying the data aggregation technique. Wireless sensor networks having two types of node deployment; uniform deployment and non-uniform deployment. Sometimes in uniform deployment node die before their energy exhausted [7]. Data aggregation consists following algorithms like LEACH, TAG and Diffusion etc. to overcome the existing issues. In this paper, an algorithm is proposed to improve the throughput and network lifetime of wireless sensor networks. For the energy efficiency, there are so many ways to improve the energy efficiency, although routing is one of the most suitable methods to increase the energy efficiency. An effective routing contains paths from source to destination available in the network means if some route may fail, then also data reached to destination from source successfully [8]. Sensor nodes consume the energy while transmitting, receiving and computing the information. However, most of the energy consumption takes place in transmitting the information from one node to another node. There are so many algorithms like Ant colony optimization (ACO), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) etc. those algorithms are used to improve the network parameters in WSNs [9]. Kumar et al. [18] analyzed data aggregation techniques and corresponding challenges in WSNs. In the similar direction, an attempt is made to improve the network Lifetime and Throughput for Wireless Sensor Networks.

This paper is organized into seven sections. Introduction is followed by related work in Section II. The proposed model architecture along with mathematical analysis is discussed in Section III and Section IV respectively. In Section V, simulation details are followed by results in Section VI. Finally the future scope is reported in Section VII.

II. Related Works

In order to conduct the review, the similar approach is adopted as considered by Zear et al. [19] & Agarwal et al. [20]. In order to review the literature, research papers were identified from various repositories like Science Direct, ACM Digital Library, IEEE Journals, Springer and Google Scholar etc Research papers related to network lifetime and throughput in WSNs considered for analysis in this section.

Shankarappa et al. [10] proposed a new routing protocol (EEDR) Energy Efficient Distributed Receiver which reduces the number of transmission packets so that overall reducing the energy consumption in the network. The main goal of the authors are to reduce the energy and improve the throughput of the network. EEDR routing protocol is based on reactive routing protocol. EEDR routing protocol compared with DSDV and AODV routing protocol; for end to end delay, number of hopes, energy consumption, residual energy, number of alive nodes, the number of dead nodes and throughput.

Halder et al. [11] explained an idea about the sensor node deployment in the network to optimizing the lifetime of wireless sensor networks. Sensor nodes and relay nodes location affect the performance the network. While deploying the sensor nodes and relay nodes concerning about the energy consumption balancing arises a problem called as hole of the network. So to overcome this problem, deployment of sensor nodes and relay nodes at specific locations are important. In their paper, they have compared their work with existing approaches in terms of network lifetime, end to end delay and percentage of faulty relay nodes.

Brar et al. [12] proposed a routing protocol called as PDORP which is the combination of DSR and power efficient gathering information system. To find out the optimal route, genetic algorithm and bacterial foraging optimization applied to the proposed algorithm. Proposed algorithm compared with LEACH, PEGASIS, DSR and OD-PRRPin terms of energy efficiency, end to end delay, bit error rate and network lifetime.

Jan et al. [13] investigated an issue regarding the energy hole in the network, which may be near to the sink or located anywhere in the network. The proposed algorithm designed for sort out the problem of energy hole in the network. Proposed algorithms called as BECHA (Balanced Energy Consuming and Hole Alleviating), EA-BECHA (Energy Aware Balanced Energy Consuming and Hole Alleviating).

Mittal et al. [14] proposed a novel protocol named as stable energy efficient clustering protocol, which insures the more stability period of the network. The stability period of the network depends on the first node die time. Increase the stability time period of network is an important issue which is preserved by the coverage characteristics of the network. In their proposed protocol cluster head selection is based on the residual energy of the node.

Mittal et al. [15] proposed a new protocol called as TEDRP (Threshold-sensitive Energy-efficient Delay-aware Routing Protocol), worked as dual hop between base station and cluster head. They also discussed a stable TEDRP protocol in their paper. Cluster head selection in stable TEDRP by applying energy aware heuristic technique. The motto of TEDRP is to increase the network lifetime while Stable TDERP designed for increasing the stability network.

Wang et al. [16] analyzed a semi-centralized approach named as SEARCH (Stochastic Election of Appropriate Range Cluster Head). Their algorithm goal was to reduce the cluster head selection in some rounds, basically this type of activities reduce the network performance. SEARCH algorithm is designed for selection of optimal number of cluster heads in every round.

