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MSESEP- Mobile Sink Based ESEP using Reliable Cluster Head and Sorting Technique

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Abstract: *The Wireless Sensor Network (WSN) is composed of sensors. These sensor nodes sense the physical parameters like temperature, pressure, humidity etc. In real time environment these sensors have different energies. In this paper we have assumed three types of sensor nodes. Now a day's most researchers are focusing on how to increase the network lifetime through efficient use of the energy. Generally the network is divided into a certain number of clusters and then a cluster head is selected from all these sensors randomly. There is a Base Station (BS) or Sink which receives aggregated data from the cluster heads and sends it to the end computer. In the existing protocols the sink is kept fixed which results the problem of data collection from the sensor node's situated at WSN boundary. In our proposed Extended Stable Election Protocol (ESEP) the sink is kept mobile. To increase the lifetime of the network the concept of reliable cluster head is used. The reliable cluster head will act as secondary cluster head in case the main cluster head would die. We have used a new approach to make the cluster head selection more deterministic i.e. sorting technique which sorts the nodes in the descending manner. The performance evaluation of the proposed ESEP is done on the basis of the First Node Dead (FND), packets sent to base station, packets sent to cluster head and total Network Lifetime. The network simulator MATLAB is used for the simulation. The simulation results show that our proposed ESEP gives better result than the existing ESEP.*

Keywords: *Base Station (BS) or Sink, Cluster Head (CH), Extended Stable Election Protocol (ESEP), First Node Dead (FND), Reliable Cluster Head, Wireless Sensor Network (WSN)*

I. Introduction

A Wireless sensor networks (WSNs) is a distributed wireless network which is a combination of autonomous devices like nodes, routers, gateway where each node having connectivity to a sensor. Each sensor node have several units like, a sensing unit (which can sense physical parameters like temperature, sound, vibration and humidity), a processing Unit (one or more microcontrollers, CPUs where processing of sensed data is done), have a RF transceiver (which consists of a transmitter for sending data and a receiver for receiving data from its 1 hop neighbors.), a storage unit which may contain multiple types of memory (program, data and flash memories), have a power Management Unit (e.g., batteries and solar cells)-for maintaining low power consumption. These sensor nodes have small batteries which are difficult to change or recharge. So we have to follow such architecture (having less traffic and reduced transmission distance) to increase energy saving. The sensor nodes are deployed in an ad-hoc manner and communicate wirelessly. Data is transmitted in a distributed manner through these nodes and monitoring of the physical or environmental conditions is done from remote location. In [11] five key features have been told which need to be considered when developing WSN solutions. There are too many fields of WSN application like Agriculture, Habitat study, environment monitoring, structural health monitoring, heavy industrial monitoring, and security monitoring [11].

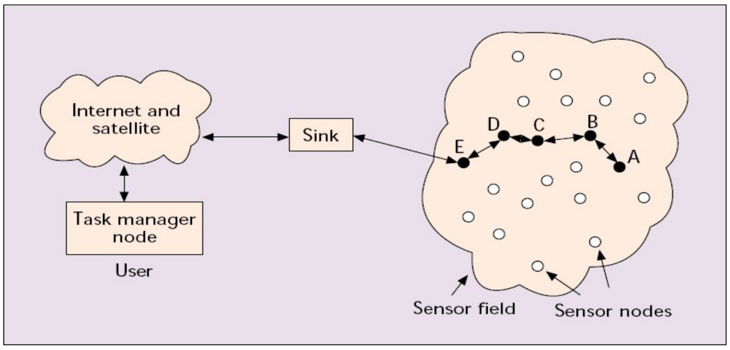


Fig.1 Architecture of the WSN [6]

There is Base Stations (BS) or Sink inside or located to sensing region. The Sink having main role in WSN as sink send queries to sensor nodes while sensor nodes sense the asked queries and send the sensed data in a collaborative manner back to sink. Sink also serves as a gateway for outside network i.e. Internet. So the collection of data and send only relevant information to user via internet is done by sink.

