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Mobile Sink Assisted Energy Efficient Routing Algorithm for Wireless Sensor Networks

Deepa V.Jose
Department of Computer Science
Christ University
Bangalore, India

Dr.G. Sadashivappa
Department of Telecommunication Engineering
R.V.College of Engineering
Bangalore, India

Abstract— A plethora of applications in our daily life uses the assistance of wireless sensor networks. The main drawback of the sensors is the resource constrained nature especially with regard to energy storage. The minute structure is an attractive feature of these sensors as they can be easily be deployed or accommodated in sensing or monitoring devices. But because of the miniature size, the energy storage, processing and memory capabilities have to be drastically reduced. The applications which uses the wireless sensor networks will have to have a continuous connectivity with the area where they are deployed without any breakage otherwise the intension of the sensor deployment will be ineffectual. In order to maintain the longevity of the network the only option is to efficiently use the available energy to the maximum extent. Each layer of the protocol stack has its own strategies in order to reduce the energy consumption. We are focusing on the network layer in which routing place an important role. As compared to the sensing and processing functions the process of communication consumes more energy and hence the importance of an energy efficient routing protocol to enhance the life time of the wireless sensor networks. A novel approach where in mobile sinks are involved is proposed with extensive simulations which showcase the efficacy of the proposed Mobile Sink Assisted (MSA) algorithm.

Keywords- Energy Efficiency; Duty Cycling; Mobile Sinks; Routing Protocols; Wireless Sensor Networks.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) has a very significant role in today's world as it is used in a variety of appliances and applications that assist us every day in our activities. They are tiny sensor nodes often called as motes which are deployed in very large numbers over an area to relentlessly monitor any continuously varying physical phenomena like temperature, humidity and so on.

A variety of disciplines uses the WSNs for numerous applications like monitoring of specific features or targets especially in rescue and surveillance applications, medical, engineering and industrial applications and many more. As they are easy to handle because of the small size and is of affordable cost the use of such sensors became common. Besides that they can be deployed in areas like underground, underwater or the normal landscape which made it more feasible.

Now a day's everywhere we can see the surveillance equipments which are deployed with sensors. Smart home environments are yet another application. Lot many applications in medical field use WSNs like patient monitoring. Target tracking and war zones extensively rely on these.

A scenario of WSN is shown in the figure1.

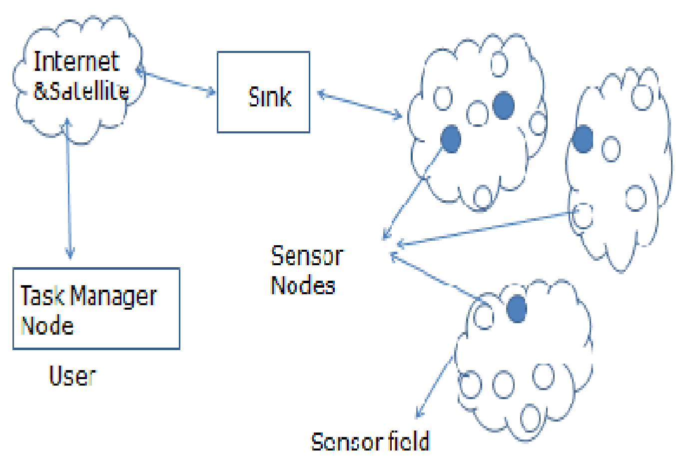

Figure 1. General Structure of WSNs

The sensor nodes deployed in the sensor field will sense the required data and will pass over to the sink, through a desired route, from where it can be passed on to the user for further processing. The sensor field implies any application area where the nodes are deployed. Each of these sensor nodes contains a sensing unit, processing and memory unit and a source of power supply and in some applications a mobilizer and positioning device. The sensor node components are depicted in figure 2.

