MODIFICATION OF ILEACH PROTOCOL TO OPTIMIZE THE LIFETIME OF WIRELESS SENSOR NETWORKS

[1]ADIT GOEL, [2]ANCHIT SHARMA, [3]ANIRUDH SINGH

[1,2,3]Delhi Technological University, Delhi, India
E-mail: [1]aditgoel94@gmail.com, [2]anchitsharma1994@gmail.com, [3]anirudhs414@gmail.com

Abstract— Wireless sensor networks are comprised of independent sensors used to monitor physical/environmental conditions for example temperature, humidity and are distributed spatially. These sensors transmit their collected data to a sink. These sensor nodes are often put in distant areas where a constant energy supply can be a major challenge. Hence the sensors are generally battery operated which limits their energy consumption. An energy efficient optimization algorithm can prevent nodes from being profligate consumers of battery power and use it judiciously instead. Hierarchical routing protocols are the best known protocols to optimize energy consumption in WSNs. ILEACH is considered one of the best among them. To optimize the lifetime, it selects sensor nodes with higher residual energy and lower distance from the Base Station (BS) as Cluster Head (CH) nodes. Then it intelligently manages these nodes by constructing clusters such that the lifetime of WSN is maximized and its average energy dissipation is minimized. TDMA protocol is used for intra cluster communication. This paper proposes a modification of ILEACH protocol by introducing intercluster communication where cluster heads are arranged in a hierarchy, further optimizing the WSN lifetime.

Keywords— Wireless Sensor Networks, Optimising ILEACH, Heuristic Multihop Algorithm, Static Wireless Nodes.

I. INTRODUCTION

Abundant energy dissipation occurs when all of the nodes in a WSN[2,4,7] transmit packets directly to the Base Station (BS). Clustering algorithms provide an energy efficient method of maximizing lifetime of WSNs by dividing the sensor nodes into clusters which would then have an internal election to choose a cluster head. Each cluster head would then collect packets from all the nodes in the cluster and send them to the Base Station.(A WSN can have multiple Base Stations). In LEACH (Low Energy Adaptive Clustering Hierarchy)[5], one of the most popular clustering algorithms, election of cluster heads is done on the basis of assigning a probability of becoming a cluster head to each sensor node. ILEACH (Improved LEACH)[2] improved the above algorithm by dividing the sensor nodes into normal nodes having lesser energy than a threshold value and advanced nodes having more energy than the threshold value. The nodes are then assigned probability of becoming a cluster head based on their type. The algorithm proposed by this paper, OHILEACH (Optimized Heuristic ILEACH), extends the clustering repeatedly, creating a hierarchy of cluster heads and shaping the network in form of an nary tree. The root of this nary tree will be the Base Station. OHILEACH uses intelligent heuristic to determine the path of a packet from the cluster head to the Base Station. Energy dissipation varies with increasing distance. As we will see in the equations used, energy dissipation over long distances can be directly proportional up to quadruple powers of distance between source and destination.
Hence, it can be deduced that a connection with multiple hops over small distances is more energy efficient than a single hop connection over a longer distance. Simulation results show that OHILEACH greatly extends the lifetime of a WSN as well as average energy of WSN over time.

II. RELATED WORK

Several techniques for cluster creation have been proposed in the literature. Sensor nodes are partitioned into clusters and nodes within a cluster elect a cluster head.
LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy)[3] Each node knows its own coordinates the receiver coordinates. No information about the location of other nodes is involved. The steps involved are cluster head election, assigning of each node to a cluster head followed by data transfer. Each node assigns itself to the cluster head involving minimum dissipation of energy upon transmission between itself and the receiver.
LEACH-E(Energy Low Energy Adaptive Clustering Hierarchy)[3] takes into account sensors having nonuniform energy level initially. The number of cluster heads should be proportional to the square root of the number of sensor nodes which is calculated using the above algorithm.
I-LEACH (Improved Low Energy Adaptive Clustering Hierarchy)[2,5] is one of the most popular refinements of LEACH encountered in the literature. The sensor nodes are initially partitioned into 2 categories normal and advanced nodes. The advanced nodes have a higher probability of becoming the cluster
heads. It also takes into account other factors such as higher neighborhood density and distance of cluster head from base station while assigning sensor nodes to one of the cluster heads.
TL-LEACH(Two Level Low Energy Adaptive Clustering Hierarchy)[3] involves formation of two kinds of cluster headsprimary and secondary. The

