Improvement in LEACH Protocol for Energy Efficiency

Monika Rajput, Sanjay Kumar Sharma, Pallavi Khatri

Abstract*: *Clustering methods in WSN for the sake of energy efficiency has been addressed by various researchers due to promising improvements in the performances. The energy consumption still possesses an opportunity for improvement in terms of complexity reduction, reduction in energy consumption and lifetime of the network. The work presented in this paper contributes a novel strategy for energy efficiency in WSN. This work consists of clustering technique using K-medoid, ANFIS and optimized ANFIS using firefly. The simulation analysis shows significant improvement in performance in terms of residual energy and energy consumption parameters along with number of dead and alive nodes with respect to number of iterations. The proposed method outperforms compared to basic LEACH protocol.

Keywords: LEACH, WSN, K-medoid, Firefly, ANFIS, clustering, optimization.

I. INTRODUCTION

Monitoring of real field data such as humidity, temperature, moisture, and air quality are some of the applications where network is formed called as wireless sensor network (WSN). In WSN, the data is sensed by sensor-nodes and sent towards collector called as sink-node. At the sink-node, the data processed with respect to required outcomes. Such WSNs may consist of battery powered nodes. The data collected by sensor-nodes are transmitted towards sink-node in which routing protocol play an important role. Route establishment procedure for successful data delivery is the main work carried out at the routing. In the networks where large number of nodes is used for sensing data and handing over towards the sink-node are prone to overload effects on particular nodes when such nodes are common in multiple routes for routing. The rapid growth in applications requiring deployment of WSNs has triggered the thoughts of power saving strategies to last long the operations. The objectives for selecting best suitable routing protocol includes mainly low energy consumption, low latency, and longer lifetime.

The clustering techniques are also used in routing protocol. The energy consumption is balanced in the network using such clustering based hierarchical network which results in overall lifetime enhancement of battery powered network [1].

The ultimate parameters based clustering strategy is mainly responsible for overall efficiency in the network by means of which all the sensor nodes are associated with particular cluster-head and it is solely responsible for the data aggregation and sending to the sink-node. Hence, the distance of cluster-head from the sensor-node, and distance of the cluster-head from base-station is the main parameter to shows the impact on total energy consumption, due transmission power requirements. Also, the hierarchical structure constitutes the packet handing over mechanism in which one cluster-head to another cluster-head data handover is done depending upon the distance. This type of strategy is responsible to consume energy of cluster-head for multiple data handover services including data from self-cluster sensor-nodes and data from other cluster-heads towards base-station. Hence, it is desirable to choose right node as cluster-head such that it will be responsible to reduce cluster-head selection attempts and uniform energy consumption amongst clusters with optimized energy consumption.

The choice of right cluster-head for data handover towards sink-node is also considerable factor in which selection mechanism consumes energy. Also, due to energy run out of one of the cluster-head that triggers the cluster-head selection process in which all the nodes in the network participate as per basic LEACH protocol. The main work presented in this paper consists of dividing the network into small clusters and to carry out the cluster-head selection process amongst nodes within that clusters only. This strategy reduces the entire network involvement in cluster-head selection and hence less overhead thereby conserving the energy of the nodes that are not participating in the cluster head selection mechanism outside the scope of boundaries.

II. RELATED WORK

Anika Mansura et al [1] have given a multi-energy threshold-based routing protocol based on LEACH. Multiple energy threshold levels of battery are considered in the method. The MET-LEACH uses the information of current battery energy level to select the CHs. The first node dies (FND), half nodes die (HND), and last node dies (LND). The packet reception ratio (PRR) and the application level latency are the parameters to evaluate the performance of the proposed MET-LEACH protocol using the Castalia simulator. The simulation results show that MET-LEACH gives significant improvement in terms of FND.

