IMPROVED ENERGY EFFICIENT LEACH IN WIRELESS SENSOR NETWORKS

[1]GAURAV KUMAR NIGAM, [2]CHETNA DABAS

[1]Assistant Professor, Department of CSE, Jaypee Institute of Information Technology, Noida, India

[2] Assistant Professor, Department of CSE, Jaypee Institute of Information Technology, Noida, India

E-mail: [1]gaurav.nigam@jiit.ac.in, [2]chetna.dabas@jiit.ac.in

ABSTRACT

In this paper, a hierarchical energy efficient LEACH is proposed using different machine learning and graph algorithms by using K-Means and Greedy Algorithms. Under Greedy algorithm, Dijkstra's algorithm is used. The shortest path determined in each iteration provides the most energy efficient path. The research gaps in the existing LEACH have motivated various authors to improve it and tried to overcome its demerits and proposed new protocols to overcome its deficiency. The simulation is performed in python 3.6 and the simulation result depicts that all nodes become dead when network completes around 1190 rounds in LEACH whereas in the proposed energy efficient LEACH protocol all nodes are dead after about 2250 rounds. Hence, the proposed protocol enhances lifetime of the network.

Keywords: *WSN, CH, BS, LEACH TDMA*

1. INTRODUCTION

Wireless sensor Networks (WSNs) comprises of a huge count of less powered nodes that are in the territory of few hundreds to thousands in number that have multiple functionalities and they are randomly positioned in an adverse environment. The sensor node is deployed in a sensing field and they are responsible for sensing the events of surroundings. When a node encounters an aberrant event, a warning message is sent to the sink node via hop by hop communication. There are distinct confrontation and design layout issues in WSNs viz. node deployment, routing, energy conservation, fault tolerance, coverage and connectivity and quality of service (QoS). Routing is considered as a dominant confrontation in WSN because of enormous number of sensor nodes due to the need to develop a comprehensive addressing scheme for the distribution of sensor nodes. In last few years, there has been a large increase in the discovery of different routing protocols in the field of wireless sensor networks, which resulted in easy distribution of data across channels [1].This resulted in secure transmission of data, but still the problem lies in the excess amount of energy dissipated.

Determining reasons for high energy dissipation or low node lifetime is a difficult task. Graph Algorithms are one of the commanding ways to evaluate and predict their future behavior and performances. Although the routing protocols deals with the transmission of data, they are not being utilized effectively in increasing the lifetime of nodes. Different methods which uses different algorithms depending upon delocalization of nodes across space based on constraints of position and velocity, which have kept them missing from achieving their objectives [2]. However, earlier the methods that were being developed basically focused on scattering of inter cluster nodes [3]. These methods lacked the ability to distribute data and instead flooded the data as a whole to the base station.

Auto generated finest paths are examined with these methods. These methods uses the threshold based algorithms to select cluster head containing data that illustrate the performance [1].

Figure 1 displays the self organization of sensor nodes when deployed in a hostile environment.

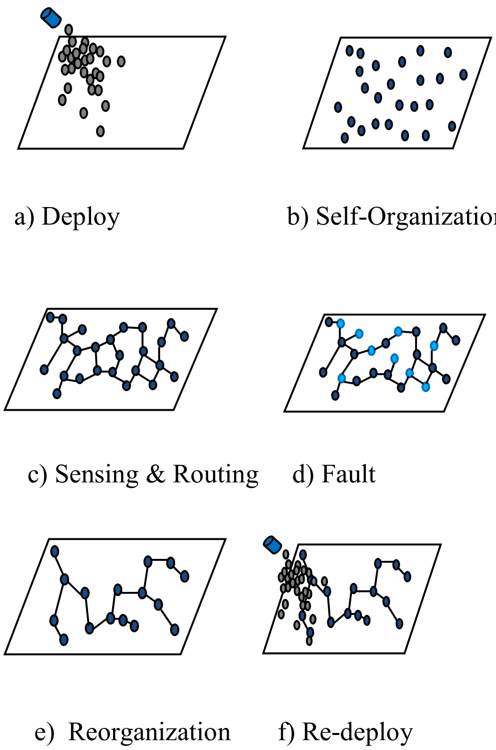

Figure 1. Self organization of sensor nodes[28]

The functioning of LEACH is distributed into two steps and these steps can further be isolated into sub-steps. Each round commences with a set-up step and is dangled by a steady state step. In set-up step bunch heads are haphazardly picked and groups are sorted out as appeared in the accompanying Fig. 2.

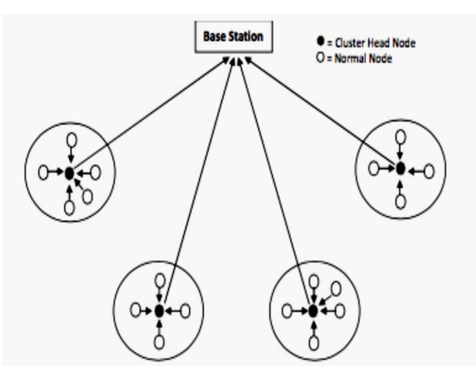

Fig. 2. Composition of Cluster formation in LEACH [30]

Random clusters are generated and threshold for each round in LEACH is computed using formula:

$$T(n) = \begin{cases} \frac{p}{1 - p * (r mod(\frac{1}{p}))}, & n \in G \\ 0, & otherwise \end{cases}$$

Where *p* stands for probability of a node to become cluster head, *r* is the existing round and G is the set of nodes that didn't participated in previous *1/p* rounds.

Probability of becoming cluster head is equal i.e. , nodes having high and low energy have the same probability of becoming the cluster head, if a sensor node having less frequency is chosen , then chances are it would die abruptly in between the process thus configuration is changed. Thus this affects the robustness and lifetime of the process degrades. Also, it does not guarantee the position or number of initial cluster formation which leads to unequal distribution of clusters in the prevailing scenario. Moreover, outliers occur in such scenarios which leads to high energy dissipation reduce overall performance of the network.