secondary cluster heads receive packets from their child nodes as well as the primary cluster heads. It may also involve data fusion and compression on the packets collected by the primary nodes as well as those collected by secondary nodes from their children. It optimizes energy consumption by reducing the number of intermediary nodes.

III. PROBLEM STATEMENT, CONTEXT AND MOTIVATION

There has been a tremendous proliferation in computation and transmission/receive powers of the sensor nodes. Any network application can be implemented by deploying hundreds of them. They have to be utilized efficiently because of their limited power to increase the network lifetime, which depends tremendously on the routing protocol being used. In case of direct transmission, nodes far away from the base station die early because of more energy dissipated in transmitting their signal.

In clustering techniques, the nodes which are far away can transmit data to their cluster heads, resulting in lesser energy consumption. The goal is to keep the network alive for a longer duration. Various routing protocols such as LEACH, DEEC, SEP and TEEN have been developed. ILEACH is one of the most popular and advanced techniques used for this purpose.

This paper builds upon the ILEACH protocol by introducing a multi hop technique with introduction of hierarchy among the cluster heads. Each cluster head first receives packets from its child nodes. It then forwards them to another cluster head. This is determined by the nary tree of cluster heads computed by each of them. Using multiple hops, the energy dissipated in transmitting data directly to the base station is saved. OHILEACH is a multihop routing protocol with two level clustering which uses heuristic search to determine the best route for sending packets from cluster head to the sink.

IV. NOTATIONS AND PRELIMINARIES

OHILEACH borrows some features of existing protocols and thus, it utilizes some terms from existing literature. This section aims to introduce the notations used in the proposed algorithm.

A. ILEACH metrics

The ILEACH protocol uses the concept of weighting probabilities (of becoming a CH (Cluster Head)) assigned to each node. The weighting probability for normal nodes[2] is defined as follows:

$$P_{normal} = \frac{P}{1+\alpha \times m}$$

While that of advanced nodes is:

$$P_{advanced} = \frac{P}{(1+\alpha \times m)} \times (1+\alpha)$$

where, m is the fraction of advanced nodes and α is the additional energy factor between advanced and normal nodes.

We define threshold for normal nodes[2] as

$$T(S_{normal}) = E_{ratio} \times \frac{P_{normal}}{1-P_{normal} \times r \bmod (\frac{1}{P_{normal}})}$$

where,

$$E_{ratio} = \sqrt{N_i} \times \frac{E_c}{E_0}$$

where, G′ are the normal nodes that have not become CHs within the last $1/P_{normal}$ rounds of the epoch, $T(S_{normal})$ is the threshold which is applied to a population of n ×(1+ m) for normal nodes, E_0 is the initial energy, E_c is the current residual energy, and N_i is the number of neighbors the i^{th} node has. Thus, each normal node becomes a cluster head exactly once every 1/(P × (1+α ×m)) rounds per epoch and the average number of CHs for normal nodes per round per epoch is equal to n × (1+ m) × P_{normal} .

Threshold for advanced nodes[2] is defined as:

$$T(S_{advanced}) = E_{ratio} \times \frac{P_{advanced}}{1-P_{advanced} \times r \bmod (\frac{1}{P_{advanced}})}$$

where, G″ is the set of advanced nodes that have not become CHs in the last $P_{advanced}$ rounds of the epoch, $T(S_{advanced})$ is the threshold for a population of n × m advanced nodes. E_0, E_c, and N_i carry the same definition as described in the previous paragraph. Hence, each advanced node becomes a CH exactly once every (1/p) × ((1 + α × m)/(1 + α)) rounds.