Ahmed et al [2] have discussed a current method of optimization of LEACH protocol. The simulation scenario is considered to differentiate LEACH compared to LEACH combined with PSO. The dead node count is monitored with respect to number of iterations to analyze the energy conservation over LEACH.

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Arslan Rafi et al [3], discussed an enhanced version of LEACH protocol with Dijkstra's Algorithm (LEACH-DA). They used shortest path selection strategy to minimize the energy consumption. The traffic level analysis is considered for selecting a node as CH. The fog computing methods are employing to increase the network lifetime compared to original protocol. Some test cases have been presented and conclude that the updates on the classical LEACH protocol improve performance in terms of the network efficiency along with network lifetime.

Gang Zhao et al [4], have proposed an improvement in clustering protocol with data transmission status for heterogeneous sensor networks. The information intensity is estimated at the cluster heads for transmission of perceived information towards sink based on threshold. If threshold level is not crossed, the CH record the received data and keep receiving data sent by the next iterations of cluster-nodes. This type of mechanism prolongs the lifetime of the network.

Mohammad Z. Masoud et al [5], have given a new Hybrid Clustering Routing Protocol (HCP). The two phase working mechanism is presented in which first phase is of cluster formation and second phase is of data forwarding process, which is used to decide for forwarding the data either to the cluster-head or to the sink-node directly based on set threshold value. Also, clustering process is avoided if total number of nodes in the network are much less thereby decreasing node density or nodes are scattered. Authors simulated HCP and compared it's performance with LEACH and LEACH-T and shows that the network lifetime is increased by 30%.

M. Udin Harun Al Rasyid et al [6], have shown experimentation of leach protocol by changing the base-station placements. The genetic algorithm is used to optimize the LEACH protocol. The simulations result of LEACH-GA have a better performance as compared to LEACH in term of longer network life, higher energy efficiency, and more data received by the base-station. A wider area is also considered for experimentation with same number of nodes in which LEACH-GA shows the better performance.

Pallavi Yarde et al [7] have presented multi-hop cluster LEACH. In his work hierarchical routing protocol is used along with physical Media Access Control and Network layers as a cross layer method. The simulation results show that the collaborative performance is better in minimization of network delay.

Adnan Yousaf et al [8], have discussed study of LEACH, LEACH-C, MH-LEACH, TL-LEACH, ELEACH, TB-LEACH, W-LEACH, LEACH-VH and compared its performance in terms of their energy efficiency. The different cluster-head selection mechanism and its impacts on energy consumption is the main focus. The MATLAB based simulation scenarios are given which includes placement strategies of source and sink nodes along with different energy level scenarios.

Yousef Jaradat et al [9], have studied the noise prone WSN environment with a proposal of model for LEACH protocol. The probability of reception is considered for noise level model. The count of successful packets received is highest when less noise is considered and count goes on decreasing with increment in noise levels. The uniform random number generator used to randomize the noise levels. The implementation carried out using Python tool to observe the effect of various noise levels on the performance of homogeneous LEACH algorithm.

Li Tan et al [10], have given LEACH-M protocol for aerial sensor networks. The vertical movement optimization in LEACH-M protocol extends network lifetime, increases the efficiency of information transmission, and optimizes its performance.

Kulsoom Manzoor et al [11], have given cluster-head selection mechanism which improves the energy-efficiency of the TL-LEACH and has been named as Extended TL-LEACH (ETL-LEACH). The simulation results show that the ETL-LEACH performs better in terms of energy consumption Also, the lifetime of the network is increased and the communication delay decreased to a significant amount.

The literature addressed here is in the view of usages and modifications in LEACH proposed by various researchers for the sake of energy efficiency in WSN. The discussion provides brief introduction and direction for the considerations of clustering techniques for the improvement in performance while using LEACH protocol in WSN.

III. PROPOSED WORK

The proposed work consists of a large wireless sensor network. The LEACH protocol is considered as a platform for clustering process to get energy efficient and long-life route selection during communication and data forwarding process. In this work two methods named adaptive neuro-fuzzy inference (ANFIS) based cluster-head (CH) and cluster-member (CM) selection strategy have been used.