Most commonly faced problem in evaluating the performance was, how many rounds or iterations need to be performed in order to generate the shortest path. In order to overcome this problem, centroid of clusters were generated using k-means clustering algorithm [4]. The protocol makes assumption that all nodes always carry some data that is to be sent and they always have the same initial energy. The CHs are predefined to a value of either 5 percent or 10 percent . It is not suitable in some cases where nodes are not uniformly deployed. CHs are elected on a random ground and the residual energy is not examined during cluster formation. The election of CH is even not uniformly distributed due to which it may happen that CH is mainly concentrated on any particular area of the network; hence it may possible that there are some nodes who do not found any CH in their vicinity. Data from CHs to BS is sent in a single hop communication, so LEACH is not suitable for large regions. Since energy is more consumed if the nodes are farther away, thereby depleting their battery early causing the node failure.

The present paper proposed an improved energy efficient LEACH that overcomes the shortcomings of existing LEACH protocol. Section 2 describes the related work related to variants of LEACH protocol that is a subclass of hierarchical routing that will boost the network endurance and diminishes the energy utilization in WSN, section 3 discuss the proposed protocol and its algorithm, section 4 presents the simulation and results and section 5 concludes the paper.

2. RELATED WORK

Energy Efficient Routing is one field which is gaining popularity day by day. Energy Efficient Routing is a research field which is related to the applications of machine learning on the information collected from the generated Cartesian plane to determine patterns and learning methods.

Rabiaa et. al [3] proposed a technique for data aggregation to increase performance using the application of Davies-Bouldin index in order to provide the extent of how good the clustering is.

SOLAIMAN et. al [2] mentioned the applications of particle swarm optimization (PSO) in which neighboring nodes communicate to locate best position. Each node is initialized a position and velocity and thus generate a fitness function, this fitness function is compared to a global fitness function, an update is made based on the characteristics.

Arumugam et. al [4] recorded the concept of node deployment based on the amount of residual energy left, node selection is based on highest residual energy left, forwarded to the base station.

M. Bani [9] proposed VLEACH that tried to minimize the energy utilization of WSN. The said protocol considers two CHs and they are called as CH and vice-CH respectively. Whenever energy of CH depletes, the vice-CH handle the remaining responsibility of CH, collates the data and sent the desired data to BS. Hence, thereby enhancing the network lifetime. The author used OMNET++ simulator, the metrics considered are initial energy of node, nodal distribution, position of BS, total number of trials, probability of CH, topology and time. It is found that total exchange of messages in VLEACH is lesser than LEACH and it implies that network remaining power in VLEACH is more in comparison to LEACH.

Ge Ran et. al [10] used fuzzy logic approach to propose a new protocol LEACH-FL. It considers battery power, distance and nodal density. There are three parameters in this protocol i.e. four fuzzy functions, an inference engine and one module for defuzzification. There is a rule used by inference engine, they are:

If a → b →c then d. here a, b, c, d represents power of battery, nodal density, distance and probability. The fuzzy rules are given below:

Probability p = [Power of battery *2 + Nodal density + (2-distance)]

Here, battery power is the major element for probability of selecting the CHs. Simulations are performed using MATLAB and it showed that the new method consumes lower energy in comparison to the traditional LEACH and lifetime of node also increases.

Hanady M. [11] proposed W-LEACH that used data aggregation algorithm for WSN to enhance the existing LEACH protocol. It is used to handle a situation where nodes are not uniformly distributed and it increases the network lifetime. Simulation is performed in 'Ç' language. W-LEACH introduces sensor weights that are used for selecting a CH. Sensor weights are generally based on the density of sensors i.e. total number of sensor nodes in surroundings and the residual energy. Sensor nodes that have larger weights are chosen as CHs and the nodes with lower weights are targeted to send their data to CHs. Simulation results showed that W-LEACH performs better in terms of average lifetime of sensor node, residual energy, and number of alive nodes in network, time of first dead node and time of last node dead.

H. Zhang [12] proposed WST-LEACH [4], it constructs a weighted spanning tree by using all CHs. The value of weight depends on residual energy of CH, distance among other CHs and distribution of other surrounding nodes of the network. The aggregated data from CH is sent to BS using the spanning tree after integration of data. The said protocol lowers the energy consumption and optimizes the data transmission path. Simulation is performed in MATLAB. Results shows that the new method increases the network life cycle and has better performance.

Jie Chen [13] proposed a new clustering algorithm called I-LEACH that differs from LEACH on the basis of criteria of selecting a cluster head. It selects a CH on the basis of node's residual energy and the distance among other CHs. The group of clusters sent data to BS in either a single or multi-hop fashion in order to save energy of CH. It increases the network lifetime and reduces the energy consumption.

Q. Zhang [14], proposed distance and energy based uneven clustering called DEUC. It uses existing energy efficient unequal clustering (EEUC) protocol i.e. an uneven cluster based routing protocol for WSNs to select a cluster head. There are two phases in constructing a cluster in DUEC. In first phase, CH is selected by using probability while in second phase, clusters formed using radius of cluster and CHs are grouped accordingly.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Tong et. al [15] proposed LEACH-B in which the election of cluster head takes place in a two-layered fashion. Initial CHs are selected randomly based on the native LEACH protocol, after that to keep up the consistent bunch heads check of n* p, where p is the coveted rate of group heads and n is the quantity of aggregate nodes, another round of choice/filtration is led. Two distinctive situations must be considered on account of the arbitrary number of group heads chosen by LEACH algorithm. On the off chance that the tally of CHs is not as much as n*p, a few hubs should be chosen from the typical hubs as the bunch heads. A clock is set for each ordinary hub. At the point when the clock terminates, and if the number is not as much as n*p , the typical hub with most brief time interim communicate an ADVCH to report its CH status by utilizing a non-persevering CSMA MAC convention. The estimation of time is set to t = k=E. In the event that the quantity of group heads is more than n*p, some low vitality bunch head ought to be wiped out to diminish the quantity of CH number to n*p. Moreover, this convention accomplishes the change of vitality utilization.

