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Rendezvous Nodes (RN Nodes) Based Cluster Head Selection and Energy Efficient Data Aggregation with Mobile Sink for Lifetime Maximization in Wireless Sensor Networks

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Abstract - Wireless sensor network (WSN) consists of a group of dedicated sensors nodes which are distributed over a certain area for observing and recording the physical conditions (like temperature, sound, pressure) of the environment and organizing the collected data at a central location. These Sensor nodes are powered by a battery, so energy conservation becomes an important aspect in WSN. The Paper proposes a way of combining traditional LEACH (Low Energy Adaptive Clustering Hierarchy) with Mobile Sink and Rendezvous Nodes (RN Nodes) along with some changes in terms of cluster head selection process. The paper aims at decreasing the number of dead nodes which in turn will relate to an increase in the total network lifetime. Particularly for large regions the proposed algorithms outperform traditional LEACH as proved in the Simulation Results.

Index Terms - Wireless sensor network, LEACH, Mobile Sink, RN nodes, Cluster Head Selection Process, Energy Efficient, Data Aggregation

1 INTRODUCTION

WSN is a network consisting of small and battery-powered sensor nodes deployed in the environment in order to sense and report, and to collaborate in order to fulfill the overall system's goal. Wireless sensor network consists of hundred to even thousand sensor nodes. There exists a base station to which these nodes transmit the data. Since the energy of the node is finite and is supplied by a battery, any long-distance communication will not be efficient and hence the network lifetime would be very less.

WSNs are used to measure environmental conditions like pollution levels, temperature, sound, humidity, wind speed and direction. The sensor node equipment has a radio transceiver and is also supported by an antenna, a microcontroller, an interfacing electronic circuit, and an energy source, usually a battery. Initially WSNs were used for military operations but its application has since been extended to health, traffic, and many other areas [1].

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There exists a base station to which these nodes transmit data. Since the energy of the node is finite and is supplied by the battery, any long-distance communication will not be efficient and hence the lifetime of the node will not be optimum. We propose a way of combining the traditional LEACH with a mobile sink and Rendezvous Nodes combined with changes in the cluster head selection process. The main idea behind this work is to decrease the number of dead nodes and thereby increase the total network lifetime.

2. RELATED WORK

There have been several researches going on in the field of Wireless Sensor Networks. The basic aim is to increase the network lifetime by somehow decreasing the energy consumption inside a network.

Multi-Hop scenario is a good way to increase the network lifetime. In a multi-hop network, each node transmits the data to other node and then data is sent to the sink. This decreases the total distance and total energy consumption as other nodes will act as routers. Though, a drawback of using this approach would be that the nodes nearer to the sink would die faster.

One more approach is by going for clustering in the network. In this approach Cluster heads would be formed for each set of nodes and then these nodes will transmit information to Cluster Head and Cluster head will then transmit to Base station. This type of approach guarantees a sustained network lifetime. Although clustering will tend to

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reduce energy consumption, it has some problems. The main problem being the energy consumption concentrated more on the cluster heads, this issue in clustering, of how to distribute the energy consumption must hence be solved. LEACH [2] is a representative solution of this problem, which is a clustering method based on a probability model.

LEACH (Low Energy Adaptive Clustering Hierarchy) is a type of clustering algorithm where Cluster Head selection process occurs periodically. LEACH has basically 2 phases 1) Setup Phase and 2) Steady Phase. In Setup Phase Cluster Heads are formed based on a probability value and in Steady phase all the data transmission takes place. When clusters are formed, the nodes transmit their data through to the CH. LEACH uses time division multiple access (TDMA) schedule to decide when each node can transmit data to CH. In LEACH, the CHs are selected randomly, and a node decides to which cluster it belongs. The CH receives information from the nodes and decreases the total number of bits by aggregating them and transmitting the effective aggregated data to the sink. LEACH performs better than the other conventional protocols as the Cluster heads are formed randomly on a probability value and the data aggregation is performed which in case decreases the energy consumption within the network and increases the network lifetime.