1.1 Nature of the Problem

Now a day's most researchers are focusing on how to increase the network lifetime through efficient use of the energy. In [13] a new approach for evenly distribution of energy load among the sensor in WSN has been explained. According to author, this approach is more effective as load can be distributed among all the nodes evenly and thus reduces the communication energy in comparison with the direct communication (DT) and minimum energy transmission (MTE).

In existing protocols [13] and [14] the nodes are assumed of the same energies, but in real time environments nodes may have different initial energies. We have assumed three different kinds of nodes. These are advanced nodes, intermediate nodes and normal nodes in the descending manner of energies. Generally base station or sink is kept fixed in the existing protocols but it faces the problem of data aggregation from the sensor nodes which are at boundary of the network. In [7] concept of mobile sink is explained. We have also used the mobile sink so that it can randomly collect the data from the sensor nodes.

To increase the lifetime of the network [1] and [3] has suggested to select a vice cluster head as a secondary cluster head which will work in case our main Cluster head would die.

1.2 Previous Work

As discussed in [13] a protocol Low Energy Adaptive Clustering Hierarchy (LEACH) in which nodes having homogenous energies. The author tells about a threshold formula on basis of which cluster head selection is done based on the weighted probabilities of sensor nodes. Although this was a probabilistic approach but it guarantees that all nodes will become cluster node once and hence the load can be distributed evenly. There were some drawbacks in LEACH so LEACH-C was proposed to overcome those problems. In [15] some improvements are done in LEACH. [5] introduced concept a new threshold with average energy and current energy of the node which has probability to be elected as cluster head and this new threshold ensures that nodes which have higher residual energy, should become cluster heads than that with the low residual energy. According to this method First Node Dies (FND) and Half Node Dies (HND) improvement is done.

In [4] and [14] focus on energy is shown which is a primary concern while designing a Wireless Sensor Network because nodes which have consumed their energy die shortly. In [4] focused on why we should have Consumed Energy as a Factor for Cluster Head Selection in Wireless Sensor Networks. In [14] author has focused on consumption of energy during communication in inner network. Author has discussed a new routing approach which is energy efficient in which sensor nodes are selected as Cluster Head ,on the basis of these certain criteria- nodes with higher remaining energy, nodes having more neighbor's, and nodes which have lower distance from the Base Station . According to author this selection process of Cluster Head selection prolongs WSN lifetime and it minimizes energy dissipation per each sensor node.

Several improvements were done in LEACH. Now a new concept of vice cluster head is used in V-LEACH. In [1] author proposed to select a vice cluster head as a secondary cluster head which will work in case the primary Cluster head would die. The criteria for selection of vice cluster head is Minimum distance between nodes, maximum residual energy in nodes, and minimum energy loss. There are vice Cluster Head which will replace the dead cluster head. Simulation results show that this new approach increase lifetime in comparison of the traditional approaches. While in [10] a new approach named Away Cluster Head is proposed the cluster head formed with this approach is well distributed in WSN in such a way that number of nodes in each cluster would be even. Therefore, energy dissipation in each round would be equal.

The protocol of [3] proposed a secondary cluster head selection in the heterogeneous network. Which already become primary Cluster Head and only primary CHs can take part in process of electing secondary Cluster Heads. Primary Cluster Heads check distance between each other's and transmit their data to those Cluster Heads which are at minimum distance from them. However, these minimum distance Cluster Heads are secondary Cluster Heads.