After reviewing these papers, it is found that number of alive nodes in the network are one of key parameter for network lifetime. It has been observed in the literature that in case of homogenous network, the energy of each node is usually equal and these nodes get dead soon because of continuous transmission of data. So in order to improve the network lifetime and throughput, the variation in terms of node energy is taken into consideration. However, the variation is taken within the permissible limits of 10% to 30%. The proposed model and algorithm designed using variable energy node for heterogeneous wireless sensor networks is presented in the next section.

III. Proposed Model and Algorithm

In this section, proposed model discussed with the help of flowchart using Figure 1. In addition to the proposed model, an algorithm for the same is mentioned in Figure 3 and Figure 4.

Energy consumption is the most important issue in wireless sensor networks. The main aim of this paper is to increase the network lifetime and throughput of wireless sensor networks. The proposed approach is the combination of direct transmission and transmission via cluster head to the base station.

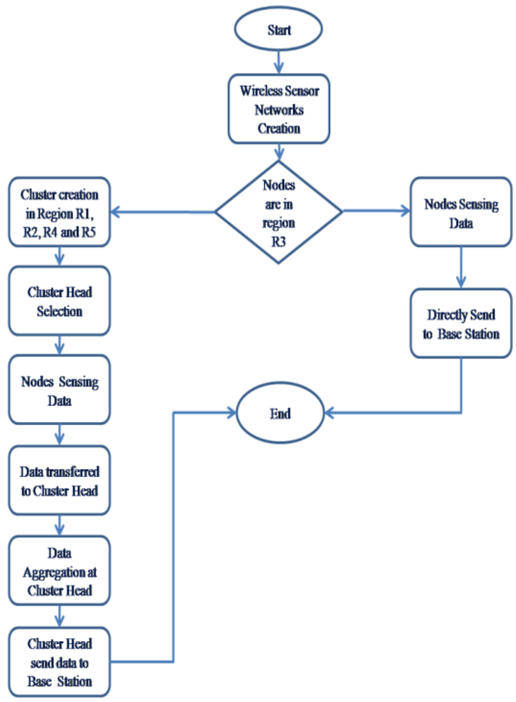

Figure 1: Flow chart of proposed model for heterogenous WSNs

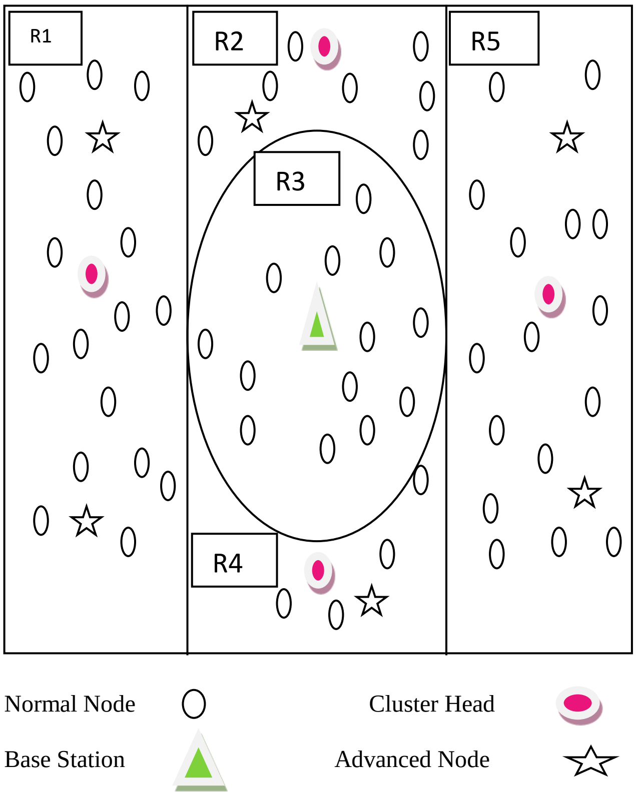

Figure 2: Heterogeneous Wireless Sensor Networks Architecture

Figure 2 represents the proposed architecture for wireless sensor networks. In this architecture, the entire network is partitioned into five regions R1, R2, R3, R4 and R5. Nodes that are under R3 region can send their data directly to the base station, but the nodes that are under the other regions are restricted to send their data to cluster head after that cluster head will forward the data to the base station.