There are many improvements that have been proposed in the context of LEACH. LEACH-C, LEACH-I, V LEACH, TL LEACH, Multi-hop LEACH was formulated to improve the performance of the existing LEACH. Various other algorithms such as PEGASIS, TEEN, HEED, EACHP, Multi-hop Relay. Sometimes Cluster Head selection process is dependent on various factors which lead to even more sustained network lifetime of WSN.

Even Mobile Sinks [3] [8] [11] [13] [14] [19] [20] are also used sometimes to increase the network life time. Mobile Sink is basically a base station that will move around the sample region and collect information from the nodes. Its movement can be controlled, or it may move randomly.

Since Mobile Sink cannot go to every node and collect data, concept of Rendezvous Nodes [4] [6] came into being. Rendezvous Nodes act as a temporary storage point and helps the nodes to communicate with Mobile Sink. As soon as Mobile Sink approaches the RN node a beacon signal is sent, and RN node transfers the data to the Mobile Sink. Combined effect of RN node and Mobile Sink [5] is that it leads to more energy efficiency in case of WSN.

Not only a single sink, even the concept of multiple Mobile sink has been implanted by various researchers [9] [12] [18] , but in this study we will take only the concept of a single Mobile Sink. Some studies have also elaborated about the delay in sending the information with use of Mobile Sink [10].

In the present paper concept of Mobile Sink and RN node has been combined with LEACH with changes in Cluster Head Selection process. The proposed method increases the lifetime of WSN.

3. PROPOSED ALGORITHM

The present study similarly has 2 stages as in traditional LEACH (Setup Phase, Steady Phase). The Setup phase includes the selection of Cluster head and RN nodes while the Steady State Phase deals with data transmission. The study considered a system composed of a fixed number of nodes placed randomly in a sampling region. All nodes have initial energy equal to E_o which is taken to be 0.3J and a MS that travels through the middle of the sampling region. Mobile Sink is assumed to be having unlimited energy. It is also assumed that the locations of the nodes and sink can be found out for each round.

The proposed algorithm was split into several rounds that are like LEACH. Each node generates information with the same rate. The cluster head selection process depends on distance of node from the sink, residual energy value, number of times a node has been Cluster head and distance between other cluster heads. During simulation the traditional LEACH (with Static Sink) is compared with LEACH having Mobile Sink and RN nodes and even with our proposed LMRNACH (Leach Mobile Sink RN with altered Cluster Head Selection process).

3.1 Rendezvous Node

As already defined RN nodes act as a storage node and it passes the data to Mobile Sink. Several nodes usually have the prerequisites to be an RN. Initially each node is assumed to be a NN and all nodes decide whether or not they meet RN conditions. RN label is attached to the node which satisfies the required condition. The most important condition for an RN is distance from the MS as shown in Eq. (1):

$$\text{if} \quad x_m/2(1-R_{thr}) <= N_{loc} <= x_m/2(1+R_{thr}) \qquad (1)$$

where x_m is the width of the sampling region, N_{loc} is the location of the node in the y-dimension and R_{thr} is a constant with a value of <1.

3.2 Cluster Head Selection

The cluster head selection process depends on distance of node from the sink, residual energy value, number of times a node has been Cluster head and distance between cluster head and other nodes [7] [16] [17].

$$T_{thresh} \begin{cases} Z(n) & \text{if } E(n)>=t1*(1/N)*\sum E(i) \\ 0 & \text{if } E(n) < t1*(1/N)*\sum E(i) \end{cases}$$

where Z(n)= a1T1(n) + a2T2(n) + a3T3(n) + a4T4(n). a1,a2,a3,a4 are 4 weighted constant parameters applied to adjust the relative influence of 4 sub-threshold terms T1(n),T2(n), T3(N)

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and T4(n).The sum of a1+a2+a3+a4 is always equal to 1 as to normalize the threshold value in contrast to traditional Leach.