Traditional protocols deal with the homogenous nodes. While in real time environments nodes can have different energies. Now the era of heterogeneity came and in [6] a new protocol was proposed which explains that stability period can be increased for heterogeneous environment which has a great concern in WSN. Author has represented a new protocol, which is heterogeneous-aware and is suitable for two-level hierarchical Wireless Sensor Network. As discussed by author according to this new protocol, nodes have the probabilities to become a cluster head on the basis of the remained energy in each node of the Wireless Sensor Network. Author has also explained that if we assume two kinds of nodes like Nodes with additional energy which would be called as advanced node and other one is having less energy would be known as normal nodes. While [6] proposed two kinds of sensor nodes, [9] has analyzed a three level hierarchical clustered heterogeneous sensor network having three types of sensor nodes with different initial energy and named them as advanced, moderate and normal nodes have been considered. Advanced and moderate nodes have more energy, longer transmission range, higher data rate in comparison with the normal nodes. So the advanced and moderate nodes have higher chances to become cluster heads in a particular round compared to a normal node, which extensively prolong the sensor network. By using the said approach, the number of alive nodes can be increase by a significant factor compared to the existing protocol as the energy drain rate is less in moderate and advanced nodes, it extends the lifetime of the network. Author has shown by simulation results that the extended SEP achieves better performance than the existing SEP algorithm in terms of network lifetime and throughput.

The concept of mobile sink has been explained in [7]. According to this traditional Clustered WSN with fixed sink generally suffer from high energy burden during transmission in a multihop fashion. Author has explained the several advantages of assuming mobile sink(s) to WSN in terms of benefits of low energy consumption, low latency and long lifetime. The author has proposed a new approach, which selects cluster heads as primary based on the fraction of advanced nodes with additional energy, and secondary on the residual energy. Author has also explained that even in this approach also cluster heads select routing path to mobile sink based on comparison between its distance to the trajectory and distance to the nearest cluster head. This approach provides energy efficient routing in Wireless Sensor Networks. According to this Mobile Sink based approach, hierarchical routing protocols are formed in such a way that it divides the network into clusters and selects cluster head on the basis of fraction of advanced nodes with additional energy and ratio between residual and initial energy. Simulation Results shows that this approach prolongs network lifetime and balances energy.

While [2] has focused on explained a new protocol for three level of heterogeneity in a WSN. According to author threshold is an important parameter while selecting the cluster head. So author has proposed a new approach which is beneficial for time critical applications. It means, nodes would transmit data only when there is an extreme change in the sensed value. Data transmission consumes more energy than sensing of data. According to [2] data transmission is done only when a specific threshold is reached.

1.3 Contribution of the Paper

In this paper a Mobile sink based ESEP is proposed which is based on reliable cluster head and sorting techniques. The sink moves randomly in the sensor network and collects data from cluster heads. A sorting technique is used which sort the all sensor nodes in the descending order of energies. Now top 10% nodes with highest energies are selected. Thus this protocol provides a deterministic approach in comparison to the probabilistic approach for cluster head selection. Simulation results shows that proposed protocol MS-ESEP gives much better results than existing ESEP.

II. The System Model

2.1. Basic Assumptions

In this paper we have made the following assumptions while setting up the sensor network.

- The sensor nodes are assumed to be fixed after random deployment in the network
- There will be unique id of each sensor nodes
- The sensor nodes are heterogeneous in energies
- The sink is kept mobile

The network has three types of nodes Advanced, Intermediate and Normal sensor nodes. All these have different energies. The boost up energy is given to the advanced nodes and intermediate nodes. So it is obvious advanced nodes will become the cluster head. After a certain rounds, advanced nodes would die and reliable cluster would act as a vice cluster head to increase the network lifetime.

2.2. Creation of a Cluster

In our proposed protocol we have assumed a three tier hierarchal clustered network. LEACH [13], which is also a hierarchal clustered protocol in which clusters are re-formed in each round. An optimal percentage of nodes Popt are assumed which tells how many cluster heads will form in each round. We have assumed the same distributed algorithm as in [1], [5], [6], [7] and [9]. We have used the same concept of threshold function of [13] to decide whether a node to become cluster head or not which is as given below Eq. (1).

$$T(S) = \begin{cases} \dfrac{P_{opt}}{1- P_{opt}(r.\mathrm{mod}(1/ P_{opt}))}, & \text{if } S \in G \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Here in Eq. (1) r represents the current round number and G is the set of nodes that have not become cluster head within the last 1/ Popt rounds. This 1/ Popt is called the epoch of the network. Nodes that have been selected as a cluster head can't become cluster head in the same epoch. According to threshold function, threshold T(s) is calculated in each round. The nodes belongs to G randomly generates a number in [0, 1]. The selection of this node to become the cluster head is done by comparing its random number with threshold T(s). If this random number is less than the T(s) then the node is chosen for cluster head in the current round.