Tripathi et. al [16] proposed LEACH-C that has a deterministic limit calculation which relies on upon the leftover vitality of the hub as well as the most recent decision of the hub as the group head. The check of bunch heads and their positions can't be ensured. The unified calculation can be utilized to shape the groups which may create better bunches through the circulation of the group head hubs.

Xu et. al [17] discussed E-LEACH that makes an improvement in selecting the CH choice strategy in situation where hubs have non-uniform vitality dispersion. It makes left-over vitality of hub as the primary parameter that chooses whether the hubs transform into heads or not following the initial round. E-LEACH is partitioned into various rounds, in the underlying round, each hub has a similar opportunity to transform into a group head, that mean hubs are arbitrarily chosen as CHs, in the coming iterations, the rest of the vitality of every hub is diverse after one round correspondence and considered for the determination of the CHs. This prompts hubs with more vitality having a higher likelihood of turning into a bunch head.

Table1 describe various clustering protocols that other authors proposed and their strength and weaknesses are discussed.

Table 1. Strength and weaknesses of various approaches

S. No.	Paper	Strength	Weakness
1	Shin et al. [18]	1. REAR supports robust network topology so if a node receives similar MREQ message more than once when it discovers its route then it discards the similar MREQ message and doesn't forward it to next hop nodes. 2. REAR uniformly consumes overall energy capacity in the network area.	1.REAR is not best suited for dense environment. 2. Reliability of disjoint multi-path routing is low
2	Kim et al. [19]	1. Source node gives priority to that node which has high energy level and hence the best candidate node is selected. 2. Network overhead and energy consumption decreases.	1. The cost of broadcasting is big for routing table. 2. The cost of flooding is big for route discovery.
3	Akshay et al. [20]	1. The smaller the size of grid, the more accurate is the estimation. 2. Grid based method has the higher probability of detection provided that object is moving along the grid lines.	1. The method is not suited for heterogeneous networks. 2. The method is not suited for sensor nodes with irregular sensing range and large coverage area.
4	Ganesh et al. [21]	1. ESRPSDC works better than LEACH and PEGASIS. 2. Packet delivery ration of ESRPSDC is more than LEACH and	1. The proposed scheme is not suitable for heterogeneous networks.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

		PEGASIS.	2. The proposed algorithm does not optimize the effective energy consumption among all nodes
5	Liang et al. [22]	1. Dynamic scheme of multi copy is used in order to enhance the reliable transmission in case of single alarm packet. 2. The cost of EEDP is lower than the traditional methods.	1. The cost of event monitoring performance is more. 2. Efficiency of the protocol is not validated
6	Liu et al. [23]	1.The network security and lifetime of network is maximized. 2. The information regarding the share division is not given.	1. The simulation indicates that if the radius of network is not less than 4 hops then the Lifetime of network will not decrease. 2. Randomly disjoint multipath routing doesn't have for selecting a fixed candidate route.
7	Gautam et al. [24]	1. Higher performance in energy is achieved in the said protocol. 2. DAIC always select large energy nodes as primary CHs having neighboring distance from BS.	1. Simulation results is not shown for routing protocol of wireless sensor networks based on dynamic setting cluster, EEEAC, and BCDCP. 2. The author assumed that when the node is staying idle then no energy was consumed..
8	Ren et al. [25]	1. The proposed EBRP makes a considerable improvement over commonly available energy efficient algorithm with respect of network endurance, throughput and energy utilization. 2. The energy consumed is evenly balanced for a given arbitrary deployed network.	1. There is a chance to further improve restrained the routing loops. 2. There is a need to understand the dynamics of time varying potential field.
9	Wu et al. [26]	1. The constructed CDS tree has the smallest energy consumption and data delay. 2. The proposed cluster based scheme has smaller delay time and less energy consumption.	1. Data delay, energy cost and aggregation is not optimized. 2. Maximum delay increases when the number of node increases.
10	Rout et al. [27]	1. The latency shrinks and continue steady irrespective of gain in node density. 2. An increase in lifetime from 2.5% to 9.55 is achieved in the proposed approach.	1. For non-duty cycled network, the lifetime of WSN is very low. 2. A simple MAC protocol is used

3. PROPOSED ALGORITHM

Clustering is the most significant procedure found in the field of Machine Learning. In this paper, we are focusing on clustering technique, since our dataset contains random nodes across the plane. So, to classify them we use k-means to determine the inter cluster relationship among neighboring nodes. Now, the main role of clustering technique is to generate centroids, train them to bind other nodes in same region space and then generates output in such a way that convergence is achieved. After the processing phase, the model is developed and being tested over isolated test configurations.

In this, threshold is generated using the function mentioned in [1] i.e. LEACH which serve as the basic algorithm for static centroid generation, then clustering is proceeded by generating k cluster heads based on the threshold generated from [1], shortest path is computed using the cluster heads for each iteration using Dijkstra's algorithm, energy is computed for that particular round.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

As per previous studies, we know it is not possible to apply the traditional clustering and optimization algorithm on the cluster nodes as the data is not generalized and it might have a specific objective and function. Several approaches have been projected, applied and verified. It was claimed that these common approaches or algorithms weren't appropriate to apply on this developing field which takes into account the path variables followed by the nodes. This paper not only uses a greedy approach for energy optimization but to also create path centric scenarios to generate a more viable output. As a novelty, the data is being tested over various iterations and configurations and energy is computed for every iteration until the convergence is achieved and the iteration with the most residual energy and shortest path is chosen out for further calculation like deriving out the overhead constraints involved in the process. The steps involved in the proposed algorithm is given below (3.1).