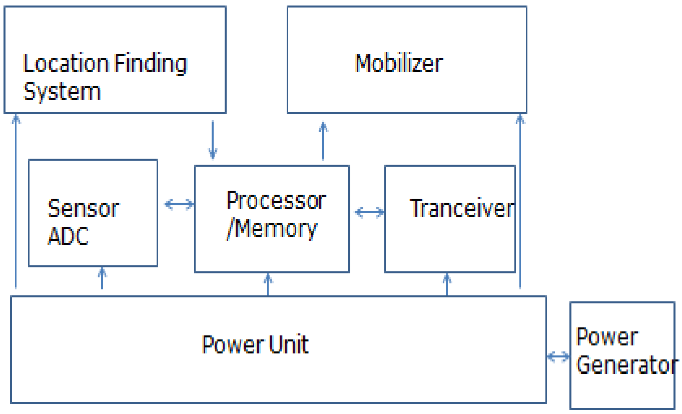

Figure 2. Components of a Sensor Node

The size of these sensor nodes will be very small as it has to be embedded in specific devices or deployed without much hurdles. This makes the storage and power capacity of them very restricted .In order to prolong the network life time obviously care has to be taken to make use of the available energy of all the nodes in an optimal way as they will be deployed in areas where replacement of power source is impractical. There are many routing techniques employed to achieve the energy efficiency. It's very important as the communication process consumes more energy than that of sensing and processing operations [1]. There are different categories of routing protocols in which the main classification is as represented in the figure 3.

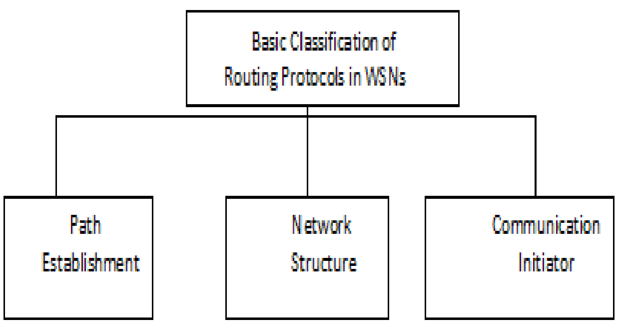

Figure 3. Classification of Routing Protocols in WSNs

The design of the routing protocols depends on the specific type of application where it is to be used. Importance have to given to various factors like the deployment strategies, node density, reliability, scalability, influence of transmission media, energy consumption etc.

Different strategies are applied to achieve the energy efficiency. Node deployment has an important role in deciding the energy consumption. The random deployment and pre defined deployment affects the energy requirements in different ways. But in WSNs the strategy to be used depends on the application for which it is deployed. In some applications nodes can be deployed in a predefined manner and the route will be static in such cases wherein some other applications where random deployments are needed, routes have to be decided dynamically. Another factor to reduce energy consumption is to apply duty cycles so as to avoid the need of all the nodes to be alive all the time thereby reducing the energy consumption. By involving sink mobility or node mobility also, energy consumption can be reduced to some extent. This paper gives an overview of the different methods to achieve energy efficiency in WSNs and proposes a new approach for the same. Section II gives the Literature Review followed by Motivation and the Problem Statement in Section III and Section IV respectively. Section V gives the detailed explanation of the Proposed Algorithm. Simulation results are shown in section VI, followed by the Conclusion and Future Enhancements in Section VII.

II. LITERATURE REVIEW

Wang et al in [1] proposes an energy efficient routing protocol where mobile sinks are employed and random deployment of nodes are done. They uses a new version of the Stable Election Protocol wherein the cluster head are selected based on the residual energy of the nodes and the data transmission also is done in a planned manner. This protocol shows good results in balancing the energy of the nodes thereby increasing the lifetime. The authors in [2] tell about the importance of duty cycling and topology management and give an overview of the different protocols used for large level and small level networks. A comparison of the different energy efficient routing protocols is also done.