$$T1(n) = \begin{cases} \frac{P^* \; E(n)}{(1/N)^* \sum E(i)} & \text{if } E(n) >= t2^*(1/N)^* \sum E(i) \\ 0 & \text{if } E(n) < t2^*(1/N)^* \sum E(i) \end{cases}$$

$$T2(n) = \begin{cases} \frac{P^*(1/N)^* \sum ds(i)}{ds(n)} & \text{if } ds(n) >= t3^*(1/N)^* \sum ds(i) \\ 0 & \text{if } ds(n) < t3^*(1/N)^* \sum ds(i) \end{cases}$$

$$T3(n) = \begin{cases} \frac{P^*(1/Q)^* \sum dch(n,i)}{(1/Q)^*(1/Q-1) \sum\sum dch(j,i)} & \text{if } Q>1 \\ (P^*2^*dch(n,Q))/M & \text{if } Q=1 \\ P & \text{if } Q=0 \end{cases}$$

$$T4(n) = \begin{cases} \frac{P^*(1/N)^* \sum Nch(i)}{Nch(n)} & \text{if round}>1 \\ P & \text{if round}=1 \end{cases}$$

Here N is total number of alive nodes in current round, M is length of the square workspace(meter),Q is number of elected CH in current round, E(n) is current residual energy of node n (in Joule), P is desired percentage of nodes to be CH, n is node index(n=1,2,3….N), i is also node index (i= 1,2,3….N), j is CH index (j=1,2….M), ds(n) is distance from node to sink(meter), dch(j,i) is distance between node i and CH j(meter) and Nch(n) is number of rounds that node n was CH.

3.3 Overall Operation

During the Setup Phase every node is initially assumed to be Normal node. A node becomes a RN node if it satisfies equation 1. Every node then chooses a random number between 0 and 1. If the random number that is generated is less than the threshold value T_{thresh} then node is elected as CH. The CH and RN transmit their advertisement message to the Normal Nodes. Every node decides its cluster and which RN is nearest. Decision is based on minimum communication distance (dependent upon the strength of the signal of the advertisement message from the CHs and RNs).Based on the number of nodes in its cluster, a cluster head will create a TDMA schedule (so that nodes can identify when to send the data to CH) and it is broadcasted back to the non-CH nodes in its cluster. Once TDMA schedule is fixed, data transmission begins. In the steady phase nodes begin to transmit the data to CHs. When all data gets received, CH aggregates the data [15]. In LEACH transmission of data from CH to MS requires high consumption of energy. In our proposed algorithm CH will send data to MS if distance between them is less than the threshold distance do.

Where

$$do = \sqrt{(Efs/Eamp)}$$

Efs is energy consumed by power amplifier in free space model and Eamp is energy consumed by power amplifier in multipath model.

If distance between CH and MS is greater than do(threshold distance), then CH transmits the data to nearest RN and then RN transmits to MS. This is done because if the transmission distance is more than 'do' then energy consumed is proportional to d^4 and if transmission distance is less than 'do' then energy consumed is proportional to d^2.

3.4 Energy Model

In order to calculate energy consumption first order radio communication model is used.

Energy consumed to transmit l bits of message to location d meters in distance is-

$$ETx = ETx\_elec(l) + ETx\_amp(l,d) \begin{cases} l^*ETx+l^*d^2 & \text{if } d<=do \\ l^*ETx+l^*d^4 & \text{if } d>do \end{cases}$$

ETx is energy consumed by radio circuit for 1-bit transmission.

Total Energy consumed to transmit and receive data is

Etotal= ETx(l,d) + ERx(l).

where ERx is energy consumed by a node in receiving mode.

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```
Xsink =0 ,  Ysink =ym/2

Distribute n node randomly in the sampling region their initial energy set to S(i). Energy = Eo
  For i = 1: n
     S(i). type =" NN" (All node assumed to be "NN" type)
  end for
  For r = 1: r max (start Round, r max is final round)
     For i =1: n
            If |Y(i) – ym /2| < Rthresh
                S(i). type =" RN"
            End if

         If S(i). Energy <= 0
            S(i). type =" dead"
            S_dead(r) =S_dead (r) +1
         else

           Remain. Eng total(r) = ∑E(n)
         End if
         If S(i) is first_dead
                Flag_First_dead(r) = 1
         End if

       If S(i) is 25% dead node
          Flag_ 25%_dead (r) = 1
       End if
     End for
  Avg – Eng – Node (r) = Remain. Eng total(r) / (n – n dead(r))
 For i = 1: n

CH Selection Process if using traditional leach use probability formula, for proposed algorithm use Tthresh.