3.1 Algorithm

1. Compute threshold for each round using T (n) threshold function, Int variable dead_node_count.
2. for ∀ node n. Assume original energy at the start of the system to be equal.
3. Compute X (H) for each node to BS i.e. lo
4. Compute X (H) for each neighboring nodes i.e. l
5. Compute shortest values of l for each neighboring node to BS using Dijkstra's algorithm.
6. Compute E_t (M, l)
7. Compute E_R
8. If ($E_t \geq$ T(n))

    {

    Then, k = no of nodes having energy ≥ T (n)

    Compute E_{CH}

    Cluster normal nodes till convergence

    }

    Else

    {

    Compute E_{normal}.

    }

9.

$$E = \begin{cases} \text{original energy} - E_{CH}, & if\ n = \text{cluster head} \\ \text{original energy} - E_{normal}, & \text{if } n = \text{normal node} \end{cases}$$

10. Average energy = $\frac{E_t + E_R}{E}$

If E==0

{

dead_node_count++ }

The flowchart of the proposed approach is shown in figure 14 at the end of the paper.

3.2 K-Means Clustering Algorithm

It is a supervised based learning algorithm that where k cluster center are selected, grouping of items are performed based on the nodes selected via threshold function in the above mentioned leach protocol. Once the clusters are finalized grouping is performed between the nodes having smallest inter node Euclidean distance. This also solves the problem caused by random outliers as it tries to stop the nodes from becoming the CH which are far away from the current CHs. For each cluster, the algorithm computes the new centroids (X (H)) using equation 1 by taking the average of the current cluster members, the process stops when convergence occurs i.e. centroids repeats itself

$$X(H) = \sum_{i=1}^{c} \sum_{j=1}^{r_i} ||p_i - q_j||^2 \quad (1)$$

Where,

$||p_i - q_j||$ is Euclidean distance between p_i and q_j, r_i is no of values in i^{th} cluster, r is the no of cluster centers

Steps for procedure:

Step 1) Let Z = {z_1, z_2, z_3……z_n} be the data values and H= {h_1, h_2, h_3….h_n} be the set of centroids

Step 2) Randomly select c centers

Step 3) Calculate distance between data values and cluster centers

Step 4) Assign data values to clusters having minimum distance from the center

Step 5) Recalculate new cluster center using:

$$h_i = \frac{1}{r_i} \sum_{x=1}^{r} z^i \quad (2)$$

Where r_i represents data points in i^{th} cluster, then compute distance between data points and new obtained cluster centers, if repetition occurs stop the process otherwise iterate the whole process again.

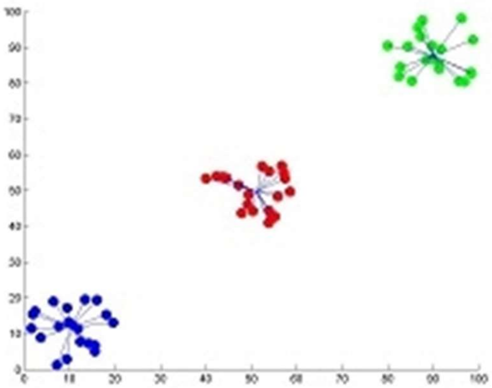

Fig 3. Result of k-mean for n=50 and c=3

3.3 Dijkstra's Shortest Path Algorithm

In this algorithm we generate a SPT (smallest path tree) with starting node and base station. It contains two sets, one which contains all nodes present in the tree, and other which are not yet included. In each step we find a node which is present in other set and has minimum distance from the initial node selected (fig1). Following are the steps required to generate this configuration:

Step 1) Create set s (shortest path set) which monitors the nodes included in the tree i.e. whose min distance from the initial node is computed.

Step 2) Assign Euclidean distance as a measure of weights in reaching to the target node from the source node.

Step 3) Since s does not possess all nodes, select a node n that is not in the given set s that has min distance, insert the node n to set s, update distance of all neighbor nodes, for ∀ node adjacent to node n, if sum of Euclidean distance of n and weight of connection between them, is < distance, then update distance value of current node.

For example: let set s be initially an empty set, and assigned distances be
{0, ∞, ∞, ∞, ∞, ∞, ∞, ∞}

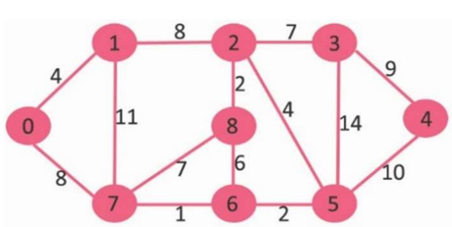

Fig 4. Initial configuration of unvisited nodes in the graph

Step 4) Now select the node with minimum distance. The node denoted by 0 is selected, assign it to set s. Now set s is {0}. After inserting 0 to s, update distances of neighboring nodes, nearby nodes of 0 are 1 and 7, distance generalized to 4 and 8 respectively, the highlighted graph below show nodes and their distances, nodes present in s are shown with green.(fig 5,6,7,8,9)

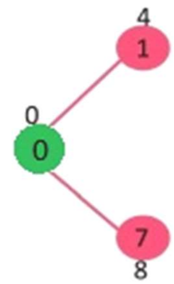

Fig 5. Insertion of node 0 in empty set s

Step 5) Select node with minimum distance i.e. not present in s. Node 1 is selected and inserted in s. Now s possess {0, 1}. Update distances of nodes adjacent to 1. Distance weight of node 2 is updated to 12.