In [3] the energy consumption of the Direct Communication protocol and Minimum Transmission Energy is assessed and compared LEACH protocol in MATLAB and a through effort is done to emphasize the importance of clustered routing to increase the energy efficiency along with a suggestion for future enhancement i.e. to develop design new energy efficient routing algorithm with a different cluster head selection strategy in order to extend the network life time. In [4] , [5] and [6] a survey of the different energy efficient routing protocols is done mentioning the different strategies adopted by each. These papers in general give an overall idea of the different energy efficient routing protocols. They compile all the different energy efficient routing protocols available in the literature.

The authors in [7] propose a new energy efficient routing protocol for Wireless Body Area Networks where the nodes are static. They use a routing approach by using the intersection of the nodes and find a path to the sink without flooding. Three different stages are used in the proposed scheme where in the first stage the nodes prepare a route and send the advertisement to the neighbours, in the second stage neighboring nodes decision of whether to reply is done and finally in the third stage the information is passed from source to the selected sink node. They claim that the proposed protocol shows better results. But additional hardware requirement of GPS is needed for the nodes to be aware of their current location and that of the sink. Besides that it is assumed all the nodes are aware of their energy levels.

Awwad et al in [8] tells about the issues in the node mobility like packet loss and energy consumption. They propose a protocol called cluster based routing with mobile nodes which proved to be better than the t LEACH Mobile protocol. Here the cluster heads receives data from all the nodes in their cluster when they are free. The proposed one shows improvement by 25% in the case of packet loss when compared with LEACH Mobile protocol. An approach where the location information of the neighboring nodes is exchanged only to the forwarding node sensing data thereby reducing the power usage is done by Kimura, Tomoki, and Iwao Sasase in [9].They use mobile nodes with multiple sinks and does not have multicast routes between them.

In [10] mobile sinks are used and by employing appropriate cluster head for effective communication and routing energy efficiency is claimed by the authors. Both the base station and sensor node mobility is addressed in [11]. They uses cluster head along with two deputy cluster heads for routing and also allows to be dormant state when not in use which achieves more energy efficiency. Taking LEACH as the base, an improvement on that with mobile nodes to achieve better lifetime is done by Nguyen et al in [12].

Xun-Xin, Yuan, and Zhang Rui-Hua in [13] proposes a new energy efficient routing using the sink mobility where the sink moves based on the average energy of the cluster. Here only one sink is mobile. They propose a future enhancement with more mobile sinks along with other normal nodes also given the mobility. For detecting a mobile target a new protocol is proposed by Yu-Chen et al in [14].In mobile target of course chances of path loss or connectivity is possible. According to the proposed protocol the nodes themselves can effectively recover the path and perform energy efficient tracking. The issues in inter cluster communication in large scale networks is addressed in [15]. The authors views that the optimization in the inter cluster head communication is not seriously dealt with in the literature and proposes a new algorithm named Broadcasting Over Cluster Head for better scalable and efficient inter cluster communication. Inter cluster communication using single hop and multihop from the cluster head to the sink is studied and a comparison is done with the existing routing protocols in [16].

A hierarchical and cluster based routing which supports sink and node mobility is proposed in [17]. It has a setup phase and a data forwarding phase. The sensor field is categorized and each node is assigned a specific role. Majority of the complicated computations are done in the sink. The author claim the proposed protocol gives better energy efficiency. A new protocol which assures better data delivery ratio and energy efficiency for a mobile sink group is proposed by Yim et al in [18]. This protocol suits best for mobile sink group in application like war and disaster rescue areas. The data will be sending by the source to the mobile sink when it moves in a particular region in a specific line. The simulation results have proved the efficacy of the proposed protocol.

In [19] the authors proposes a method to route data from static source to mobile sink in a reliable manner where in the source use some prediction technique to predict the location of the sink. Related to latency, reliability and energy efficiency the proposed one outperforms the conventional routing protocols. The power control issues are studied in detail in [20] where in the different active and passive methods are discussed in detail with different metrics. It provides detailed information with respect to the different power control and management schemes, its need and cost as well as the side effects. For balancing the energy transmission the traditional multihop transmission is improvised dividing it in to two phases and taking network life time as an optimization problem in [21].Overall it gives three different transmission policies which gives an extended life time for the wireless sensor networks.