      If (S(i). type ~=" RN"
     (depends on algorithm scenario)

         If (S(i). Energy=>Eaveragenet (r)
         (depends on algorithm scenario)

            S(i). type = "CH"
          end if

      end if

   end for



for i = 1: n
      If S(i). type == "NN"

 Find nearest "CH" and transmit normal node data to nearest CH

    S(i). Energy = S(i). Energy - ET and reduce receive energy from selected CHs initial energy.

      End if

  If S(i). type =="CH"

     If dist_from_CH_to_sink(i) > do

       Find nearest lived RN

       Transmit data to selected RN and reduce transmit energy from its Initial energy

          If |YRn - Ysink| < do

Transmit data to selected RN and reduce transmit energy from RN's Initial energy

           End if

      End if

  Else
Transmit data from CH to sink directly

        S(i)ChEnergy = S(i)ChEnergy-Er
    End if

    End for


Xsink= Xsink +ΔX
Ysink= Ysink +ΔY

End for
```

Pseudo Code of Algorithm

4. Simulation

For the simulation of traditional LEACH with Mobile Sink and RN node five scenarios were considered.

1) Mobile Sink-1 – In this Scenario RN's do not participate in the CH selection process and all other nodes can be CH based upon threshold.

2) Mobile Sink-2 – In this Scenario RN's do not participate in the CH selection process and all other nodes can be CH based

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upon threshold energy, the remaining energy should be greater than the average energy.

3) Mobile Sink-3 – In this Scenario RN's participate in the CH selection process and all other nodes can be CH based upon threshold.

4) Mobile Sink-4 – In this Scenario RN's participate in the CH selection process and all other nodes can be CH based upon threshold but their energy remaining should be greater than the average energy.

5) Static Sink- In this Scenario our Sink does not move and is positioned at the centre of the sampling region. (Traditional LEACH case).

