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Research Article

Hybrid Energy Efficient Eagle Strategy Invasive Weed Optimization Clustering Algorithm for WSN's

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Abstract

Clustering is one among the efficient techniques to optimize energy consumption in wireless sensor networks (WSNs). In the proposed paper, a hybrid approach namely ESIWO algorithm has been presented which combines Eagle strategy and Invasive weed optimization techniques. The selection of cluster heads in a WSN is facilitated by the proposed Single-Sink hybrid Eagle Strategy - Invasive Weed Optimization (Single-Sink hybrid ES- IWO) algorithm with a single sink. It is obvious and vital to achieve the balance of local and global searches, and they (intensification and diversification) are achieved with the IWO and ES respectively. A wide range of simulations are carried out on ES-IWO algorithm by varying the number of sensors, cluster heads and other scenarios of WSNs. This hybrid algorithm maximizes the network lifetime and provides the QoS for the whole network by considering the features of Eagle and weed optimization. Later computations are done in terms of effectiveness of the algorithm ES-IWO which was proposed in this paper, and compared with few standard clustering algorithms.

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1. Introduction :

Optimization problems could be solved using either traditional optimization algorithms viz. Hill-climbing, simplex method; heuristic methods like genetic algorithms or by combining appropriate techniques. In solving Global optimization problems [2, 4, 6, 8, 16, 19, 20] such as NP-hard problem under which travelling salesman problem is one amongst, Modern meta heuristic algorithms play a key role by exhibiting a notable performance. To illustrate, PSO a powerful algorithm introduced by Kennedy et.al in [6], is developed basing on the behaviour of swarm such as fish and bird learning from nature. Currently it is extensively being used in optimization applications. One more example, the Firefly Algorithm has shown potential dominance over many algorithms [24]. Controlled randomization and exploiting much better solutions are the authoritative search approaches in such multi-agent algorithms. Nevertheless, such randomization techniques typically use either Guassian or Uniform distribution. Of course the fact is that, later to the development of PSO, few more algorithms were developed which outperformed PSO in various ways [17, 19].

Satyanarayana. Mummana & Kuda Nageswara Rao [25] proposed new data aggregation technique for clustering and fusion so as to reduce the distance of transmission of data. In this technique, Cluster head selection had taken place using the Invasive Weed Optimization algorithm to get optimum cluster head and in turn to reduce the energy consumption.

Although the real-world optimization problems exhibit better performance, there is some impact of uncertainty and random noise on them which in turn influences the associated objective functions. In such case, a standard optimization problem exhibits stochastic behaviour. Usually those methods which work better on standard problems may not directly be applied to the optimization problems which are stochastic in nature. On the other hand, the results obtained in such experimentations may not be correct and meaningful. In some cases the optimization problems are to be reformulated and in some other cases, they must be modified accordingly, while in most of the cases both processes must be done [9, 10, 18]. In this paper, we are intended in formulating a novel Meta heuristic search method Eagle Strategy (ES), in which the L´evy walk search and the Firefly Algorithm (FA) are combined. A comparative study was done on ES in combination with PSO and few more relevant algorithms is done and specified. Firstly the basic ideas of the Eagle Strategy are outlined after which the essence of firefly algorithm is also given. Finally the performance evaluation and comparisons of the proposed algorithm is done.

Rao et al. proposed an Energy Efficient Cluster head Selection algorithm (PSO-ECHS) in [24], which is based on PSO. The algorithm is developed basing on the fitness function of an energy efficient scheme of particle swarm. The parameters considered in computing the energy efficiency of Particle swarm approach are the distance between CH and sink, residual energy of the sensor nodes and intra-cluster distance. The algorithm was evaluated by varying the cluster heads and number of sensor nodes, which resulted in a variety of scenarios of wireless sensor networks (WSNs). The performance comparisons are drawn with the existing algorithms consequently with which the PSO-ECHS algorithm had exhibited a superior performance.

2. Preliminaries

2.1 Requirement Of Nature Inspired Meta-Heuristic Optimization Algorithms.

The sensor nodes are distributed randomly in challenging environments. The energy consumption relies on the distance between the communicating nodes and the internal signal processing by electronics. It also relies on the source and sink inter distance, which is a no-linear dependency.