In ANFIS based CH and CM selection strategy, the main focus is on following features:

1. Distance of a node from base station (BS) and other nodes
2. Residual energy
3. Previous load
4. Minimum level of energy

The first objective of the work is to optimize the CH selection process using ANFIS. In every round, all the participating nodes in CH selection are responsible for estimating the required parameters values and exchanging amongst other nodes. In this process, fuzzy inference system based on learning algorithms is used.

The partitioning of network structure into clustered groups, an algorithm is proposed for CH selection in conjunction with ANFIS. The assumptions are set while developing the new strategy which is described below.

Assumptions:

The WSN with modified LEACH protocol for energy efficiency is the main objective of the development and the assumptions are:

1. The clustering process for cluster-head selection and associating the nodes in network with specific cluster-head as cluster member should possess minimum network overhead.
2. The control packets required to exchange the required information for clustering should be minimum, and also should travel minimum number of hops and distance to control energy consumption and traffic overhead.

3. The clustering process should possess minimum complexity in terms of minimum processing delays.
4. The cluster-head of particular cluster is responsible for handing over the data collected from all sensor nodes within that cluster and also, the data from other cluster-heads, depending on its location from base station.
5. As cluster-heads are responsible for handling all the data as per assumption 4, the energy consumption of each cluster-head is directly proportional to the traffic load.
6. The energy consumption of cluster-heads due to traffic handling mechanism is required to be controlled to prevent complete run out of energy and particular node being complete dead, to keep maximum number of alive nodes in the network, for long duration.
7. Locations of sensor-nodes are not linearly distributed (non-grid / random distribution) and hence, total number of members of particular cluster may not be fixed.
8. The cluster-head selection at first time and periodic re-selection process can be limited in terms of coverage area to save un-necessary attempts of re-selection for the nodes belonging to other clusters with less traffic conditions.

With consideration of these assumptions, the process of WSN clustering can be divided in two phases: 1) Setup phase and 2) Re-clustering Phase.

1. Setup phase

This phase starts when network starts for the first time. It consists of clustering using K-medoid method. The early clustering in setup phase using k-medoid is considered with following reasons.

1. The ANFIS based approach requires information of distance, energy level, and load on particular node. Exchanging this information amongst nodes during first attempt of clustering and CH selection process may become ambiguous when all the nodes of entire network participate in the process.
2. The first attempt of clustering using ANFIS directly may lead to generate huge traffic in the network which may require traffic handling mechanisms, and extra overhead in the network.

Hence simplistic first attempt of clustering is very much important when network starts for the first time and continuing using ANFIS is prove to be more efficient.

Also, pre-clustered network and re-clustering depending on the necessity which may reduce number of attempts of clustering process and hence, ultimate energy conservation. Another perspective is the complexity of clustering algorithm. The ANFIS, in first attempt of semi supervised learning strategy appears to be more complex and hence supervised learning using pre-clustered contents may reduce the complexity.

The network with random distribution of nodes has main constraints of irregular nodes' density in clusters and increased complexity in CHs selection. Also, nodes' density and respective total number of cluster members in particular zone are important parameters to define total load handling needs to be carried out by a particular CH. Also, due to beyond the capacity or zonal irregular density, distribution is responsible for irregular run out of energy amongst CHs which, again have to rely on Vice CHs or have to perform re-clustering.

The energy consumption in the network is depends on different aspects such as,

1. Energy required to sending the data,
2. Energy required in clustering process that depends on the complexity of the clustering algorithm.
3. The traffic load handled by the CH is ultimately depends on total members in the cluster and run out of energy of CH based on traffic handling.
4. Energy require in every attempt of clustering process and mechanism of collecting all the necessary nodes' information.