III. MOTIVATION

In the area of WSNs, energy efficient routing protocols has been always a hot research area but the mobility factor is not addressed in an appropriate level as it is evident that majority of the routing protocols assumes the nodes to be static. But we can find that in most of the applications where wireless sensor networks are involved like disaster applications or medical care etc the nodes can be mobile. So mobility of the nodes i.e. either the source or the sink has to be considered. Literature have shown that mobile sink assisted routing helps to reduce energy consumption to a great extend. Hence we thought of developing an energy efficient routing algorithm which is supported by the mobility of multiple sinks.

IV. PROBLEM DEFINITION

Routing is an important networking activity as it is the major factor that affects the efficiency of a network in terms of delay, throughput, energy consumption etc. WSNs consist of hundreds and thousands of tiny sensors or motes which are deployed randomly in an area where the sensing of a particular event has to be done. There are a variety of applications which employ WSNs like disaster rescue operations, wild fire protection, war zones, engineering, medical and agriculture fields, robotics etc where the direct intervention of human is comparatively risky or sometimes impossible. In many cases replacing the batteries are also not feasible because of its huge number as well as the restrictions of the deployed region. If one node goes out of power and dies off the entire connectivity can be affected which makes the intention of the network futile. Because of the resource constraint nature, the power backup capabilities are very limited and the only possible way to retain the network connectivity is to efficiently use the available energy so as to extend the lifetime of the entire network. So the proper design of every layer in protocol stack is very important. Network layer activities especially routing can save energy to a great extend because the communication process consumes more energy compared to sensing and other processing activities and hence our focus is on development of an energy efficient routing protocol so as to enhance the life time of the entire network.

V. PROPOSED ALGORITHM

According to the literature energy efficiency is dealt by the hierarchical routing category where the concept of clustering is used. We propose an algorithm called Mobile Sink Assisted (MSA) routing which considers the drawbacks of existing algorithms like shortest hop, LEACH, modified LEACH and Artificial Bee Colony routing strategies. The detailed concept of the proposed algorithm called Mobile Sink Assisted (MSA) routing along with the assumptions are described in detail below.

A. Assumptions

According to the design simulation time is given as 50ms initially. There is a static sink and four mobile sinks which are assumed to be rechargeable. Movement of the mobile sinks can be decided by the static sink. As the nodes are assumed to be deployed randomly every time, in order to have a uniform style of movement the mobile sinks are made to move from the centre to the four corners of the deployed rectangular region. The numbers of nodes, area of deployment, initial energy of the nodes, range of the sensors etc can be varied to have an extensive simulation results. We assume sensors are distributed randomly across the network. Mobile sinks can navigate the network to collect the packets and report the data to the static sink. The path for mobile sink is assumed to obstacle free. The mobile sinks are assumed to have higher communication range, so it can reach the static sensor node.

B. Algorithm Description

The proposed algorithm consists of three phases namely;

1. Network clustering phase
2. Mobile sink navigation phase
3. Data collection phase

Detailed explanation of each phase is given in following subsections.