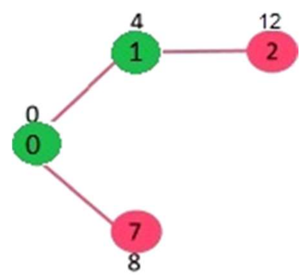

Fig 6. Insertion of node 1 following node in set s= {0}

Step 6) Select node having minimum distance value and not present in s. Node 7 selected. S is updated to {0, 1, and 7}. Overwrite distance next to node 7. Distances of 6 and 8 are now 15 and 9 respectively.

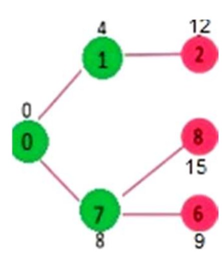

Fig 7. Insertion of node 7 in set s= {0, 1}

Journal of Theoretical and Applied Information Technology
28th February 2019. Vol.97. No 4

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

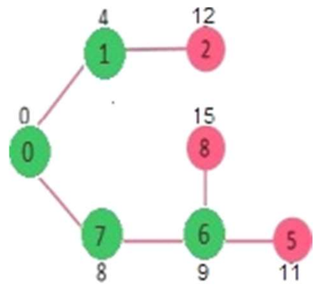

Fig 8. Insertion of node 6 in set s= {0, 1, 7}

Step 7) Repeat the steps until s contains all nodes of the scenario. SPT generated for following scenario:

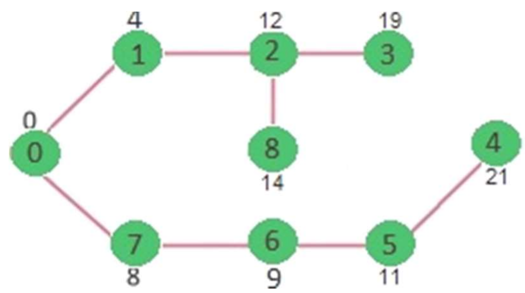

Fig 9. Final Configuration of all visited nodes

4. DATA SIMULATION AND RESULTS

The simulation parameters are given in table 2. Simulation is performed in python 3.6.

If F bits of message is forwarded across u distance, then energy dissipated can be computed using equation 3.

$$E_t(F,u) = \begin{cases} FE_g + Fu^2, & u < u_o \\ FE_g + FE_h u^4, & u > u_o \end{cases} \quad (3)$$

Where, E_g defines energy dissipated per bit, E_f and E_h are the transmission ability and u_o is Euclidean distance from sender node to base station.

To retrieve M bit, system spends:

$$E_R = FE_g \quad (4)$$

Energy dissipated by cluster heads is computed using equation 5.

$$E_{CH} = \left(\frac{n}{k} - 1\right) FE_g + \frac{n}{k} FE_D + FE_g + FE_f l_{BS}^2 \quad (5)$$

Here, k is the number of clusters, E_D denotes the processing cost, l_{BS} is the average distance between the cluster head and the base station. The energy released from normal nodes is computed using equation 6.

$$E_{normal} = FE_g + FE_f u_{CH}^2 \quad (6)$$

Where u_{CH} is the average distance between normal nodes and cluster heads. Shortest path is calculated for nodes having optimum energy reserved. For each iteration, cluster heads are rotated based on the energy parameters mentioned above. For each iteration shortest path and energy reserved is computed.

Table 2. Specifics of the parameters

PARMETERS	VALUES
Total nodes (N)	100
Starting energy of node	0.5 J
Cluster head probability (p)	5% = 0.05
amplifier energy consumption for small distance	10^3 pJ/bit/m^2
amplifier energy consumption for larger distance	$1.3*10^{-3}$ pJ/bit/m^4
Circuit energy consumption to forward/receive signal	50 pJ/bit
Length of packet (k)	4000 bits
Processing Cost (E_D)	$1.3*10^{-15}$ nJ/bit
Transmission ability (E_f/ E_h)	50*10-9 pJ/bit/m^2
Energy dissipated per bit (E_g)	10^{-11} pJ/bit/m^4

Firstly we calculated energy consumed by each node in every round by above mentioned protocols. Figure 10 depicts the initial traditional LEACH plot in the scenario.

Instead of calculating energy from each node to base station we calculate energy distribution among neighboring nodes which is a measure of Euclidean distance between the nodes, as energy distribution among close proximity nodes are low, it can be computed for the entire graph too. Figure 11 depicts the plot for energy efficient LEACH.

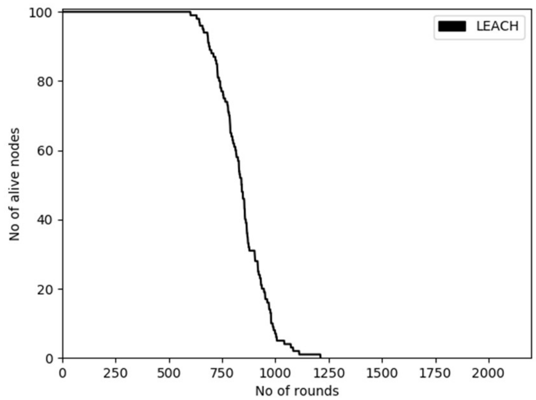

Fig 10. Traditional LEACH

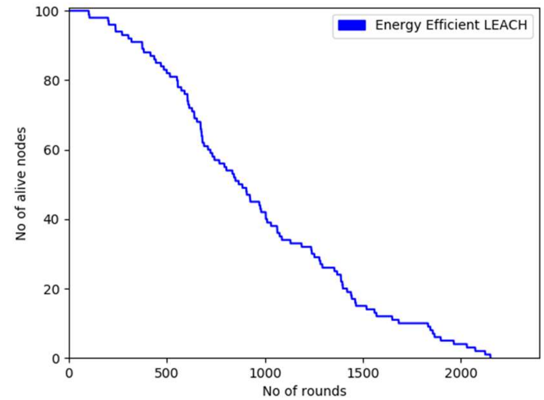

Fig 11. Energy Efficient LEACH showing increase in no of rounds

Figure 12 depicts the comparison of LEACH and Energy Efficient LEACH. Further the author compared the two protocols with ESO LEACH [29] and the results are plotted in Figure 13.

