

# ENERGY EFFICIENCY IN AD HOC NETWORKS

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## ABSTRACT

*Wireless Ad Hoc Networks comprise a fast developing research area with a vast spectrum of applications. Wireless sensor network systems enable the reliable monitoring of a variety of environments for both civil and military applications. The Energy efficiency continues to be a key factor in limiting the deployability of ad-hoc networks. Deploying an energy efficient system exploiting the maximum lifetime of the network has remained a great challenge since years. The time period from the instant at which the network starts functioning to the time instant at which the first network node runs out of energy, i.e. the network lifetime is largely dependent on the system energy efficiency. In this paper, we look at energy efficient protocols, which can have significant impact on the lifetime of these networks. The cluster heads get drain out maximum energy in the wireless ad hoc networks. We propose an algorithm that deals with minimizing the rate of dissipation of energy of cluster heads. The algorithm LEAD deals with energy efficient round scheduling of cluster head allocation of nodes and then followed by allocation of nodes to the cluster heads maximizing network lifetime using ANDA [1, 2]. We compare our results with the previous works.*

## KEYWORDS

*Clustering, ANDA, energy efficiency, LID, energy factor, network lifetime, LEACH, LEAD, network, energy, efficiency, dissipation, Ad hoc*

## 1. INTRODUCTION

The limited availability of the energy resources poses as quite a challenge in designing wireless adhoc networks. and quite significantly these are limited in wireless networks than in wired networks. The network lifetime is defined as the time instant at which the network starts functioning to the time instant at which the first network node runs out of energy. In this paper we deal with the design of techniques to maximize the network lifetime in case of cluster-based systems.

We have worked and researched on mainly studying and implementing the ANDA, integrating LID with ANDA, and finally we have proposed our own original algorithm for improving the ANDA and bringing a maximum network lifetime. We have also used the traditional LEACH Algorithm concept in designing our own original algorithm. We tend to show in our paper that the proposed Algorithm quite outperforms the traditional Algorithms proposed related to the network lifetime field till date.

CLUSTERING is defined as the grouping of similar objects or the process of finding a natural association among some specific objects or data. Sensor Networks uses a cluster based system to transmit processed data to base stations. In these systems the network nodes are partitioned into several groups where each group has one node as the primary cluster head and the rest of the nodes are the ordinary nodes.

Cluster-formation is a two-phase process consisting of cluster-head election and assignment of nodes to cluster-heads[4, 5]. The cluster-head is the co-ordinator of all transmissions within the cluster, so also it handles the inter-cluster traffic and also delivers the packets destined for the cluster etc. Obviously these cluster-heads would experience a very high-energy consumption thereby leading to exhausting their energy resources more quickly than the ordinary nodes. It is therefore required that the cluster-heads' energy consumption be minimized (optimal) thus maximizing the network lifetime [1].

We first discuss the related work done in this field like the ANDA, LID and LEACH and then move on to our algorithm LEAD, its detailed working and explanation and our simulation environment that we have deployed the algorithm in.

## **2. RELATED WORKS**

### **2.1. ANDA**

ANDA [1], Ad hoc network design algorithm, assigns the ordinary nodes to the cluster heads such that energy is not drained out from them easily and the lifetime of the whole system increases drastically. A matrix is computed which lists, the probable lifetime of the cluster head if a particular node is assigned to it, for all the cluster heads. ANDA algorithm basically comprises two algorithms. One, the covering algorithm [1] which is applied to the static and dynamic case and second, the reconfigure algorithm [1] which applies only to the dynamic scenario. Dynamic means the nodes change their position after every  $[\delta]$  time. Covering performs the optimal assignment of nodes to cluster-heads that presents the longest functioning time computed from the matrix. Reconfigure algorithm makes use of  $[\delta]$  to obtain new nodes assignment every time the network configuration changes. But this algorithm takes into account a fixed set of cluster-heads which continuously dissipate energy throughout the network functioning time. We came up with the idea of having dynamic set of cluster-heads, thereby distributing the energy dissipation among the set of nodes for a better lifetime.