C. Network Clustering Phase

The network is partitioned to clusters using clustering algorithms of LEACH with fewer number of cluster heads possible. Once cluster head nodes are chosen, they broadcast beacon to advertise their presence within their communication range. Based on the received signal strength each non cluster nodes choose their cluster heads to which they belong to. The cluster heads nodes send their information to the static base station also. Because of this arrangement sensor nodes need only low power to transmit their data to the cluster head nodes. The cluster head nodes will aggregate the data and keep it in their memory and wait for mobile sink nodes to reach near them to collect the data. figure 4 gives the pseudo code for the clustering procedure, data aggregation and routing in general.

```
//Clustering procedure

Nodetype is the type of node
RSS is the received signal strength
T is the threshold energy
n is the number of nodes
neigh[] is the array of neighbour nodes
Mindist is the minimum distance
for all node i=1 to n
    if nodetype==2  and RSS==high then  form cluster
      if nodeenergy>T  and nodetype==1 elect as CH
      end
    end
end

//Duty cycling procedure
for all  node cycletime= 1 to m
    for all node i=1 to n
     pos=mobsinkpos-CHpos
        if nodedist<range/2
               if pos<Tdist
               CH sends data to MS
               end
         end
     end
end

//Data aggregation algorithm
for all node i=1 to n
    if data[neigh[i]]==data[i] then
    data=data[i]
    flag=1
    else
    flag=0
    end
    if flag==1
    send data to MS
    If MSdata[1]==MSdata[2]==MSdata[3]==MSdata[4]] then
    data= MSdata
    end
end
//Routing algorithm
For all node i=1 to n
if flag==1
Nodes sends data to CH
CH sends data to MS
MS sends data to Static Sink
end
```

Figure 4.Pseudo code for clustering, data aggregation and routing

D. Mobile sink Navigation Phase

Once the static sink receives the cluster head information; it does a path planning to find the optimal number of sensors to navigate the network. The path planning proceeds as follows. From the available cluster heads, static sink picks cluster heads one by one and begins to put in one group till the time the round trip time of travel in that group is bounded by a deadline Td. If the round time exceeds Td then a new group is created. For each group, one mobile sink is allocated. If there are more mobile sinks even after allocating one for each group, the groups are sorted in descending order based on round trip time and mobile sinks are allotted one for group till the number of mobile sink is expired. The rational here is to cover the group with long round trip delay with more mobile sinks.

Once the paths for mobile sinks are decided they are made to move in the path between the cluster heads. If there are more mobile sinks per group, then each mobile sinks is made to start from different nodes. The pseudo code for path planning is given below in figure 5.

```
Algorithm : Plan Path
Input : locations of each cluster head , NM – number of mobile sink , deadline time Td
Ouput : The path for each mobile sink
Group = { all cluster head};
AllGroupSet= null;
        while group is empty
            T← randomly pick one CH from group
            NewSet= {T};
           RTT=0;
           While RTT< Td
              RN←Pick a nearby node to nodes in NewSet;
              Add RN to NewSet.
            Recalculate RTT for NewSet
           End
           AllGroupSet = {AllGroupSet , [ NewSet,RTT] };
        end
        Sort AllGroupSet in descending order of RTT,
        AMS ← 0
        Pos<-0
        While AMS != NM
           Add MobileSink(AMS) to NewSet(Pos);
         Pos = (pos +1)%length(NewSet);

         AMS++;
        end
```

Figure 5. Pseudo code for path planning

E. Data collection phase

The mobile sink once reaches a cluster head node, will advertise a beacon which requests the cluster head node to give all the data stored to the mobile sink. The cluster head node will forward all the aggregated data to the mobile sink. The mobile sink node will forward the data to the static sink. The static sink forwards the data to any application which needs to process the data. Node deployment is done randomly and they are assumed to be homogeneous. Clusters are formed based on the received signal strength and the general behavior of the nodes. The residual energy of the nodes is also taken into consideration. The mobility of the sink nodes plays a vital role in reducing the energy consumption. We are assuming that the sink nodes are rechargeable. The cluster heads will decide the time slot for each node to send data to it which will be aggregated and passed on to the nearest mobile sink. The mobile sinks collects all the sensed data from the cluster heads aggregates it again and finally pass on to the static sink from where the user can get the information. The two ways aggregation process still minimizes the need for each cluster head to transmit to the sink which again reduces the energy consumption [9].