A nominal partitioning of nodes with respect to distance metric is carried out to reduce the size of zone in clustering. For this the CH selection process is considered.

Also, early phase of simple clustering before the attempt of ANFIS may provide supervised learning strategy which results in energy efficient processing due to less complexity.

K-medoids clustering in setup phase:

Dividing around Medoid or K-medoid calculation is a parcel bunching calculation which marginally adjusted from the K-medoid calculation. The two of them endeavor to limit the squared-error however the K-medoid calculation is heartier to commotion than K- medoid calculation. In K-medoid calculation, the pick implies as centroids however in the K-medoids, information indicates are picked be the medoids. A medoids can be characterized as the object of a bunch, whose normal divergence to every one of the items in the group is negligible. Consequently, the data separation of every hub from its neighbor is considered.

The fundamental thought of this calculation is to initially register the K delegate objects which are called as medoids. In the wake of finding the arrangement of medoids, each object of the informational index is allocated to the closest medoid. That is, object i is placed into group v_i, when medoid m, v_i is closer than some other medoid m_w.

Applying K-Medoids:

1. In K-medoid based clustering, first random nodes are selected as CH.
2. The selected CH communicates with the nodes that are only in their direct coverage area.
3. The distance based association of common nodes has associability with only those CHs which have less distance from particular node.
4. Hence only less distance is the criteria to become a cluster member associated with particular CH.

Application of k-medoid algorithm in setup phase:

1. Select random nodes as CH (centroids) when network starts.
2. Estimate the distance of each node that comes in coverage area of the CH
3. Set distance as criteria to become member of cluster.

If $D_{in} < D_{jn}$ Associate with i

Where, i and j are CHs selected randomly during start phase, n is node common in range for CHs i and j and D is the distance calculated by,

$$Di = \sqrt{(x_i - x_n)^2 + (y_i - y_n)^2}$$
$$Dj = \sqrt{(x_j - x_n)^2 + (y_j - y_n)^2}$$

where, (x_i, y_i), (x_j, y_j) and (x_n, y_n) are the location coordinates of CH_i, CH_j and node respectively.

1. Repeat steps 2 and 3 until clustering is not complete else stop the process.

2. Re-clustering Phase:

The selection of new CH can be done by using ANFIS based method. In this process semi supervised strategy is used for selecting cluster-head and may take more processing time with respect to number of cluster members. The optimization of clustering process in FIS is a part of ANFIS which can be done using firefly optimization.

The energy consumed is calculated, the residual energy level is updated in every data transmission. The reception attempted by normal node is estimated in two cases:

(1) When distance of the node is greater than the threshold value. The formula used is

$$E = E- (E_{TX} \times (Bt) + E_{mp} \times Bt \times (D_0 \times D_0 \times D_0 \times D_0)) \quad \ldots(1)$$

where, E is initial energy of a node, E_{TX} is energy required to transmit each bit, Bt is number of bits, E_{mp} is transmit amplifier energy, D_0 is minimum distance for transmission, that is range of communication in normal amplification of signal.

(2) When distance of the node is less than the threshold value. The formula used is

$$E = E - (E_{TX} \times (Bt) + E_{fs} \times Bt \times (D_0 \times D_0)) \quad \ldots(2)$$

where, E_{fs} = friss loss energy of amplifier

The energy consumed by cluster-head while receiving the data is given by,

$$E_{ch} = E_{ch}\text{- (}(E_{RX} + E_{DA}) \times Bt \quad \ldots(3)$$

where, $E_{ch\,=}$ Initial energy of the cluster head, E_{RX} = Energy consumed for reception, E_{DA} = Energy consumed for data aggregation.

ANFIS:

The data are prepared from basic leach simulation. The handcrafted changes for improvement in the performance and prepared data are used as input to ANFIS for training.

The training data consist of feature vector which contains information about the residual energy of the node, distance of the node from cluster-head and base station, last communication traffic load. The four inputs of each node that are participating will be used to select the CH.