### **2.2. LID**

The LID algorithm is the Lowest Id Algorithm [2, 3] which is clustering algorithm. It defines which nodes will behave as clusterheads and determines the nodes that constitute the cluster. LID defines the nodes which will behave as cluster heads. ANDA is then implemented to cover the nodes. We assign a unique ID to each node in the network. The LID algorithm chooses arbitrarily the node with the lowest ID as the cluster-head and declares all the nodes within the range of this cluster-head as its members. This process continues until all nodes in the network have been grouped into cluster-heads. We calculated the network lifetime using our simulator and then compared with the ANDA. This whole thing is basically implemented in a dynamic scenario. The above scenario was implemented on a simulation platform. We took a dynamic scenario whereby nodes were also changing their positions at regular intervals, thereby considering speed of nodes. Basing on these factors the LID and ANDA algorithms were applied, to calculate lifetime.

### 3. LEAD

LEAD deals with dynamic selection of cluster heads among the set of nodes in the network and then allocation of the rest ordinary nodes to the clusterheads dynamically. It adapts to the network and selection and allocation is done according to the current status of the network.

LEAD achieves three goals. First, we select a set of cluster heads among the nodes randomly which is very practical in case of wireless ad hoc networks instead of having a fixed set of cluster heads. Second, set of cluster heads are selected dynamically after a time  $\Delta$  in a round schedule balancing the load (energy dissipation) throughout the nodes of the network thus increasing the lifetime. Third, dynamically allocates the nodes to the cluster heads using the enhanced feature of ANDA thereby reducing the load on each cluster head to sustain them for other rounds.

LEAD is proactive: each node periodically broadcasts HELLO messages that contain the nodes status (i.e., whether or not the node is currently a cluster head), its current energy, no of nodes under it, its range. From these HELLO messages the nodes calculate the lifetime if it is pseudo assigned to a particular cluster head and thus calculating final allocation of the node. The nodes together form the matrix of the ANDA using these messages. The state of the nodes change every  $\Delta$  time so they periodically send the HELLO messages after every  $\Delta$  time.

#### 3.1. Cluster Head Selection

Let  $SC = f1...Cg$  be the set of cluster-heads,  $SN = f1...Ng$  be the set of ordinary nodes to be assigned to the clusters. Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round according to the table created periodically updated every  $N/C$  rounds. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. After a broadcast of HELLO messages the total network data is clubbed together and the nodes are sorted according to their current residual energy.

```
Selectcluster
If (N/C divides  $\Delta$ )
  Begin nodeSort
  for (every i2Sc)
    for (every j2Sn)
      if (energy[i] > energy[j])
        swap (i, j)
      end for
    end for
  end nodeSort
end if
```

#### 3.2. Node Assignment

Let  $SC = f1...Cg$  be the set of cluster-heads,  $SN = f1...Ng$  be the set of ordinary nodes to be assigned to the clusters. We choose the set of cluster-heads SC Major Contributions to power consumption in nodes are: power consumed by the digital part of the circuitry, Power consumption of the transceiver in transmitting and receiving mode and output transmission power. The lifetime is calculated according to the following equation:-

$$L_i = \frac{E_i}{\alpha r_i^2 + \beta |n_i|^2}$$

where  $E_i$  is the initial amount of energy available at cluster-head  $i$ ,  $r_i$  is the coverage radius of cluster-head  $i$ ,  $n_i$  is the number of nodes the control of cluster-head  $i$ , and  $\alpha$  and  $\beta$  are constants.

Considering that the limiting factor to the network lifetime is represented by the cluster-heads functioning time, the lifetime is defined by

$$L_s = \min_{i \in S_c} \{L_i\}$$

We need to devise techniques to maximize  $L_s$ . The Algorithm for assignment of the nodes is as follows:

```

Begin Assignnodes
for (every  $i \in S_c$ )
    set  $E_i$ =initial energy of cluster-head  $i$ 
    for (every  $j \in S_N$ )
        Compute  $d_{ij}, |n_{ij}|, l_{ij}$ 
    end for
end for
 $L_s$  (new) =  $L_s$  (old) =  $L_s$ 
 $\Delta=0$ 
while ( $L_s$  (new)  $L_s$  (old)  $-\Delta$ )
     $\Delta=\Delta+1$ 
    for (every  $i \in S_c$ )
        for (every  $j \in S_N$ )
            Recompute  $E_i=E_i-\Delta(\alpha r_i^2 + \beta |n_{ij}|)$ 
            Update  $l_{ij}$   $\forall i \in S_c, j \in S_N$ 
        end for
    end for
    Call Selectcluster and update  $L_s$ 
     $L_s$  (new) =  $L_s$ 
end while
endAssignnodes