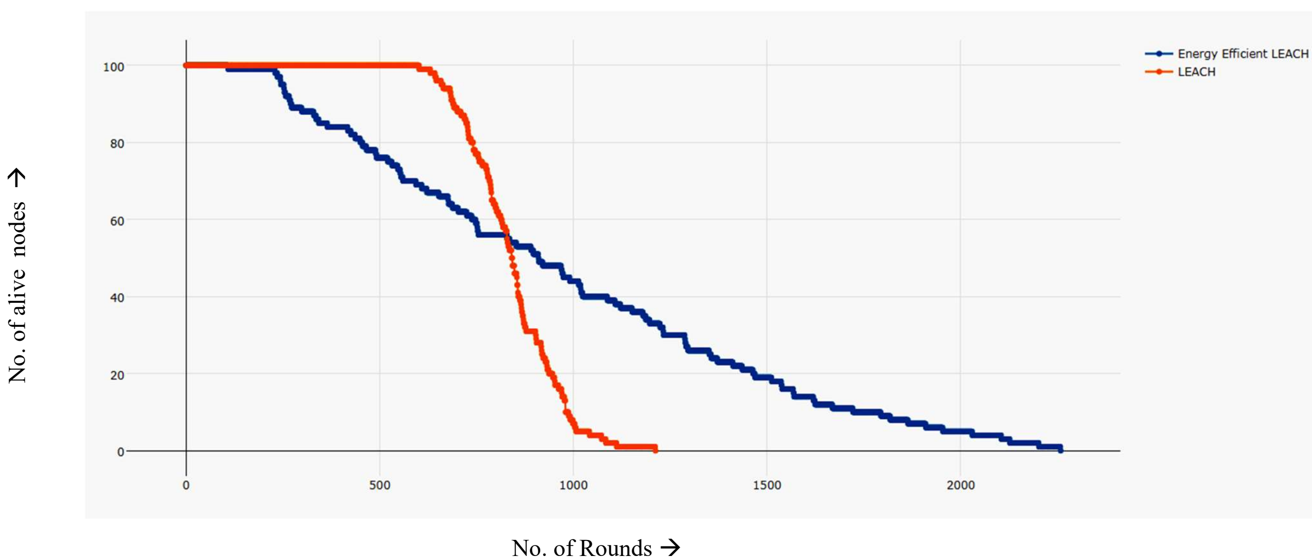

Fig. 12 . System lifetime using LEACH and Energy Efficient LEACH.

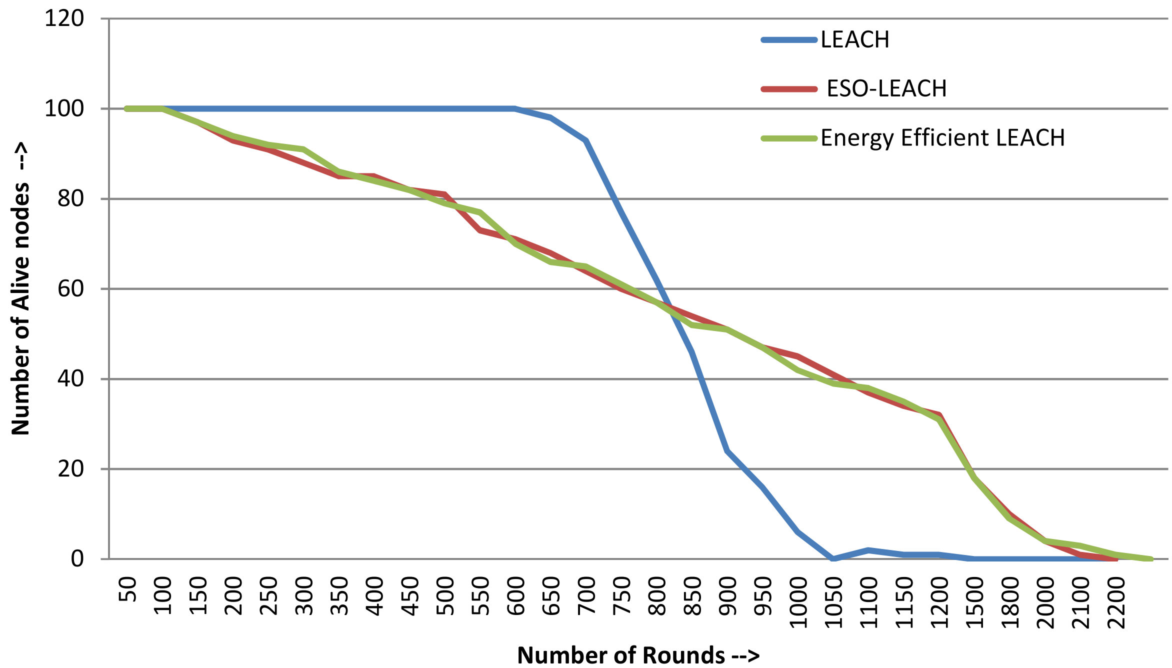

Fig. 13. System lifetime using LEACH, ESO-LEACH.and Energy efficient LEACH

5. CONCLUSION

In this paper, we provided an insight to how graph algorithm can be used to minimize the excess energy consumption in the field of hierarchal routing and this can further leads to low number of possible dead nodes and in turn increase the overall lifetime of the process. In addition, the Euclidean distance is used as a measure of energy consumed, as more the distance between the nodes, the more energy is dissipated in transferring the data to the other node, thus this leads to decrease in the overall lifetime of that node, whereas in our procedure we send data to that nearby node which possess low overall transferring weight, data is aggregated there and send to the successive low weighted node, this process is carried until data is collected from all the nodes. The proposed approach of this paper can be used in the different real world scenarios in future which involve different configurations of node deployment. Other optimized graph algorithm can be used to carry out process in the future. Other variables such as inter cluster distance can be taken into account and this approach can be applied within the clusters for more energy optimization.