2.3. Optimal number of clusters

We have also used the same radio model for energy dissipation to transmit the L-bit message over distance d, used in [9].

$$E_{Tx}(l,d) = \begin{cases} L.\ E_{elec} + L.\ \varepsilon_{fs}.d^2, \text{ if } d<d_0 \\ L.\ E_{elec} + L.\ \varepsilon_{mp}.d^4, \text{ if } d\geq d_0 \end{cases} \quad (2)$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or receiver circuit, ε_{fs}(free space fading) and ε_{mp} (multi path fading) are the energy expenditure of the transmitting one bit data to achieve an acceptable bit error rate and d is the distance between a cluster member node and its cluster head .By equating the two expression of Eq. (2) and putting $d= d_0$, we get

$$d_0=\sqrt{}\ \varepsilon_{fs} / \varepsilon_{mp} \quad (3)$$

The optimum number of clusters K_{opt} in our network, having n sensor nodes which are distributed randomly in a (M×M) sensor field can be calculated as done in [13].

$$K_{opt}=\sqrt{}\ n / 2\pi *\sqrt{}\ \varepsilon_{fs} / \varepsilon_{mp} * M/d^2 \quad (4)$$

The optimum probability of a sensor node to become cluster head can be calculated by the formula given below in Eq. (5)

$$P_{opt} = K_{opt}/ n \quad (5)$$

III. Our Proposed Protocol

In this paper we have analyzed a heterogeneous WSN. In this protocol m and x are the fractions of advance and intermediate nodes respectively? Also 'a' is extra energy for advance nodes and 'b' is extra energy for intermediate nodes. We have elaborated our proposed protocol with eight steps algorithm.

Step1: First of all initialization of the sensor network will be done by setting up various constants and variables of the network. Like diameters of sensor network, distance of base station from the network, no of nodes, probability of a node to become cluster head, energy supplied to each node, transmitter energy per node, receiver energy per mode, amplification energy, distance between cluster head and base station etc. However as this research work focuses on the mobile sink therefore the location of the sink remains moveable but it is assumed that it will stay within the sensor field.

Step2: For every sensor node i if any node has 0 or negative energy then node will be set as dead and continue to next step.

$E_{int}=E_{nrm}.(1+b)$

$E_{adv}=E_{nrm}.(1+a)$

Where,

E_{nrm}= Energy of a normal node

E_{int} = Energy of an intermediate node

E_{adv} = Energy of an advanced node

The total initial energy of all three types of nodes is as given below.

$$E_{t0}= n.\ E_{nrm}.\ (1-x-m) \quad (6)$$

$$E_{t1}= n.\ x.\ E_{nrm}.\ (1+b) \quad (7)$$

$$E_{t2}= n.\ m.\ E_{nrm}.\ (1+a) \quad (8)$$

Where,

E_{t0}= Total initial energy of a normal node

E_{t1}= Total initial energy of an intermediate node

E_{t2}= Total initial energy of an advanced node

The total energy (E_{total}) of the new heterogeneous sensor network model is given by equation (9):

E_{total}= n.E_{nrm}. (1−x−m)+ n.x. E_{nrm}. (1+b)+ n.m. E_{nrm}. (1+a)

E_{total}= n. E_{nrm}. (1+m.a+x.b) (9)

Step3: The optimal weighted probabilities are defined using Eq. (10), (11) and (12) has shown probabilities of normal, intermediate and advance nodes which will be used for cluster head selection. Where P_{opt} is the optimum probability for cluster head selection whereas

P_{nrm} = P_{opt}/(1+m.a+x.b) (10)

P_{int} = P_{opt} .(1+b)/1+m.a+x.b) (11)

P_{adv} = P_{opt} .(1+a)/1+m.a+x.b) (12)

Step4: Sort the nodes according to their energies in descending fashion. Select top 10% nodes as cluster head.