Since past few years, optimization is a thriving area of research in providing optimal solutions to real-time and complex problems. The techniques gained the attention of several researchers and are on-demand so as to solve the real-time problems. Distinguished researchers have proposed their unique solutions in which various optimization techniques were significantly used. Historical problem-solving techniques are classified into two categories namely the ‘Extract’ and ‘Heuristic’ methods. Extract methods involve Mathematical and Logical programming to solve NP-complete problems, where in which traditional methods fail [19].

On the other hand a heuristic approach is defined to be an empirical search or optimization technique which is used to solve the problem and they do not have any solid proof which the physicists or mathematicians expect. Nobody could know whether the technique gives the best solution to the problem and it is always used as a short cut to solving difficult problems. Nature-inspired Meta heuristic algorithms are designed which mimic the biological or physical phenomenon.

The characteristics that made Meta heuristics optimization algorithms prominent in using them to solve a wide variety of problems are:

a) They are simple and easier to implement,
b) They avoid local optima,
c) Their versatility of wrapping wide variety of disciplines.

Meta heuristic algorithms contribute to two phases: intensification and diversification. Most of the real-time optimization problems encounter difficulty to get solved using exact optimization methods and it is due to the properties like multimodality, high dimensionality, non-differentiability and epistasis (parameter interaction). Therefore approximate algorithms could be an alternative method in solving such problems. Approximate algorithms are categorised into heuristic and meta-heuristic. Meta and Heuristic are the words derived from ancient Greek among which Meta means upper level, while heuristic represents the art of determining new strategies.

2.2 Low Energy Adaptive Clustering Hierarchy Aggregation (LEACH)

Low Energy Adaptive Clustering Hierarchy (LEACH) introduced by Heinzelman et al (2000)[5], is a cluster-based protocol which uses a distributed cluster formation algorithm and hence it could be said as cluster routing based data aggregation algorithm. It operates in rounds where in each round comprise two phase viz. setup phase and steady-state phase. During the former phase, p% of n sensors shall be randomly chosen basing on a threshold value, and they act as Cluster Heads, Equation for the threshold value is as shown in (2.1).

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left(t \bmod \left(\frac{1}{p}\right)\right)}, & \text{if } n \in G \\ 0, & \text{otherwise} \end{cases} \tag{2.1}$$

Where p represents the required cluster heads number, t for the present round, and G designates the nodes which are not Cluster Heads during last $1/p$ rounds. The preceding aspect ensures that all the sensors shall be designated to become CHs, consequently with which the energy consumption will be fair and increase in network life. Due to the random choice of Cluster Heads in the algorithm non-uniform networks are not considered.

In the latter phase, the collection of data by the CH from the sensor nodes in the respective cluster, and the underlying feature besides data collection is Time Division Multiple Access (TDMA). Subsequently CHs compresses the data which is collected and further the compressed data is forwarded to a BS (Abdul salam & Ali 2013) [23].

Satyanarayana. Mummana & Kuda Nageswara Rao [26] proposed a Hybrid PSO-LEACH algorithm that optimizes the energy consumption, which further improves network life in multi-sink environment. The proposed algorithm deploys multiple sinks with which the inter transmission distance of sink and Cluster Head is reduced which in turn reduces the energy consumption.

Firstly the total sensor nodes are divided into many clusters among which one node shall be selected as CH for the respective cluster. Selection of CH happens basing upon pre-computed probability whereas the non-CH nodes, depending on the received advertisement message strength from CH, shall join the nearest cluster. Alternatively, a non-CH node senses the environment, gathers data and sends it to the CH. Now the responsibility of CH is to forward the received data to its corresponding BS. Although the energy consumption seems to be reduced the random selection of CH node results in poor clustering setup. Moreover there might be redundancy in the CH nodes. As the distribution of CH nodes is non uniform, the data transfers may happen through long-distances and hence energy gets depleted in WSNs (Chang & Ju, 2012)[22].

LEACH is an approach which implements hierarchical routing in wireless sensor networks and in this algorithm the signal strength influences the Cluster formation process. On the other hand the algorithm aims at ensuring data aggregation for WSNs.