Each advanced node is having little higher energy as compared to the normal nodes. A combination of normal nodes and advanced nodes makes this network as heterogeneous network.

Algorithm.1
Proposed Algorithm Pseudo Code For Data Transformation

```
1.  Create sensor network with n nodes.
2.  for i=1 to n
3.        if (n.region==R3)
4.                 sensed the data
5.                 data send to the base station
6.        else
7.                 cluster formation
8.                 cluster head selection (region R1,R2,R4 and R5)
9.                 sensed the data
10.                data send to cluster head
11.                apply data aggregation at cluster head
12.                data send to base station
13.       end else
14.       end if
15. end for
```

Figure 3: Pseudo Code for Data Transformation

Algorithm.2
Cluster Head Selection Pseudo Code

```
1.  Objective function f(x), x= (x1,x2,……..xm)
2.  Generate initial population of sensor nodes xi (i = 1, 2, . . . , m)
3.  Node energy Ei at xi is determined by f(xi)
4.  Define energy absorption coefficient α
5.  while (t<MaxGeneration)
6.  for i = 1 to m
7.  for j = 1 to i
8.  if (Ej>Ei), Move cluster head itowards j
9.  end if
10. Cluster head selection varies with distance rvia exp[−αr]
11. Evaluate new solutions and update energy
12. end for j
13. end for i
14. Rank the node and find the current best
15. end while
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Figure 4: Cluster Head Selection Pseudo Code

Figure 3 represents pseudo code of the proposed approach while Figure 4 represents pseudo code for cluster head selection used in the proposed approach. Mathematical analysis of the proposed model is discussed in the next section of this paper.

IV. Mathematical Analysis

In this section, mathematical analysis for computation of the network energy in WSNs for heterogeneous environment is mentioned.

Sensor node may be failed or damaged due to some physical damage, so the probability of a sensor node reliability can be computed by Poisson distribution with time interval (0,t) as shown in Equation (1).

$$R_i(t) = \exp(-\lambda_i t) \quad (1)$$

where $R_i(t)$ is the reliability or fault tolerance of sensor node i, λ_i is the failure rate of sensor node i and t is the time. Scalability of the network is computed using the Equation (2).

$$\mu(R) = (N\,\pi R^2)/A \quad (2)$$

where N is the number of sensor nodes, A is the area of network and R is the radius or transmission range of sensor node. In LEACH protocol cluster head selection based on threshold value T(n) is computed using the Equation (3).

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(r mod \dfrac{1}{P}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (3)$$

where, P is the probabilities to being cluster head and r is round for number of iterations.

Energy Model Analysis- Energy consumed in WSNs may be considered in three ways; first one is energy consumption in data transmitting, second one is energy consumption in data receiving and third one is in data processing. Equation (4) and (5) is used for computing the energy consumption in transmitting the data.