- N = n/10; % Get 10 highest energy values for initial number of cluster-heads, depending on your numerical solution for N_{opt}.
- Set N energy with the largest values, this will be the initial number N of cluster-heads in the proposed strategy.
- If any CH has very low energy in a round (i.e. last rounds) then a vice cluster head will be initiated for the same.
- Now packets communication will be done between member nodes to CH and CH to base station

Step 5: Now select node as cluster head and reliable cluster head based upon T (n) thresholding function. These threshold functions would be derived from Eq. (10), Eq. (11)

Step 6: Now operations come in action for sending and receiving the packets.

Step7: Now Evaluate the energy dissipated using Eq. (2). While d can be calculated by using Eq. (13)

d=√((CH.Xaxis−BS. Xaxis)^2+(CH.Yaxis−BS. Yaxis)^2) (13)

Step8: Update the remaining energy of each node (i) and move to step 2 again.

IV. Simulation And Results

TABLE I PERFORMANCE EVALUATION

No	Simulation Parameter		
	Parameters	Representation	Unit
1	n	Number of sensor nodes	100
2	N	Percentage of sensor nodes having highest energy	n/10
3	E_O	Initial energy of sensor nodes	0.5 nJ/bit
4	E_{DA}	Data Aggregation Energy	50 nJ/bit
5	ε_{fs}	Free space model of transmitter amplifier	10 pJ/bit/m^2
6	ε_{mp}	Multi-path model of transmitter amplifier	0.0013pJ/bit/m^4
7	E_{elec}	Energy dissipation to run the radio device	50 nJ/bit
8	p	Probability	0.1
9	m	Advanced sensor nodes probability	0.2
10	x	Intermediate sensor nodes probability	0.2
11	a	Alpha boost up energy for advanced nodes	2
12	b	Beta boost up energy for intermediate nodes	1
13	l	Packet length	4000

In order to evaluate the performance of the proposed ESEP (i.e.MS-ESEP) MATLAB tool is used. In this work, we have assumed 100 sensor nodes which are randomly distributed over the 100×100 m^2 area. The heterogeneity of advanced sensor nodes, intermediate sensor nodes and normal sensor nodes are continuously 20, 20 and 60. Initially the sink or base station position is 50×50. Once after network is established the sink will remain randomly mobile. The packet size that the nodes send to their cluster heads as well as the aggregated packet size that a cluster head sends to the sink is set to 4000 bits. The initial energy of each normal node is set to 0.5 Joule. The proposed approach has been implemented in MATLAB and the performance has been evaluated by simulation. In this work, we have measured the lifetime of the network in terms of rounds when the first sensor node dies. All the parameter values including the first order radio model characteristic parameters are mentioned in the Table I.

1.4 Performance Analysis – In this part performance analysis of the experiment have been done.

1.4.1 Network in Active State

Once the implementation starts, the first view that comes to be perceived is shown in Fig.2. The output screen is divided into various regions called clusters. Each cluster thus formed has a cluster head represented by the purple diamond. The entire network has a base station that is responsible for the collection of data from all other nodes shown in big diamond with Pink color. Circle with yellow color are normal nodes which are not cluster head at this time. The green triangles are intermediate sensor nodes and green diamonds are advanced sensor nodes.