The training phase is configured with maximum 50 epochs; bell-shaped membership function in generalized sense is used and three parametric dependencies are evaluated which is given by,

$$f(x; a, b, c) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}}$$

Where, b is usually a positive parameter. Also, c is the location of center of the curve.

Fuzzy Inference System:

The first step is to analyze participation capabilities of fluffy sets and decide the space availability factor. In Fuzzy Logic Toolbox™ based programming, continuously fresh information is used for restricted sets in terms of information variables (for this situation the interim somewhere in the range of 0 and 10). This s applied to fluffy set such that the passing of information done in terms of etymological set (consistently the interim somewhere in the range of 0 and 1). Hence, Fuzzification is query assessment or capability assessment based on information content.

This model is based on three guidelines, and every one of these standards relies upon settling the contributions to various distinctive fluffy phonetic sets: administration is poor, administration is great, nourishment is smelly, nourishment is tasty, etc. Before the guidelines assessed, the data sources must be fuzzified.

The main objective of FIS is to obtain single best solution in which all the membership values are evaluated in terms of antecedent. The fuzzified input data is used to obtain one number that represents the result of antecedent. Hence, based on two or more membership values, Fuzzification of input data is defined and then process of obtaining final single value in each vector.

Firefly-ANFIS

So as to gain proficiency with the Adaptive Neuro-Fuzzy Interference System (ANFIS), to utilizing the firefly calculation, first the issue condition or the scope of factors which ought to be advanced and the wellness capacities are resolved. In this examination, root mean square error (RMSE) is utilized as the wellness work for assessing the exhibition of the ANFIS framework learned by the firefly calculation. Every firefly comprises of a lot of forerunner and consequent parameters. These expecting three information factors as vector (x1, x2, x3), yield variable (y) and utilizing three fluffy sets with Gaussian-type participation capacities.

$$ys = Psx1 + qsx2 + ksx3 + tsx4 + rs \quad \ldots(4)$$

where, P, q, k, t, and r are biasing estimations of the FIS got for streamlining the element parameters.

Utilizing firefly, the prepared model of ANFIS is enhanced as for neurons structure which decreased multifaceted nature of the model.

The assessed new least separation, leftover vitality, and number of endeavors of information total are utilized to prepare ANFIS for re-bunching stage. The objective values calculated in firefly optimization from set of features used in ANFIS consist of intensity, attractiveness, and distance between two flies. These values are considered analogues to energy level, nearest CH and distance from base station.

The energy out of total set of energy values vector is selected by using,

$$Ei= E/ D^2 \quad \ldots(5)$$

Where, Ei is calculated average energy (intensity) for squared distance D from CH.

The nearest CH is selected using formula

$$\beta = \beta_0\, e^{-(D0\ r2)} \quad \ldots(6)$$

Where, β_0 is the attraction towards CH when distance with respect to CH tends to zero, D_0 is the distance of coverage area. The maximum value of β is more on attraction to get selected. The distance (D) is estimated with current CH taken for calculation. The distance from base station is calculated using Cartesian distance formula.

$$D = \sqrt{(x_1 - x_2)^2 + (y_3 - y_4)^2} \quad \dots (7)$$

Where (x_1, y1) and (x_2, y_2) are coordinates of the node and CH.

Load handling capacity:

The load handling capacity of particular node is estimated by,

$$L_h = E/L_o \quad \dots (8)$$

Where, E is residual energy and L_o last iteration load of particular node.

Algorithm:

Setup Phase:

1. Initialize the network.
2. Set random centroids to choose primary CH.
3. Perform distance estimation (D), Use K-medoid based clustering approach to associate and become primary CMs of all the nodes in network with particular CH.