$$E_{Tx}(I, d) = E_{Tx-ele}(I) + E_{Tx-amp}(I, d) \quad (4)$$

$$E_{Tx}(I, d) = \begin{cases} I * E_{ele} + I * \varepsilon_{fs} * d^2 & if\ d < d_0 \\ I * E_{ele} + I * \varepsilon_{mp} * d^4 & if\ d \geq d_0 \end{cases} \quad (5)$$

where E_{Tx} is the energy consumption in data transmission, I is the number of bits, d is the distance, E_{ele} is the energy consumption in per bit to run the data transmitter, ε_{fs} and ε_{mp} are the characteristics of amplifier of transmitter and d_0 is the threshold value.

$$E_{Rx}(I) = E_{ele} * I \quad (6)$$

$$d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \quad (7)$$

where E_{Rx} is the energy consumption in a data reception mode which is computed using the equation number 6. In context to energy amplification of node, the threshold value for the sensor node is computed using the equation number 7.

These equations from Equation (1) to (7) are used during the result analysis while doing simulation in Matlab 2013a. Further details about the simulation setup are mentioned in the next section of the paper.

V. SIMULATION SETUP

Implementation has been done on Matlab R2013a. In the proposed work, area of wireless sensor network is considered 100 by 100 in meter for analysis. Here sink node positioned at 50 by 50 positions. During the simulation, a heterogenous wireless sensor network is designed which have 10% to 30% nodes as advanced nodes. Energy of advanced nodes is taken as a double of the energy of the normal nodes.

Table 1
Simulation Parameters

S.No.	Parameter	Value
1	Network Area	100*100 Meter*Meter
2	Number of Nodes	90
3	Sink Node Position	50,50
4	Percentage of Advanced Nodes	10% to 30%
5	Initial Energy of Advanced Nodes	2* Initial Energy of Normal Nodes
6	Initial Energy of Normal Nodes	.5 Joule
7	Number of Iterations	7000, 8000

Simulation results are discussed in the next section along with suitable figures for better interpretation.

VI. RESULTS

To evaluate the performance of heterogeneous network in WSNs, three parameters are taken; (i) packets to the base station, (ii) number of alive nodes and (iii) number of dead nodes per round. The performance of the network is analyzed using the proposed algorithm in two phases. In the first phase 30% nodes were considered with variable energy (higher energy). Thereafter, in the second phase, 10% nodes were taken with variable energy (higher energy) out of total considered nodes. Figure 5 to Figure 7 shows the results for the 30% of variable in energy nodes and Figure 8 to 10 show the result for the 10% of variation in energy nodes.

Table 2
Number of Iterations At Which First Node Get Dead During The Packet Transmission

Algorithm used	Number of iterations at which first node get dead with 10% of advanced nodes	Number of iterations at which first node get dead with 30% of advanced nodes
LEACH	1050	1075
SEP	1084	1248
Proposed	1544	1545