B. Notations in the proposed algorithm

OHILEACH

In OHILEACH, the following notations have been used:

d_{ij} : distance between cluster head i and j
d_i : distance of cluster head i from the sink
E_{fs} : Power loss of free space
E_{mp} : Power loss of amplifier
E_{TX} : Energy loss in transmitter
E_{DA} : Data aggregation energy
E_{ij} : Energy reqd. to send packet from node i to j
E_{di} : Heuristic function for energy to send packet from node i directly to base station(sink)

V. CONTRIBUTION

To minimize extensive energy loss in the network, in OHILEACH implementing network of static nodes, each hop calculates optimum path to send its packets through the network to the root (sink). Rather than focusing on minimizing loss of energy to the individual node, the path is decided to minimize the overall loss to the network. Figure 5.1 is a schematic image giving a representation of a wireless network.

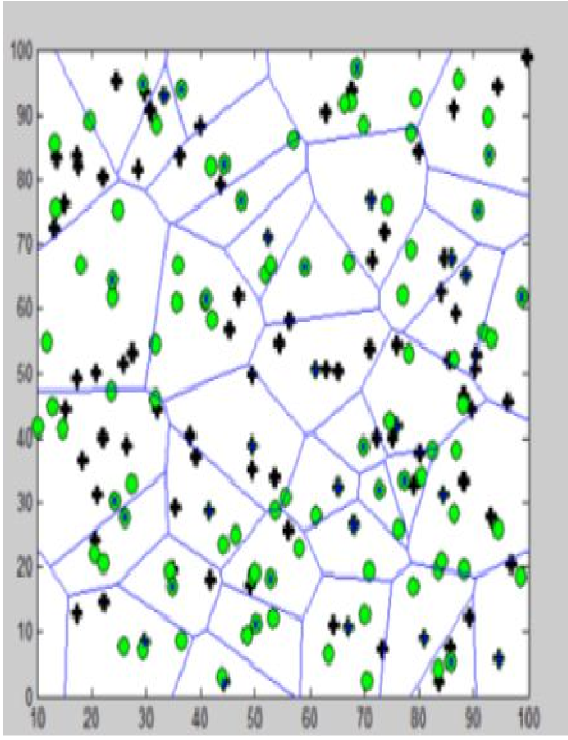

Fig 5.1: A schematic diagram of a wireless network of static nodes with clusters shown in polygons, and cluster heads depicted with blue dots in middle of the node.

In OHILEACH, nodes have to store two additional elements or values :

Parent: Each node(clusterhead), which cluster head or sink it will be sending its packet to. This node becomes its parent. This information is necessary to form the the nary tree structure.

estimated_en_loss: Energy Loss incurred by the whole network if a packet in sent from this node.

Storing this value will give other nodes an estimate of the energy loss which would be incurred by the network, if they send their packets via this particular node. In pseudocode, this is depicted by variable *energyloss* in ClusterHead array . For each clusterhead, *u*, following algorithm is applied to get the best path. Here EP(v) is a set of eligible parents, for that node. This set is all the nodes closer to sink in absolute distance (Euclidean Distance) than *u .imm_en* is the loss of energy to the node u when it sends its packet. Firstly, we sort the array of clusterheads in increasing order of their distance from sink. Let the index of current clusterhead node in the sorted array for which we want to calculate the energy loss be *i. Then*, we iterate in the array for which index be j which ranges from 0 to i1. For each of this iteration, we consider j to be parent of i. Now we find that j sending through which energy loss would be minimum in the overall network. To calculate this energy loss we add energy loss for node j (and since j<i energy loss for j would be already calculated) with energy loss for sending packet from i to j. A pseudocode form of the algorithm can be seen in text section below:

Algorithm used to implement OHILEACH protocol

```
sort(ClusterHeads, ClusterHeads + n)
for clusterhead i ∈ (0 , n) {
   ClusterHead(i).energyloss =
energy_loss(i,sink)
   z=sink
   for clusterhead j ∈ (0 , i-1){
      en = node(j).energyloss+energy_loss(i,j)
      if(en<node(i).energyloss){
         node(i).energyloss = en
         z=j
      }
    ClusterHead.parent(i) = z;
  }
}
```

Running above procedure for all cluster heads from 1 to n, will give us an nary tree, root of which is the sink.This protocol is predicated on all cluster heads in the network knowing the location of all other cluster heads in the network as well as the location of the sink.