For the proposed algorithm, in which cluster head selection process will depend on four factors, 2 scenarios were considered namely Proposed Mobile Sink 2(PMS2) and Proposed Mobile Sink 4(PMS4). MS1 and MS3 are not considered since energy value is taken into consideration during the formulation of Tthresh. Simulation of these scenarios was done for 4 different regions 200m, 250m, 300m and 450m.

Simulation Parameters

Parameters	Value	Description
Xm, Ym	200m,250m,350m,450m	Length and Width of Region
Eo	0.3J	Initial Energy
ETx	50 nJ/bit	Energy consumed by radio in transmit mode
ERx	50nJ/bit	Energy consumed by radio in receive mode
EDA	5nJ/bit/signal	Energy consumed for data aggregation
Eamp	0.0013pJ/bit/m^4	Energy consumed by amplifier in multipath
Efs	10pJ/bit/m^2	Energy consumed by amplifier in free space
l	4000bit	Data packet Size
Rthresh	16%	Constant related to width of sampling region
n	100	Number of nodes

Traditional Leach with Mobile Sink and RN node

Table 1

First Dead Node (in rounds)

Dimension (in m)	Mobile sink-1	Mobile sink-2	Mobile sink-3	Mobile sink-4	STATIC
200*200	243	206	161	180	229
250*250	52	123	99	82	67
350*350	28	13	14	19	19
450*450	10	12	4	13	11

Table 2

25% Dead Nodes (in rounds)

Dimension (in m)	Mobile sink-1	Mobile sink-2	Mobile sink-3	Mobile sink-4	STATIC
200*200	553	566	625	648	487
250*250	418	312	545	539	300
350*350	220	161	257	278	110
450*450	80	93	102	87	40

Table 1 shows the occurrence of first dead node (in rounds) in traditional LEACH with Mobile sink and RN node.

Table 2 shows the occurrence of 25% dead nodes (in rounds) in traditional LEACH with MS and RN. These parameters are important as they help in assessing the quality of network and the network lifetime (especially 25% dead nodes). As the dimension increases the performance gets better. The Mobile Sink algorithms outperformed the Static sink by long way as the dimension increases.

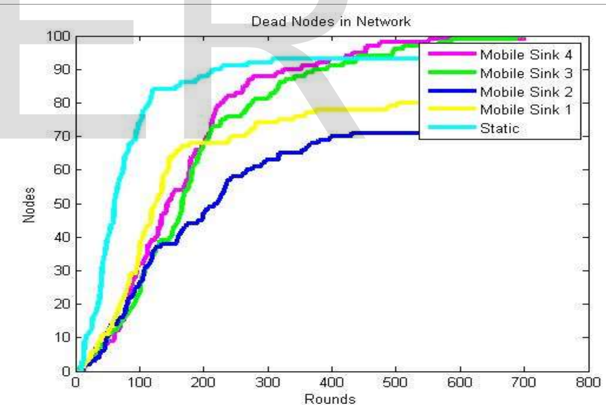

Fig. 1. Number of dead nodes in Different Scenarios (450*450)

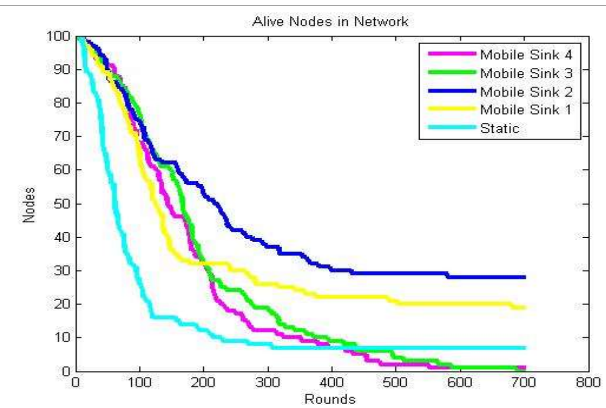

Fig. 2. Number of alive nodes in Different Scenarios (450*450)