```

#### 4. NUMERICAL RESULTS

The performance of LEAD is derived in terms of the network life time measured at the time instant at which the first cluster head runs out of energy. We derived results by using a software tool designed by us using Java. We simulated an ad hoc network composed of slowly changing network topology. The network nodes are randomly distributed. The simulated area is a 1000 x 1000 matrix. The nodes can attain a maximum speed of 5m/sec and the mobility of nodes is random. We assumed that the initial energy of all the nodes in the network is 5000J and it can support up to 1000 nodes and even if a node is not a cluster head it loses some amount of energy due to radio transceiver and transmission amplifier. Figure 1 shows the variation between the percentage of nodes becoming cluster heads and lifetime of the network in LEAD.

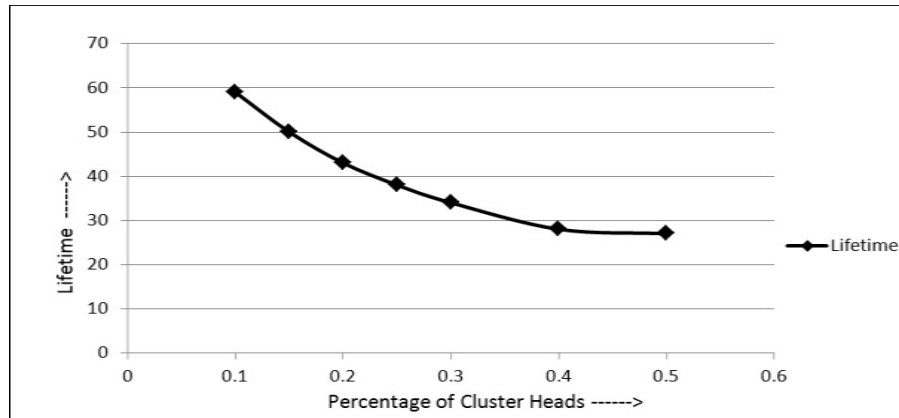


Figure 1. Lifetime as a function of the number of nodes becoming cluster heads. (LEAD)

First, we compare the performance of LEAD with the results obtained by using ANDA (Ad hoc network design algorithm) in which cluster heads are known apriori. Figure 2 shows the network lifetime as a function of the number of nodes, for a percentage of cluster heads  $P=0.05$ . The life-time decreases as the number of nodes grow; however for a number of nodes greater than 100, the life-time remains almost constant as the number of nodes increases. Lifetime decreases because Clusterheads have to cover more nodes as the number of nodes in the network size increases. But LEAD shows significant improvement over ANDA, this is because in ANDA the cluster-heads are determined apriori but in case of LEAD cluster-heads are chosen in a random basis and each node becomes a cluster head in  $1/P$  rounds i.e. the nodes that are cluster-heads in round 0 cannot be cluster-heads for the next  $1/P$  rounds. From the comparison with the performance of ANDA, we observe that the improvement achieved through LEAD is equal to 35 %. Energy is uniformly drained from all the nodes and hence the network life-time is significantly increased.