To explain further, formation of the network in form of an nary tree, we make use of an example. In this example, we assume 8 nodes (numbered 29) and a sink (numbered 1). Let us assume the following conditions. Nodes are numbered in increasing order of their distance from sink i.e. distance of node 2 is less than distance of node 3 less than node 4 and so on. By running above algorithm, we get interconnections in these nodes where zero or more connections could bring in packets, and only one connection is used to send packet out. Doing this we assume that we get values given in table 5.1. For all values of x, respective z values are their parents. Using these value we have created the nary tree represented in figure

5.1 . Now, each cluster head (node) will send

```
1 Iterate i from 2 to 9.
2 node(i).energyloss=energy_loss(i,1)
3 z=1
4 Let j range from 2 to i-1
5 en=node(j).energyloss+energy_loss(i,j);
6 if(en<node(i).energyloss)
7 node(i).energyloss=en
8 z=j
```

Pseudo Code by including given values

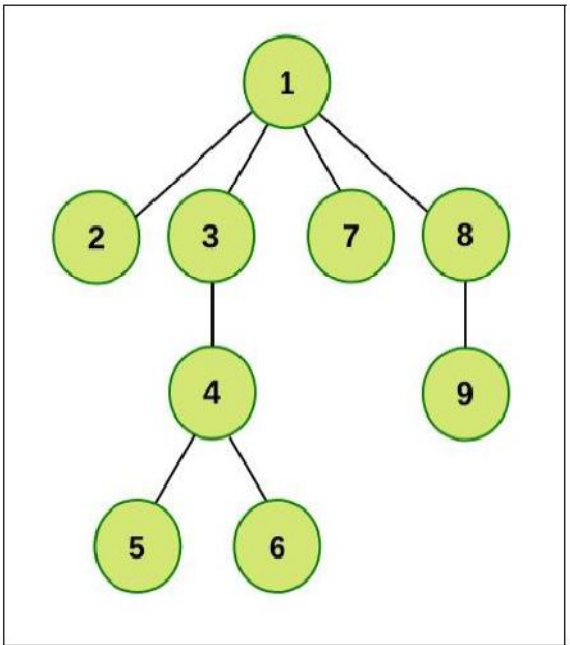

Figure 5.2 : Representation of formed graph(n-ary tree) for the given nodes after applying OHILEACH protocol.

x	z
2	1
3	1
4	3
5	4
6	4
7	1
8	1
9	8

Table 5.1 gives values for x(node) and z(corresponding parent)

Rounds	Average Energy(J)		
	LEACH	ILEACH	OHILEACH
20	0.128	0.13	0.138
40	0.098	0.108	0.13
80	0.056	0.08	0.118
120	0.039	0.056	0.104
160	0.02	0.044	0.092
200	0.01	0.028	0.073

Table 6.2 : A tabular depiction of figure 6.1. Energy reading taken at every 20th round.

information up the tree, following connections (edges) until it reaches the sink(root). Each cluster head forwards packets to its parent node. The tree is modified after every round of cluster head election and assignment of nodes to their respective cluster heads.

VI. RESULTS

To evaluate the performance of OHILEACH, we performed multiple simulations using Custom Built

Parameters	Value
Network Area (meter)	100*100
Number of Nodes	200
Location of Sink	(150,50)
Initial Energy	0.1J
ETX	50 nJ
ERX	50 nJ
Eamp	0.0013 $pJ/bit/m^4$
Efs	10 $pJ/bit/m^2$
Eda	5 nJ/bit/signal
Number of Rounds	200