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Figure 1 and 2 shows that how Mobile Sinks performs better than Static Sink in terms of network lifetime. By comparing the slopes, it can be easily seen that in Static Sink nodes die faster and hence network lifetime decreases

Proposed Algorithm Results

Table 3

First Dead Node (in rounds)

Dimension (in m)	Mobile sink-2	Mobile Sink-4
200*200	178	88
250*250	29	43
350*350	4	4
450*450	2	2

Table 4

25% Dead Nodes (in rounds)

Dimension (in m)	Mobile sink-2	Mobile Sink-4
200*200	493	489
250*250	592	408
350*350	318	309
450*450	216	197

Table 3 shows the occurrence of first dead node (in rounds) in our proposed algorithm LMRNACH. Only 2 cases have been considered as the nodes are energy aware because of the threshold (Tthresh).

Table 4 shows the occurrence of 25% dead nodes (in rounds) in our proposed algorithm LMRNACH. When our Proposed Mobile Sink is compared with traditional LEACH the results were extremely good. As the network dimension increases the proposed LMRNACH outperforms the traditional LEACH with Mobile Sink. In network dimension of 450*450 proposed algorithm performed nearly twice as good as existing traditional LEACH with MS.

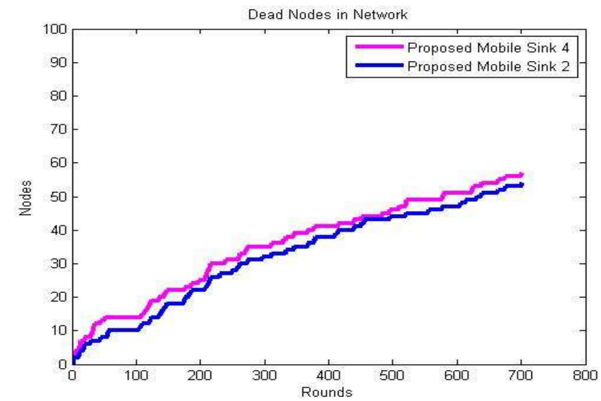

Fig. 3. Number of dead nodes in Proposed Mobile sink (450*450)

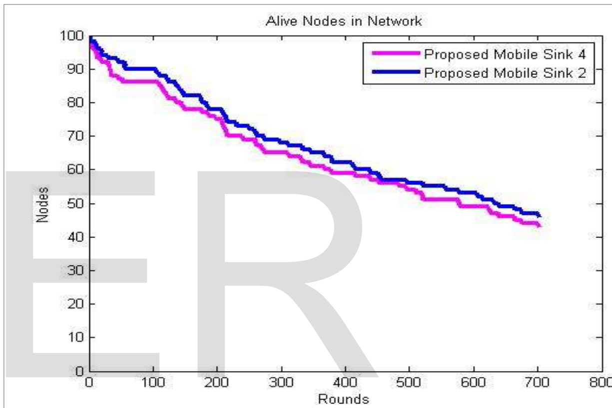

Fig. 4. Number of alive nodes in Proposed Mobile sink (450*450)

Figure 3 and 4 shows that PMS2 performs better than PMS4 this is due to fact that MS2 the RN nodes don't participate in CH election process and energy is not wasted in it, rather RN nodes simply pass the information directly to Mobile Sink.

Comparison between proposed and existing algorithm

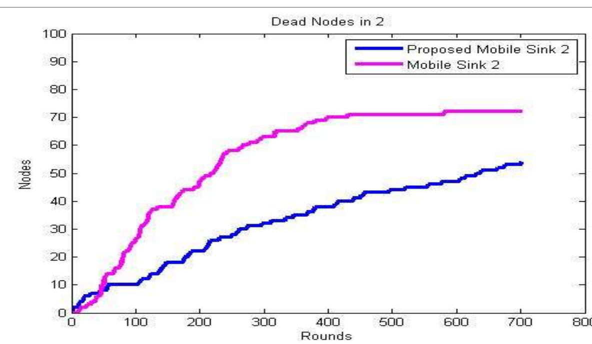

Fig. 5. Comparison between dead nodes in MS2 and PMS2 (450*450)

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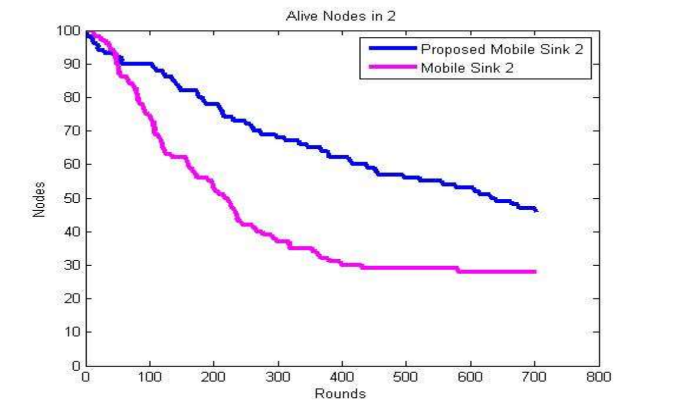

Fig. 6. Comparison between alive nodes in MS2 and PMS2 (450*450)