Re-clustering Phase:

1. Use Base station distance (D), residual energy (E), and distance from all the CMs from same cluster.
2. Estimate normal load handling capacity (L_h) of particular CH with respect to traffic density.
3. Consider last traffic load for selecting new CH to prevent complete run out of energy of CH and being complete dead.
4. Use previous load handled record along with BS distance, all CMs distance and new residual energy to perform clustering using ANFIS for selecting new CH. Go to step 6.

IV. RESULTS AND ANALYSIS

The proposed modified LEACH protocol is evaluated by experimentation in MATLAB. The configuration used in the experimentation is sown in table 1.

Table 1: Experimental parameters configuration

Parameters	Values
Sensor deployment area (field)	1000 x 1000 m^2
Number of nodes	1000
Location of sink node	Center of the field
Initial Energy of each node	200 J
Transmission energy	50 nJ
Reception energy	50 nJ
Data aggregation energy	5 nJ
Number of data bits	4000
Protocols	Basic LEACH, ANFIS_LEACH, ANFIS_FIREFLY_LEACH
Number of iterations	50
Performance Parameters	Number of dead nodes, Residual Energy

Analysis of number of dead and alive nodes:

The performance evaluation is done by using the metric number of dead nodes with respect to number of iterations. Table2 shows the comparative analysis of three protocols to count the number of dead nodes with respect to iterations and figure 1 shows the graphical representation. For each protocol the total alive nodes are analyzed in each iterations. The results of which are shown in table 2 and figure 2.

Table2: Number of dead nodes with respect to number of iterations

Number of Iterations	LEACH Basic		ANFIS_LEACH		ANFIS_FIREFLY_LEACH	
	Alive Nodes	Dead Nodes	Alive Nodes	Dead Nodes	Alive Nodes	Dead Nodes
10	701	299	1000	0	1000	0
20	526	474	988	12	996	4
30	432	568	947	53	969	31
40	383	617	899	101	925	75
50	354	646	848	152	877	123

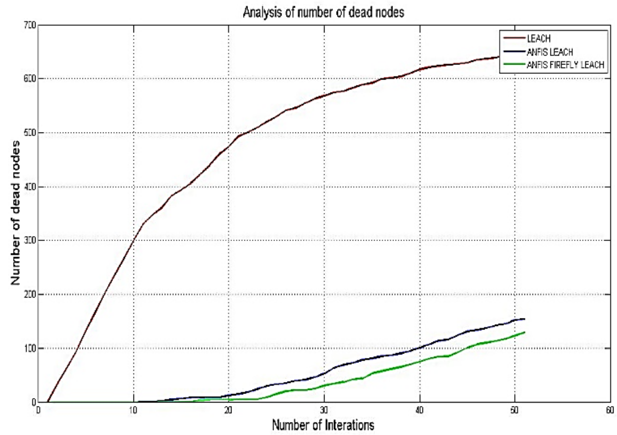

Figure1: Number of dead nodes Vs number of iterations

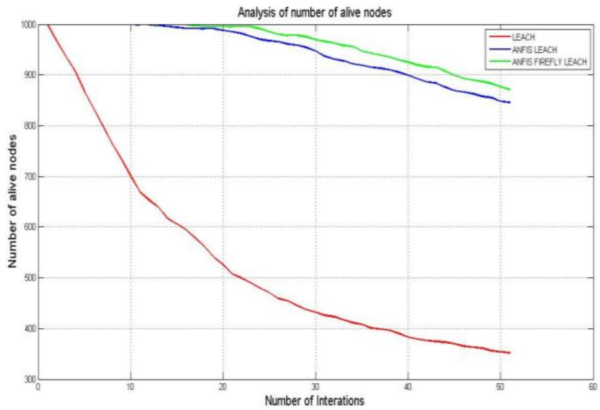

Figure2: Number of alive nodes Vs number of iterations

Analysis of Residual Energy:

Performance evaluation is done in term of residual energy parameter by measuring remaining energy with respect to iterations. Table 3 shows the residual energy of three protocols with respect to number of iterations and figure 3 shows the graph for the same.