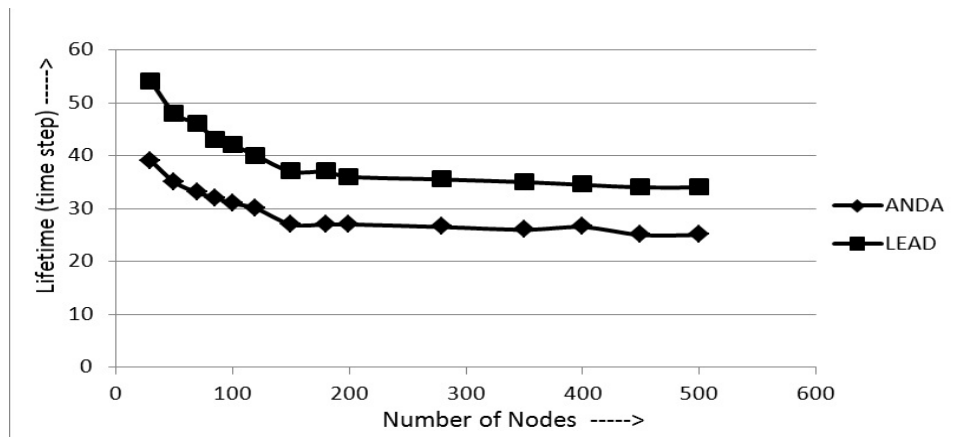


Figure 2. Lifetime as a function of the number of nodes, for a percentage of nodes becoming cluster heads equal to 0.05. Results obtained through ANDA and LEAD scheme are compared.

Figure 3: shows the network life-time as the number of cluster-heads,  $C$ . Curves are obtained for  $N=1000$  and nodes distributed randomly over the network area. In ANDA we observe that as the number of cluster heads increases for a given number of nodes, the life-time is increased, this is due to the fact that increasing  $C$ , cluster heads now have to cover less number of nodes and energy of each node is drained at a slower rate. But, in case of LEAD we observe that network life-time decreases with the increase in percentage of nodes becoming cluster-heads ( $P$ ). For less percentage of nodes becoming cluster-heads the time interval between successive elections of a node as cluster-head is large but if percentage of nodes becoming cluster-heads is high, the time interval is small i.e. a node is again elected as a cluster-head in less number of rounds. So, energy is drained early resulting in a decreased network life-time.

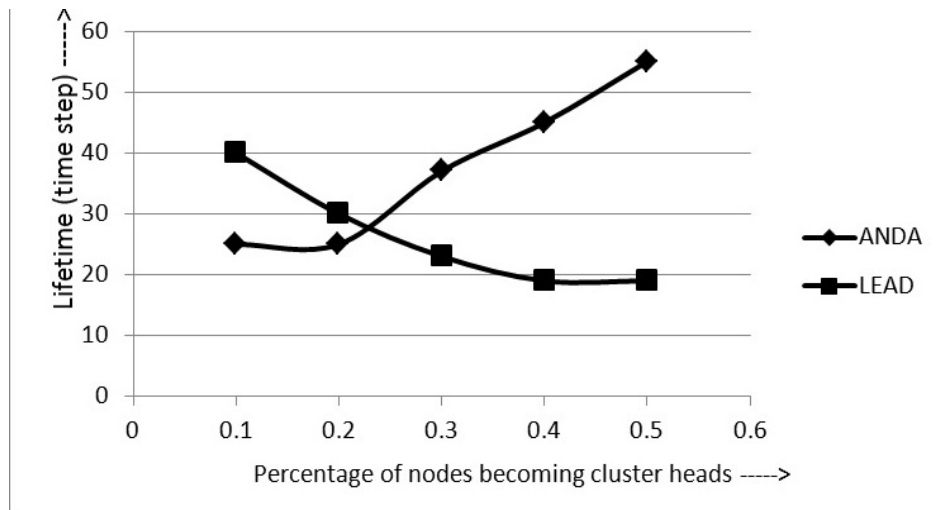


Figure 3. Lifetime as a function of the percentage of nodes becoming cluster heads. Results obtained through ANDA and LEAD scheme are compared.

## 5. CONCLUSION

This paper mainly deals with the problem of maximizing the life-time of a wireless ad hoc network, i.e. the time period during which the network is fully working. We presented an original solution called LEAD which is basically an improvement on ANDA. After making a brief comparative study of our work, we see that as we move on from ANDA to our proposed Algorithm, we gradually get an increased network lifetime. From the various graphs and tables, we can successfully prove that our Algorithm quite outperforms the traditional energy efficient algorithms in an obvious way. The LEAD algorithm outperforms the original ANDA algorithm by 35 percent.

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