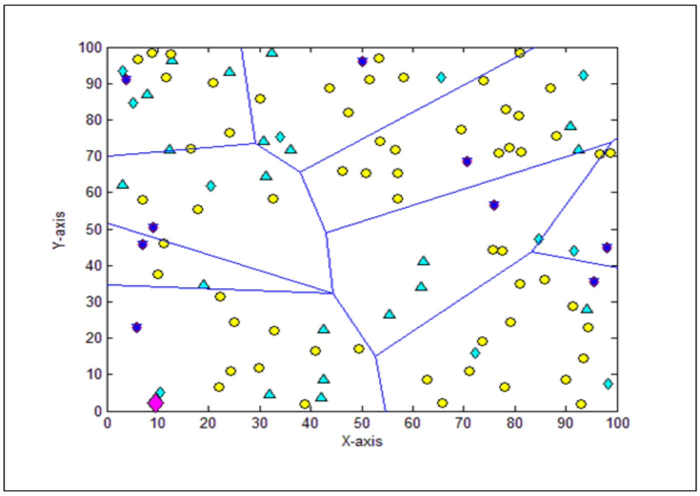


Fig.2 Network in active stage

1.4.2 Network when all normal nodes are dead

Fig.3 is showing, when all normal nodes are dead in WSN. The red circle nodes are representing the dead node(s).

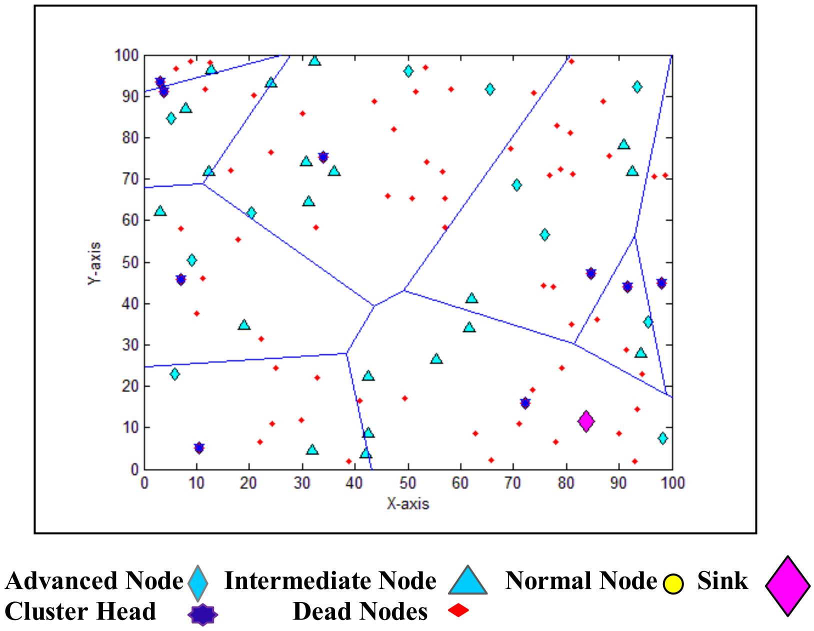
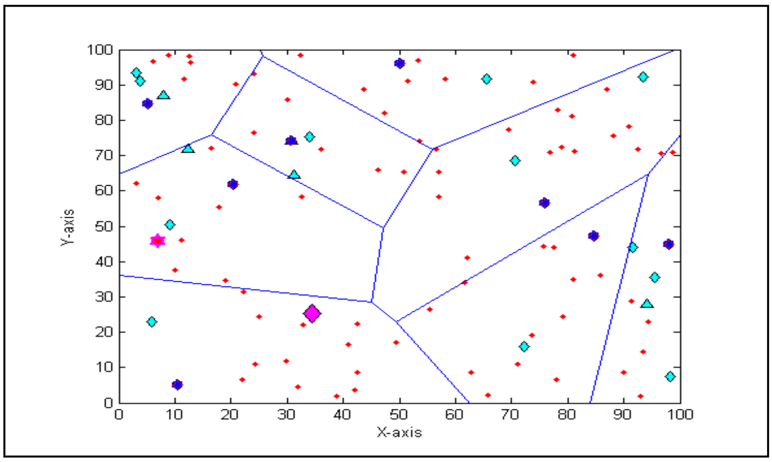


Fig.3 WSN when all normal sensor nodes are dead

1.4.3 Network showing presence of Reliable Cluster head

Reliable cluster head is shown as pink star in Fig.4. It presents first time in round number 5558.