Table 2 represents the details about the moment at which first node gets dead in term of number iterations with respect to each algorithm for the considered network. During the implementation it is observed that first node gets dead initially in LEACH then in SEP algorithm and after that first node get dead in the proposed approach with respect to the 10% advanced nodes. However, by considering the 30% advanced node results were same for the LEACH and SEP and negligible difference is found for the proposed approach. So, the proposed approach with 10% advance node is better solution as compared to 30% advanced node because the difference is very negligible with respect to the three times of deployment cost of advanced node in later scenario using 30% advanced nodes.

Table 3
Number of Packets reached at Base Station

Algorithm used	Number of packets reached at base station with 10% of advanced nodes	Number packets reached at base station with 30% of advanced nodes
LEACH	89754	140652
SEP	158933	209675
Proposed	207440	206212

Table 3 represents the number of packets reached to the base station. When a simulation performed with 10% advanced nodes then less number of packets reached to base station in LEACH approach as compare to other two approaches i.e. SEP and proposed scheme. However, by considering the 30% advanced nodes maximum packets reached to base station are 209675 in case of SEP protocol. The proposed approach is also able to deliver the 207440 packets with the help of only 10% advanced nodes may be better choice than the SEP protocol in current scenario due to less requirement of higher energy node with less cost too.

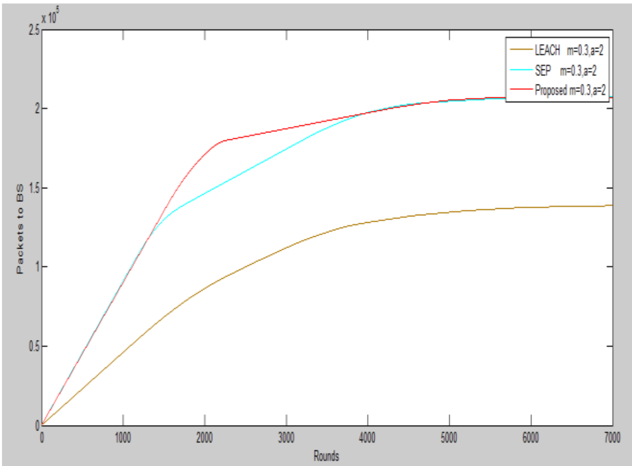

Figure 5 : Throughput of the Network

Figure 5 shows the throughput of the network where x axis represents the number of iteration and y axis represents the number of packets reached at the base station. Proposed approach compared with LEACH and SEP protocols. It is found that proposed scheme outperformed as comparable to LEACH and SEP protocols with m=0.3. Here m=0.3 denotes the 30% of advanced nodes. Advanced having the double energy as compared to the normal nodes. Significance of value of m represents the percentage of advance nodes and a represents the number of times energy of advanced node as compare to normal node at all places for the rest of the figures.

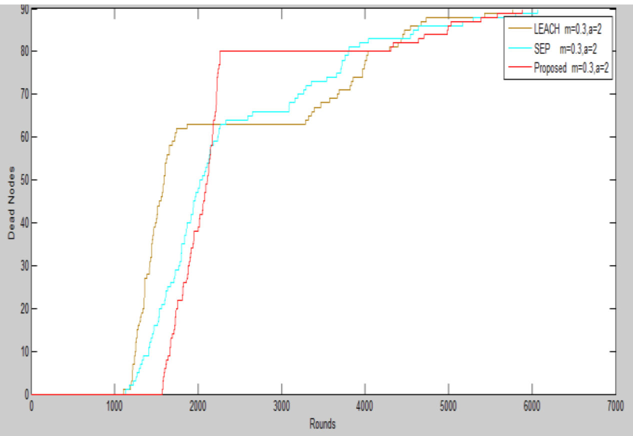

Figure 6: Dead Nodes Per Round

Figure 6 shows the dead nodes per round where the x axis represents the number of iterations and the y axis represents dead nodes in the network. The proposed algorithm outperforms in term of the number of dead nodes in the network till first 2000 rounds and thereafter performance get degraded slightly. And after 4000 rounds improved again.

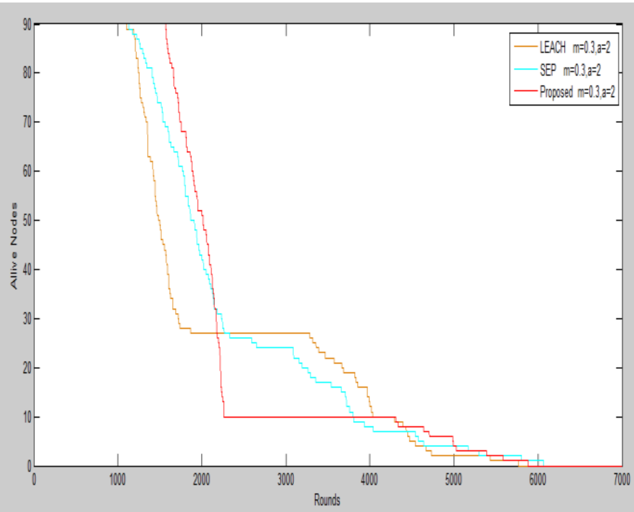

Figure 7: Network Lifetime

Figure 7 shows the network lifetime where x axis represents the number of iterations and y axis represents number of alive nodes. The proposed approach in comparison with LEACH and SEP protocols found better in higher rounds. However it’s lack initially when the number of rounds were less. Later the network gets trained and may be sustained with more alive nodes using proposed approach as compare to the LEACH and SEP protocols. In Figure 5 to 7, parameters taken are m=0.3 and a=2 for analysis. Here m=0.3 represents 30% advance nodes and a represents the energy of advance node is “**a**” timer higher than normal node, which is 2 during the current implementation.