VI. SIMULATION RESULTS

The MSA routing algorithm is compared with the shortest hop path algorithm, LEACH, modified LEACH and Artificial Bee Colony routing techniques. The SH algorithm gives a feel that since it always takes the shortest path or the shortest hop, it will work efficiently in terms of energy, delay etc. But here the problem is since it always takes the shortest route which will obviously be the same route, the nodes in that region will drain energy fast and rest of the nodes with full energy will be left unused. Here focus is only on the shortest hop. But the energy level of the nodes is not balanced in the network which is a major factor to be addressed otherwise network failure will result. Since we are using the mobile sinks this problem is avoided and the number of hops is also reduced as the sink is mobile there by reducing the energy to a great extent.

LEACH is a traditional energy efficient routing algorithm which uses the clustering technique. Here the main drawback is while selecting the cluster heads it just depends on a probability measure and does not consider the energy level of the nodes. In MSA this issue is taken into consideration.

According to Artificial Bee Colony optimization it is assumed that all the nodes are able to transmit to the sink or the base station. When all nodes start doing this, it is actually wasting the energy of all the nodes. Besides that no data aggregation happens whereby inclusions of redundant data can happen which energy is consuming but fruitless operation. These problems are also solved in the proposed method.

The simulation is done using MATLAB with initial parameters as given in Table I.

TABLE I. SIMULATION PARAMETERS

No of Nodes	100
Area of simulation	100*100 m
Range of Sensor	10 m
Initial Energy at sensor	50 Joules
Transmission Energy	.5 Joules
Receiving Energy	.2 Joules
No of mobile sink	4
No of static sink	1
Deployment Model	Random

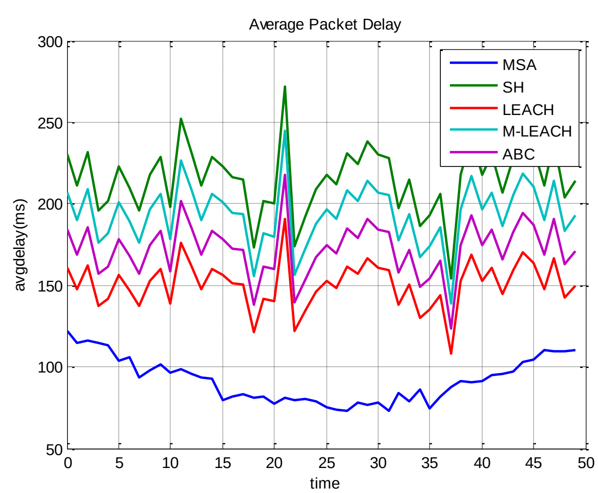

Figure 6. Average Packet Delay

The average packet delay is the time taken by a data packet to arrive in the destination which includes the delay caused by route discovery process and the queue in data packet transmission. How many data packets are successfully delivered to destinations will only be considered for finalizing the delay factor.

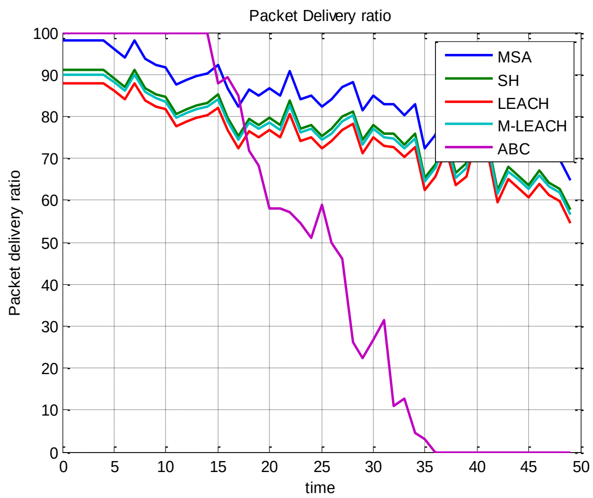

Figure 7. Packet Delay Ratio

The value of delay is lower implies better performance of the protocol. From figure 5 it is evident that the MSA is showing less delay compared to SH, LEACH , M-LEACH and ABC protocols. The average packet delay in the entire scenario is depicted in figure 7.