Advanced Node **Intermediate Node** **Normal Node** **Sink**
Cluster Head **Dead Nodes** **Reliable Cluster Head**

Fig.4 WSN when all normal sensor nodes are dead

1.4.4 Network when all nodes are dead

Fig.5 has shown the final stage of WSNs; when all nodes become dead. The dead nodes are shown with red dots. A node is called dead if it has no remaining battery time that means no longer available for communicating the packets. All dead nodes dead round is also called WSNs network lifetime. In the proposed ESEP the last node die in round number 6409.

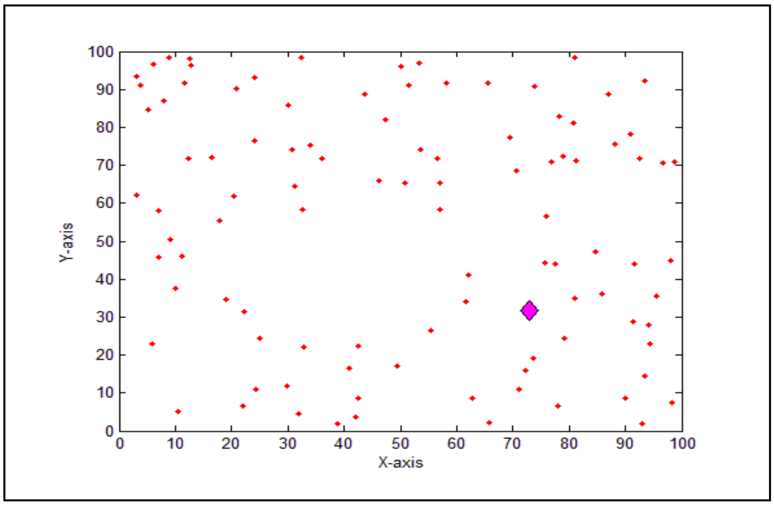


Fig.5 WSN when all sensor nodes are dead

1.4.5 Network Lifetime comparison

The histogram in Fig.6 shows the lifetime comparison between existing ESEP and Proposed ESEP. The heterogeneity ratio of the advanced and intermediate nodes is m= 0.2 and x=0.2. The Existing ESEP is shown with red line and Proposed ESEP is shown with green line. The stable period of the network depends on the FND. It is clear from the histogram that FND in Extended SEP is 1600 while in proposed ESEP it is 1785. Hence it is clear that the proposed ESEP provides longer stable period. The Network Life time of the proposed ESEP is 6409 rounds in comparison to 4322 rounds of the Existing ESEP. So network lifetime of the Proposed ESEP is much larger than Existing ESEP.

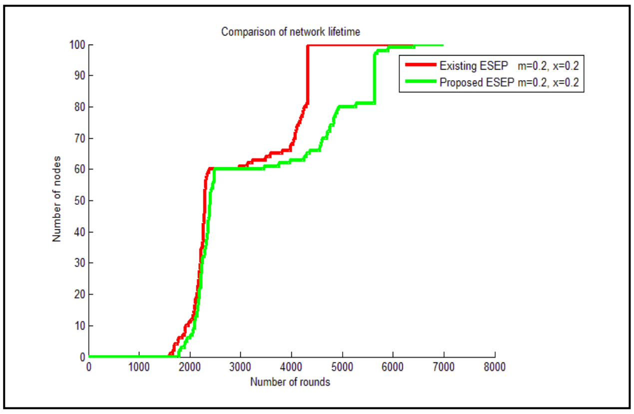


Fig.6 Network Lifetime comparison between Extended SEP and Proposed ESEP

1.4.6 Comparison of packet sent to base station

The packet sent to base station is also termed as the throughput of the network. The throughput of Existing ESEP is shown with pink color while proposed ESEP is shown with blue color. In the histogram Fig.7, it can be observed easily that, the Existing ESEP provides stable throughput till 4100 rounds. It is clear that the proposed ESEP provide the better network throughput in comparison with the Existing ESEP.