Figure 6 shows that in comparison with Mobile Sink 2 our proposed mobile sink performs way better. Numbers of alive nodes in Proposed Mobile Sink 2(PMS2) are greater than Mobile Sink (MS2).

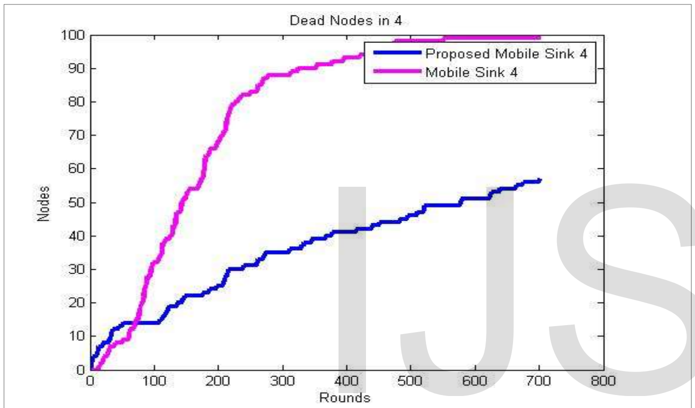

Fig. 7. Comparison between dead nodes in MS4 and PMS4 (450*450)

It can be inferred from graph 5 that Proposed Mobile Sink has a smaller number of dead nodes as compared to Mobile Sink with traditional Leach. So, it is clear from the simulation results that LEACH with Mobile Sink and RN nodes with altered Cluster Head Selection process (LMRNACH) is a good method to increase the network lifetime as compared to traditional LEACH with Static sink or even with Mobile Sink.

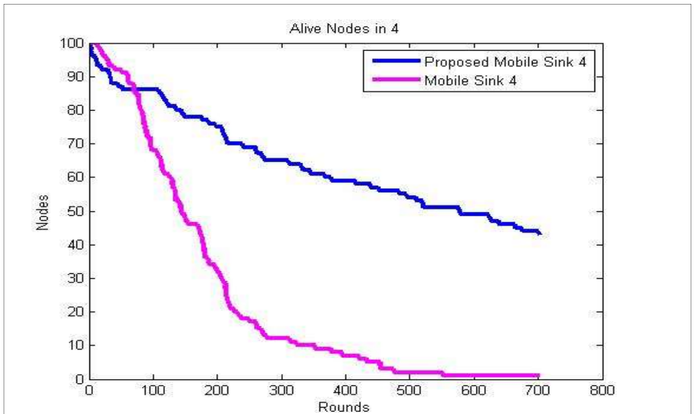

Fig. 8. Comparison between alive nodes in MS4 and PMS4 (450*450)

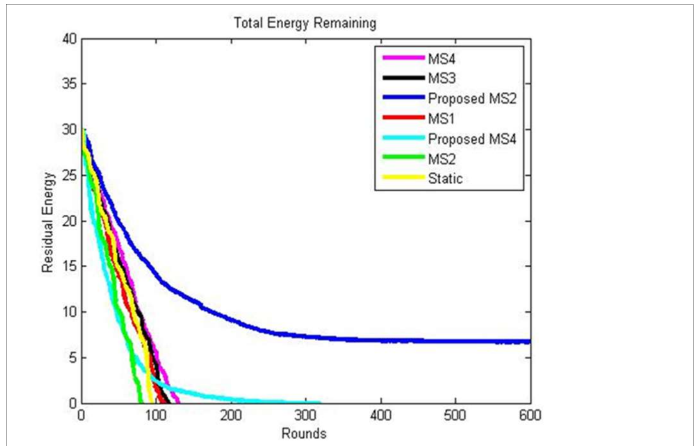

Fig. 9. Residual energy in all the scenarios(450*450)

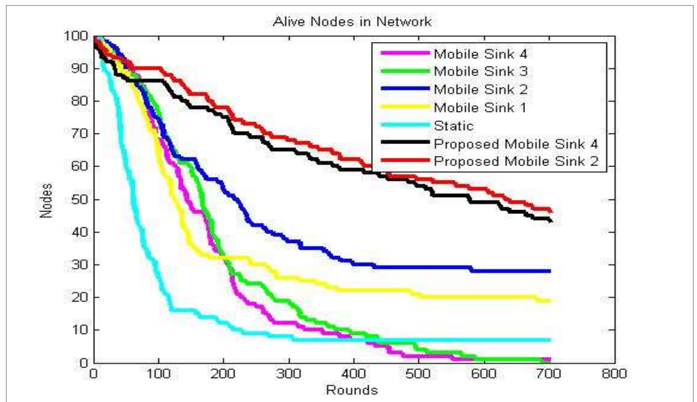

Fig. 10. Alive nodes in the network in all scenarios (450*450m^2)

Figure 7 and 8 in a similar way shows that in comparison with Mobile Sink 4, PMS4 performs better and has a larger network lifetime.

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5. Conclusion

Network Lifetime is a key issue for any Wireless Sensor Network. The present study was aimed at prolonging the Network lifetime. The LMRNACH algorithm considered LEACH with Mobile Sink and RN nodes, with altered Cluster Head selection process. Even the simulation of traditional LEACH with Mobile Sink and RN node was performed. It was seen that in traditional LEACH case the Mobile Sinks (MS1, MS2, MS3, and MS4) performed better than the static sink.

LMRNACH was performed by altering the cluster head selection process and it was dependent on 4 factors distance of node from sink, distance of node from other CH, Residual Energy and Number of times a node has been CH. Simulation results clearly proves the proposed algorithm outperformed traditional LEACH mobile sink and RN node (particularly in large network dimension).

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