Table 6.1 : Initial Parameters used in simulation

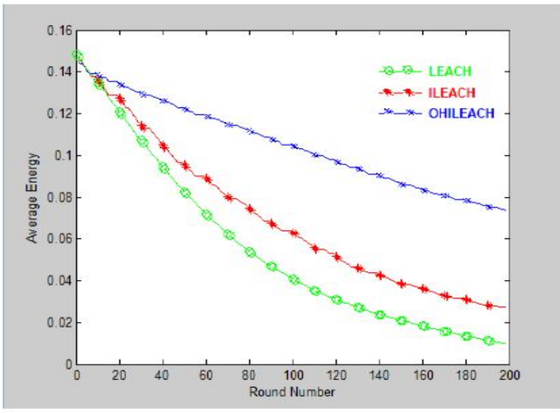

Figure 6.1 : A graphical representation of average Energy left v/s number of rounds completed

Iterative Based Simulator in MATLAB 7.14.0.739 (R2012a). The initial parameters used can be seen in table 6.1.simulation are given in Table 6.1. We compare the performance of OHILEACH with that of LEACH and ILEACH[2] based on two parameters.

A. Average Energy of each node in the network

We compared the average energy of each node in the network after a certain number of rounds, for LEACH, ILEACH and OHILEACH. The better performance of OHILEACH can be inferred from the graph below: A comparative study of the three protocols on the basis of average energy of each node led to the table below showing the value of average energy at specified round numbers for the three protocols can be seen in table 6.2. The above information can be depicted as bar charts in figure 6.3.

As can be inferred, the average energy of each node in the network increased considerably using

OHILEACH when compared to those using both LEACH as well as ILEACH.

B. Number of Dead Nodes

We compared the number of dead nodes in the network after a certain number of rounds, for LEACH, ILEACH and OHILEACH. The superior

Rounds	Total Dead Nodes		
	LEACH	ILEACH	OHILEACH
40	12	12	**1**
80	60	52	2
120	105	70	4
160	137	115	24
200	160	132	40

Table 6.3 : A tabular depiction of figure 6.2. Energy reading taken at every 20th round.

performance of OHILEACH is depicted in the graph in figure 6.2. A comparative study of the three protocols on the basis of number of dead nodes led to the table below showing the value of the parameter at specified round numbers for the three protocols can be seen in table 6.3. The above information can be depicted as bar charts in the figure 6.4. As can be inferred from the graph, after completion of 200 rounds, the number of dead nodes in OHILEACH reduced by 75% when compared to LEACH, and by 69.7% when compared to ILEACH.

CONCLUSION

This paper introduces an optimisation of existing

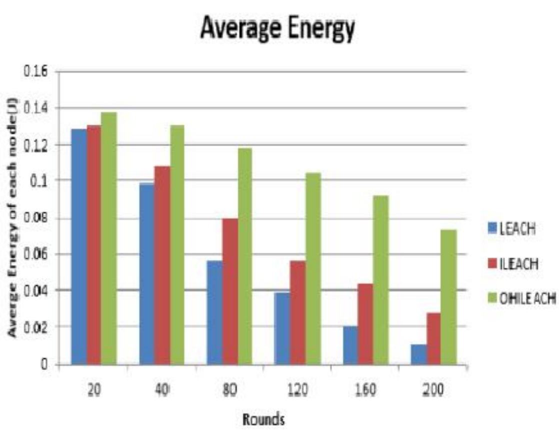

Figure 6.3: A bar graph representation of average Energy left v/s number of rounds completed

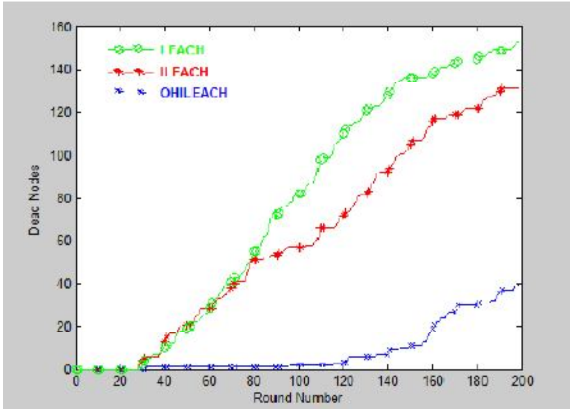

Figure 6.2 : A graphical representation of number of dead nodes v/s number of rounds completed