REFERENCES:

[1] Singh, Sunil Kumar, Prabhat Kumar, and Jyoti Prakash Singh. "A survey on successors of LEACH protocol." IEEE Access 5 (2017): 4298-4328.

[2] SOLAIMAN, B. (2016). Energy optimization in wireless sensor networks using a hybrid k-means pso clustering algorithm. *Turkish Journal of Electrical Engineering & Computer Sciences*, *24*(4), 2679-2695.

[3] Rabiaa, E., Noura, B., & Adnene, C. (2015). Improvements in LEACH based on K-means and Gauss algorithms. *Procedia Computer Science*, *73*, 460-467.

[4] Arumugam, G. S., & Ponnuchamy, T. (2015). EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN. *EURASIP Journal on Wireless Communications and Networking*, *2015*(1), 76.

[5] Heinzelman, W. R., Chandrakasan, A., & Balakrishnan, H. (2000, January). Energy-efficient communication protocol for wireless

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

microsensor networks. In *System sciences, 2000. Proceedings of the 33rd annual Hawaii international conference on* (pp. 10-pp). IEEE.

[6] Ali, M., & Sai Kumar, R. (2008). Real-time support and energy efficiency in wireless sensor networks.

[7] C.S.R. Murthy, B.S. Manoj "Adhoc Sensor Networks – Architecture and Protocols" 2nd Edition, PHI, 2004.

[8] Heinzelman, W. B., Chandrakasan, A. P., & Balakrishnan, H. (2002). An application-specific protocol architecture for wireless microsensor networks. *IEEE Transactions on wireless communications*, *1*(4), 660-670.

[9] Yassein, M. B., Khamayseh, Y., & Mardini, W. (2009, June). Improvement on LEACH protocol of wireless sensor network (VLEACH. In *Int. J. Digit. Content Technol. Appl. 2009*.

[10] Ran, G., Zhang, H., & Gong, S. (2010). Improving on LEACH protocol of wireless sensor networks using fuzzy logic. *Journal of Information &Computational Science*, *7*(3), 767-775.

[11] Abdulsalam, H. M., & Kamel, L. K. (2010, December). W-LEACH: Weighted Low Energy Adaptive Clustering Hierarchy aggregation algorithm for data streams in wireless sensor networks. In *2010 IEEE International Conference on Data Mining Workshops* (pp. 1-8). IEEE.

[12] Zhang, H., Chen, P., & Gong, S. (2010, May). Weighted spanning tree clustering routing algorithm based on LEACH. In *Future Computer and Communication (ICFCC), 2010 2nd International Conference on* (Vol. 2, pp. V2-223). IEEE.

[13] Chen, J. (2011, August). Improvement of LEACH routing algorithm based on use of balanced energy in wireless sensor networks. In *International Conference on Intelligent Computing*(pp. 71-76). Springer, Berlin, Heidelberg.

[14] Zhang, Qi, and Weiqing Qu. "An energy efficient clustering approach in wireless sensor networks." Computer Science and Electronics Engineering (ICCSEE), 2012 International Conference on. Vol. 1. IEEE, 2012.

[15] Tong, M., & Tang, M. (2010, September). LEACH-B: an improved LEACH protocol for wireless sensor network. In *Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on* (pp. 1-4). IEEE.

[16] Tripathi, M., Gaur, M. S., Laxmi, V., & Battula, R. B. (2013). Energy efficient LEACH-C protocol for wireless sensor network.

[17] Xu, J., Jin, N., Lou, X., Peng, T., Zhou, Q., & Chen, Y. (2012, May). Improvement of LEACH protocol for WSN. In *Fuzzy Systems and Knowledge Discovery (FSKD), 2012 9th International Conference on* (pp. 2174-2177). IEEE.

[18] Shin, K. Y., Song, J., Kim, J., Yu, M., & Mah, P. S. (2007, February). REAR: reliable energy aware routing protocol for wireless sensor networks. In *Advanced Communication Technology, The 9th International Conference on* (Vol. 1, pp. 525-530). IEEE.

[19] Kim, K., Lee, I. S., Yoon, M., Kim, J., Lee, H., & Han, K. (2009, December). An efficient routing protocol based on position information in mobile wireless body area sensor networks. In *Networks and Communications, 2009. NETCOM'09. First International Conference on* (pp. 396-399). IEEE.

[20] Akshay, N., Kumar, M. P., Harish, B., & Dhanorkar, S. (2010, December). An efficient approach for sensor deployments in wireless sensor network. In *Emerging Trends in Robotics and Communication Technologies (INTERACT), 2010 International Conference on* (pp. 350-355). IEEE.

[21] Ganesh, S., & Amutha, R. (2013). Efficient and secure routing protocol for wireless sensor networks through SNR based dynamic clustering mechanisms. *Journal of Communications and Networks*, *15*(4), 422-429.

[22] Liang, L., Gao, D., Zhang, H., & Yang, O. W. (2012). Efficient event detecting protocol in event-driven wireless sensor networks. *IEEE Sensors Journal*, *12*(6), 2328-2337.