Table3: Analysis of residual energy Vs number of iterations

Number of Iterations	Residual Energy		
	LEACH	ANFIS_LEACH	ANFIS_FIREFLY_LEACH
10	99121.64	197252.35	200708.15
20	69097.36	175075.09	182528.75
30	55652.86	154504.55	164872.42
40	47081.52	138510.18	149545.71
50	99121.64	197252.35	200708.15

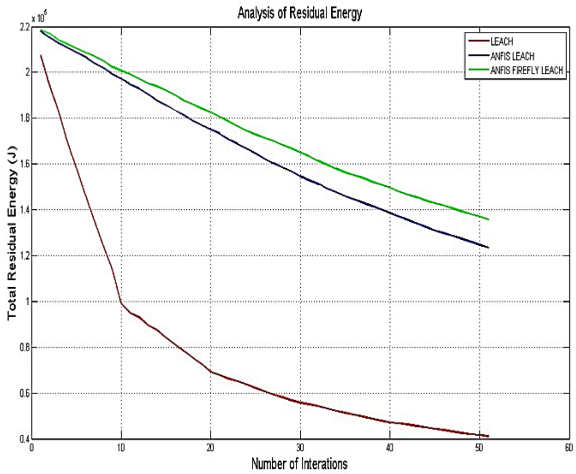

Figure3: Analysis of residual energy Vs number of iterations

Analysis of Consumed Energy:

Performance evaluation is done for consumed energy parameter by measuring energy consumed with respect to iterations. Table 5 shows the consumed energy of three protocols with respect to number of iterations and figure 4 shows the graph for the same.

Table4: Analysis of energy consumed with respect to number of iterations

Number of Iterations	Consumed Energy		
	LEACH	ANFIS_ LEACH	ANFIS_FIREFLY _LEACH
20	151102.64	45124.91	37671.25
30	164547.14	65695.45	55327.58
40	173118.48	81689.82	70654.29
50	178638.97	95528.29	83210.72

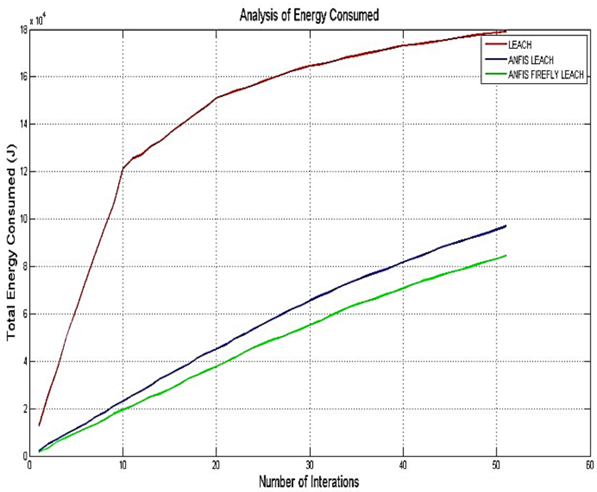

Figure4: Analysis of consumed energy with respect to iterations

Annotations:

The dead node counting analysis shows the number of nodes being dead with respect to iterations is more in normal leach when field area is 1000m x1000m. The number of dead nodes are less with respect to iterations in ANFIS_LEACH protocol also number of dead nodes in FIREFLY ANFIS LEACH protocol are quite less compared to other two.

1. The energy efficiency of ANFIS LEACH is better than basic leach. Also energy efficiency increases in FIREFLY ANFIS LEACH.

V. CONCLUSION

This paper contributes a novel strategy to LEACH modification using state-of-the-art-methods ANFIS and Firefly. The result of LEACH with ANFIS and Firefly optimization shows significantly better performance in terms of improved energy efficiency and extended lifetime of the WSN. The comparison of ANFIS and ANFIS with Firefly proves its use and shows that it is suitable in performance improvement.

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