ILEACH protocol by introducing multihop routing in the cluster heads and using a heuristic approach, OHILEACH. As the results show, OHILEACH greatly benefits from multihop approach. This happens due to reduced interhop distance which saves overall energy of the network, where r is distance between the hops. Introducing hierarchy helps evening out the dissipation as well, as farther nodes would dissipate energy over large distances and the nearertosink nodes would dissipate energy because of high interaction. For future work, we intend to implement Dijikstra's algorithm over the network to further optimise the energy loss between the node and the sink. Furthermore, we look forward to implement this protocol in real world scenario.

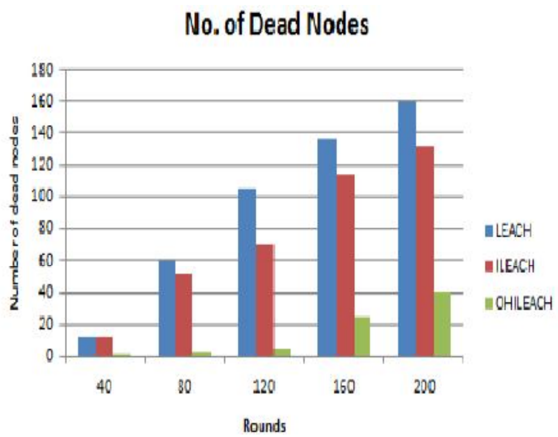

Figure 6.4 : A bar graph representation of number of dead nodes v/s number of rounds completed

REFERENCES

[1] Zhang, X., Zhang, W., Zhang, X., Xu, Z., & Zhang. "Optimized deployment of cluster head nodes in wireless network for the greenhouse". IEEE, WiCOM'08. 4th International Conference on (pp. 15), 2008.

[2] Zhang, J., Ci, S., M.,Sharif, H., & Alahmad. "Lifetime optimization for wireless sensor networks using the nonlinear battery current effect". In Communications , IEEE International Conference on (pp. 16), 2009.

[3] Dhawan, H., S., & Waraich. "A comparative study on LEACH routing protocol and its variants in wireless sensor networks: a survey". International Journal of Computer Applications , 95 (8), 2014.

[4] Miah, M. and Koo. “Performance analysis of ILEACH and LEACH protocols for wireless sensor networks”. Journal of information and communication convergence engineering , 10 (4) on (pp.384389), 2009.

[5] Fu, C., Jiang, Z., Wei, W.E.I. and A., Wei. “An Energy Balanced Algorithm of LEACH Protocol in WSN”. International Journal of Computer Science, 10(1), on (pp.354359), 2013.

[6] Sharma, N., V. and Verma . Heterogeneous LEACH Protocol for Wireless Sensor Networks. International Journal of Advanced Networking and Applications, 5(1), on (p.1825), 2013.

[7] Shankar, S., T. and Shanmugavel. “Energy optimization in cluster based wireless sensor networks”. Journal of Engineering Science and Technology, 9(2), on (pp.246260), 2014. 40

[8] Jindal P, Gupta V. “ Study of en ergy efficient routing protocols of wireless sensor networks and their further researches: a survey”. Computer Science Communication Engineering, 2013.

[9] V.Loscri, G.Morabito, and S.Marano, “A TwoLevels Hierarchy for LowEnergy Adaptive Clustering Hierarchy (TLLEACH),” IEEE, 62nd Vehicular Technology Conference, vol3 on (pp.18091813), 2005.

[10] J.Gnanambigai, Dr.N.Rengarajan, and K.Anbukkarasi, “Leach and Its Descendant Protocols: A Survey,” International Journal of Communication and Computer Technologies (IJCCT), vol. 01, issue 02, no.3 on (pp. 1521), 2012.

[11] Akkaya, K. and Younis, M., A survey on routing protocols for wireless sensor networks. Ad hoc networks , 3 (3), pp.325349, 2005.

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