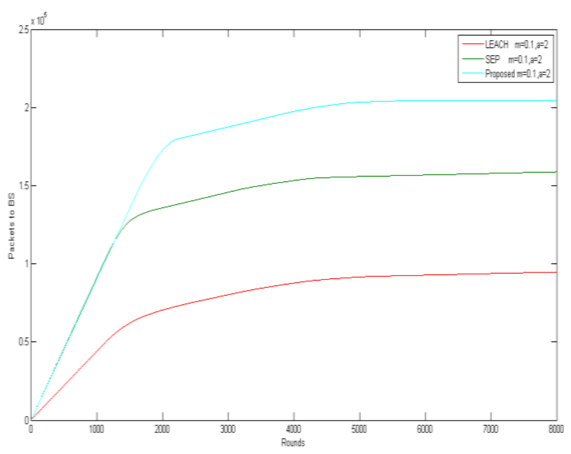

Figure 8: Throughput of the Network

In Figure 8 to 10, parameters taken are m=0.1 and a=2 for analysis. Here m=0.1 represents 10% advance nodes and **“a”** represents the energy of advance node is “**a**” timer higher than normal node, which is twice during the current scenario. Figure 8 shows the throughput of the network where the x axis represents the number of iterations and the y axis represents packets reached at the base station. Proposed approach gave the same performance as given by SEP till 1500 iterations, but after that the proposed approach gave better result as compare to the LEACH and SEP approach till 8000 iterations.

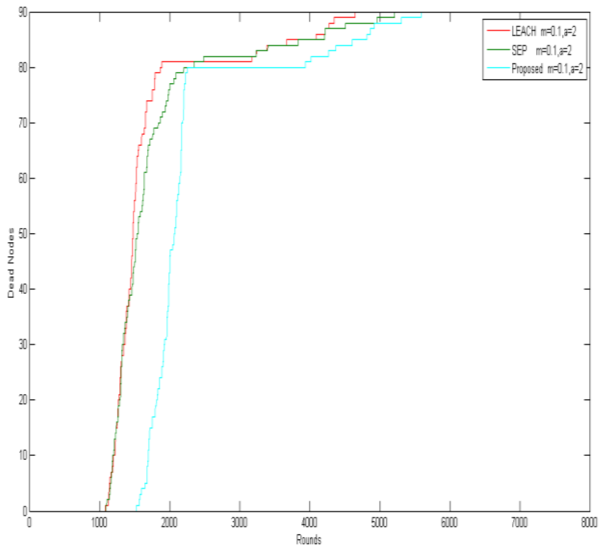

Figure 9: Dead Nodes Per Round

Figure 9 shows the dead nodes where the x axis represents the number of iterations and the y axis represents dead nodes. In the proposed approach number of dead nodes are less as compared to the LEACH and SEP protocols. First node gets dead in LEACH, SEP and proposed approach at 1050, 1085 and 1544 iterations respectively.

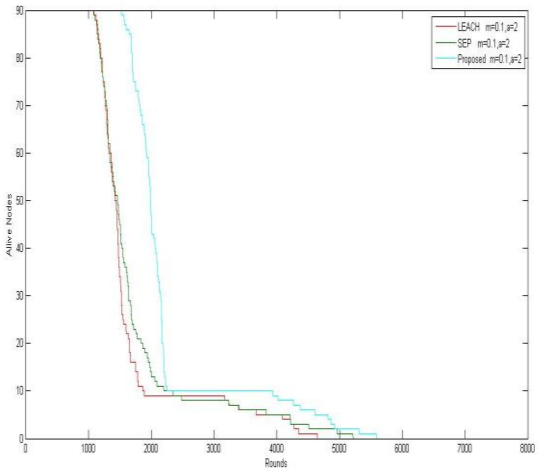

Figure 10: Network Lifetime

Figure 10 shows the network lifetime where x axis represents the number of iterations and y represents the number of alive nodes. Proposed approach gave better network lifetime as compare to LEACH and SEP protocols.

After comparing the variations in the number of advanced nodes, it is identified that during the simulation, the network with 10% advanced nodes gives better results in comparison to the network with 30% advanced nodes. On further increasing the number of advanced nodes in the network, the throughput of the network gets degraded. However the permissible range up to 10% advanced node (node with higher energy) may lead to better results in terms of throughput and network lifetime for heterogeneous WSNs.

VII. Conclusion And Future Scope

The proposed algorithm is implemented using 90 sensor nodes in two phases. During the first phase, the numbers of advanced nodes taken 30% of total nodes. Thereafter, in the second phase the numbers of advanced nodes taken 10% of the total nodes in the network. On further increasing the number of advanced nodes in the network, considered parameters get degraded and the cost of the network also goes up. So keeping in view the importance of network performance along with additional cost required for advanced node. Using a small fraction of advanced nodes, which require very less cost, efforts made to improve the overall network performance for heterogeneous WSNs. In future the performance may be analyzed with higher number of nodes along with other set of network parameters. Proposed algorithm performance may further be improved using the artificial intelligence based optimization techniques. Efforts may be put in checking the network performance along with some additional parameters along with the existing ones for heterogeneous networks. The proposed algorithm is better in terms of network lifetime and throughput as compared to the existing LEACH and SEP algorithms.

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