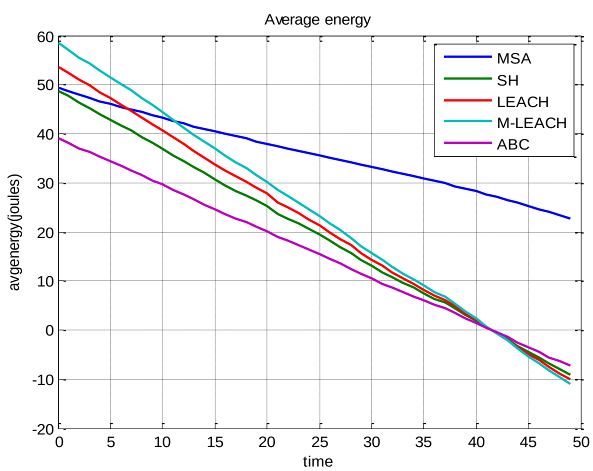

Figure 8. Average Energy

In extending the lifetime of the network the average energy of the nodes plays an important role. From Figure 8 we can see that in the proposed protocol the average energy of all the nodes remains to be uniform for a longer time compared to others which is an evidence that the residual energy of the nodes are high in the proposed strategy. This implies the energy efficiency of the MSA protocol.

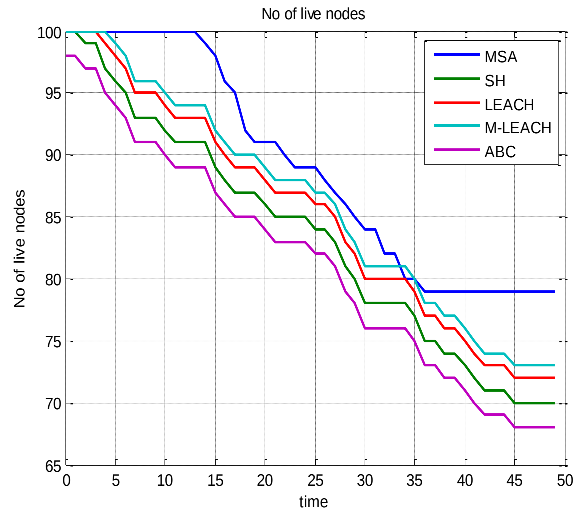

Figure 9. Number of Live Nodes

As mentioned above if efficient use of energy is done the number of live nodes will be more. figure 9 gives an illustration of this fact in which the number of live nodes are more in the proposed protocol compared to the others over a period of time.

VII. CONCLUSION

Energy efficiency enhancement is always a matter of concern in wireless sensor networks. In this paper an energy efficient routing algorithm with mobile sinks called MSA routing is proposed with the details about the implementation and simulation results. Extensive simulations have proved that the proposed one gives much better performance than the existing protocols like shortest hop, LEACH, modified LEACH and Artificial Bee Colony algorithms in terms of life time, the average energy of nodes, packet delay and the average packet delivery ratio. The real time implementation of this algorithm will serve many applications to save energy to a greater extend. The future work will be dealt in the area of finding optimal path for the movement of the sinks so as to save energy of the nodes by reducing the number of hops which can enhance the lifetime of the entire network.

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AUTHORS PROFILE

Ms.Deepa V. Jose has completed MCA, M.Tech. (IT) and M.Phil. in Computer Science. Currently pursuing Ph.D. in Computer Science from Christ University Bangalore. Her research interests are in the field of Wireless sensor networks and Cryptography.

Dr.G Sadashivappa is currently working as Associate Professor in the Department of Telecommunication Engineering, RV College of Engineering, Bangalore. He have more than twenty five years' experience in teaching research and industry. His research interests include Fiber optic communication, Signal Processing and Applications and has authored many books and have many research papers to his credit.