[23]] Liu, A., Zheng, Z., Zhang, C., Chen, Z., & Shen, X. (2012). Secure and energy-efficient disjoint multipath routing for WSNs. *IEEE Transactions on Vehicular Technology*, *61*(7), 3255-3265.

[24] Gautam, N., & Pyun, J. Y. (2010). Distance aware intelligent clustering protocol for wireless sensor networks. *Journal of communications and networks*, *12*(2), 122-129.

[25] Ren, F., Zhang, J., He, T., Lin, C., & Ren, S. K. D. (2011). EBRP: energy-balanced routing protocol for data gathering in wireless sensor networks. *IEEE transactions on parallel and distributed systems*, *22*(12), 2108-2125.

[26] Wu, Y., Li, X. Y., Li, Y., & Lou, W. (2010). Energy-efficient wake-up scheduling for data collection and aggregation. *IEEE Transactions*

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

on parallel and distributed systems, *21*(2), 275-287.

[27] Rout, R. R., & Ghosh, S. K. (2013). Enhancement of lifetime using duty cycle and network coding in wireless sensor networks. *IEEE Transactions on Wireless Communications*, *12*(2), 656-667.

[28] Nigam, G. K., & Dabas, C. (2015). A survey on protocols and routing algorithms for wireless sensor networks. In *Proceedings of the World Congress on Engineering and Computer Science* (Vol. 2, pp. 21-23).

[29] Nigam, G. K., & Dabas, C. (2018). ESO-LEACH: PSO based energy efficient clustering in LEACH. *Journal of King Saud University-Computer and Information Sciences*.

[30] Arumugam, G. S., & Ponnuchamy, T. (2015). EE-LEACH: development of energy-efficient LEACH Protocol for data gathering in WSN. *EURASIP Journal on Wireless Communications and Networking*, *2015*(1), 76.

Journal of Theoretical and Applied Information Technology
28th February 2019. Vol.97. No 4

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

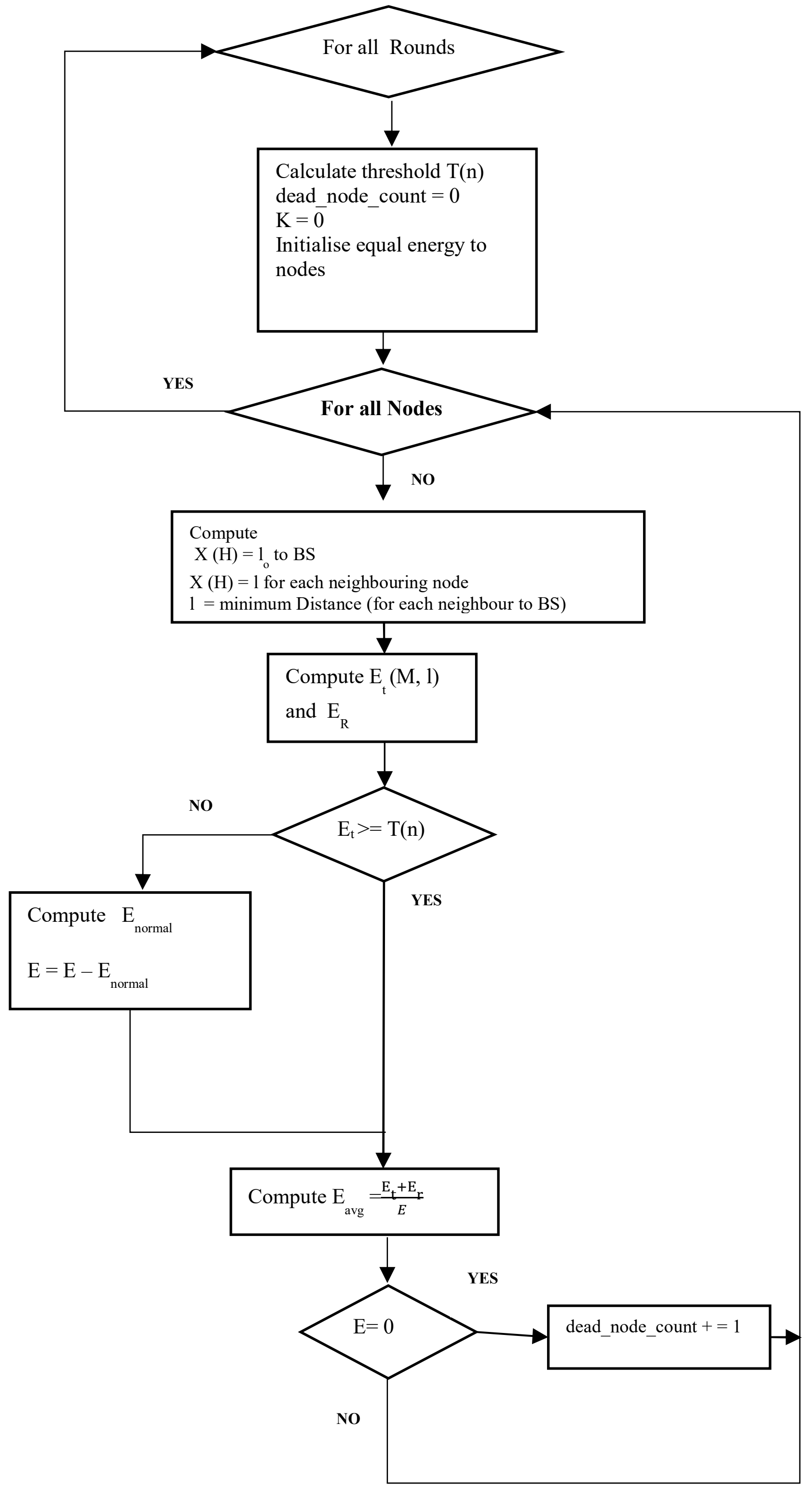

Fig 14. Flowchart of Energy Efficient LEACH