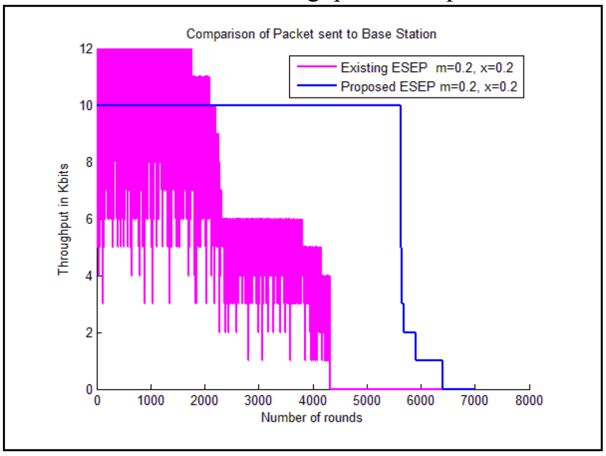


Fig.7 Comparison of packet sent to base station / Throughput

1.4.7 Comparison of packet sent to cluster head

The histogram in Fig.8 shows the packet sent to Cluster Head. The Existing ESEP is shown with red color and proposed ESEP with blue color. It is clear that the number of packet sent to cluster head in proposed ESEP is much larger in comparison with the Existing ESEP.

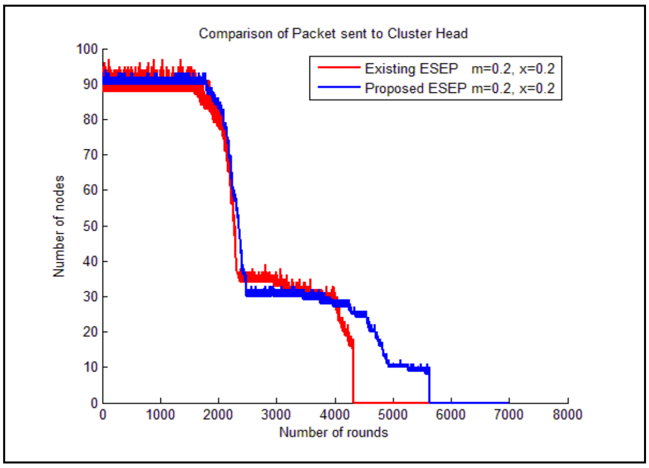


Fig.8 Comparison of packet sent to Cluster Head

1.4.8 Comparison of round in which Node's die

The Table II shows the different rounds in which nodes die. It explains the round wise difference between ESEP and proposed ESEP.

TABLE II COMPARASION OF ALGORITHMS

S. No	Node death rounds	Algorithm	
		ESEP	Proposed ESEP
1	First node death round	1600	1785
2	Tenth node death round	1917	2093
3	Twenty fifth node death round	2174	2213
4	Fiftieth node death round	2300	2398
5	Seventy Fifth node death round	4142	4822
6	Last node death round	4322	6609

V. Conclusion

In this work, focus on understanding the existing research on energy consumption problems in heterogeneous WSNs has been done. Much research has been done in WSNs to increase the network lifetime. Many researchers have found many optimized way to find the optimal clusters. But it is found that the most of the existing researchers has neglected the problem of the mobile sink in heterogeneous WSNs. Therefore we have modified ESEP for mobile sink. The cluster head selection has been further improved by using the deterministic cluster head selection. The reliable cluster head technique is also used to improve the lifetime of the network. The proposed strategy is designed and implemented in MATLAB. The experimental results have shown the significant improvement of the proposed strategy over Existing ESEP.

In near future work related to improving the performance of the mobile sink based extended SEP using fuzzy based deterministic cluster head technique will be done . Also inter cluster data aggregation will also be used to improve the results further.

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