The advantages of LEACH are as listed below:

- It proves to be better when compared to conventional routing protocols due to the reason that it is distributed in nature and the control information sharing by the BS seems to be optional.
- Knowledge regarding the global network is not required.

Besides the advantages, the drawbacks that LEACH suffers are:

- The additional overhead with respect to dynamic clustering.
- Random Cluster head selection disregarding the energy consumption
- Coverage of areas to a little extent.
- Non uniform distribution of CHs. (Handy et al 2002)[7].

Some of the deficiencies in process of CH node Election in LEACH algorithm are:

- The size of clusters in the network could be large as well small simultaneously.
- There shall be instances where improper CH selection might happen despite the nodes possessing different energy levels.
- Once CH dies the energy depletion takes place in the member nodes of cluster.

The location of nodes is not considered.

2.3 Eagle Strategy

Aquila Chrysaetos which means the golden eagles exhibit their foraging behaviour which seems to be inspiring and is much like the L´evy flights. An eagle hunts in its own region besides flying freely in an arbitrary way. After it looks at a prey, the eagle changes its search line of attack to a rigorous chase tactic in order to catch the prey as proficient as possible. Eagle’s hunting strategy constitutes two major steps - random search by L´evy flight and focussed chase on the prey. Additionally, the studies made resulted in various animals’ as well insects’ behaviour in terms of their flight had proven their typical characteristics same as of L´evy flights [12, 13, 14, 15]. In the recent study on exploring the landscape of fruit flies which is also called as Drosophila melanogaster done by Reynolds and Frye, it had been proven that the series of straight flight paths interposed by a sudden 900 turn, leads to a L´evy-flight-style intermittent scale-free search pattern. Further, not only the studies done on hunting-gathering patterns of human beings such as the Ju/'hoansi, but also the flight behaviour of light shows the typical feature of L´evy flights. Later on the noted behaviour was applied to optimization problems for which the results prove to be promisingly capable [3, 11, 13, 15].

In conceptualizing the process of an eagle's hunting behaviour, as a first step, we presume the eagle to perform the L´evy walk in the complete domain. After finding a prey the strategy gets altered. In the later step, the hunt strategy could be a local search which is intensive in nature. The optimization technique to be incorporated could be one among steepest descent method, or the downhill simplex or Nelder-Mead method [1]. As a substitute, also we can use any competent meta-heuristic algorithm such as PSO or FA, to perform focussed local search.

The pseudo code for the proposed eagle strategy is outlined in Algorithm 1.

Eagle Strategy

Obj. Func. $f_1(y)$, ..., $f_N(y)$
Preliminary guess $y^{t=0}$
while ($\|y^{t+1} - y^{t}\|$ > tolerance)
Perform Random search by L´evy walk
Evaluate Obj. Func.
Perform local search (using a hyper sphere via NMA or FA)
if (better solution)
    Update current best
end if
t = t+1
Calculate mean and SD
end while
Evaluate and visualize results

Algorithm 1: Pseudo code for the Eagle Strategy.

2.4 Invasive Weed Optimization (IWO) For Cluster Head Selection in WSN

Invasive Weed Optimization (IWO) is one among the effective meta-heuristic algorithms which mimic the inhabitant behaviour of weeds so as to adapt to the external environment. IWO is a recent numeric stochastic optimization protocol. It was developed by Mehrabian and Lucas. The protocol has a simple process with good exploration and diversity. IWO imitates the activity of weeds in colonizing as well as discovering an adequate location for growing as well as reproducing in nature. The optimization process is initialized by randomly generating solutions in the space. IWO refers to a population-based metaheuristic protocol which imitates the colonizing activity of weeds for adapting to an external environment. The fundamental characteristics of weeds are that they grow their population completely or mainly in a specific geographic locale that may be considerably huge or tiny. Initially, a particular quantity of weeds is arbitrarily distributed across the whole space. They gradually grow and implement. The algorithm seems to be simple and effective which converges to an optimal solution in terms of seeding, growth, and competition.

The essential steps of the algorithm are as follows.

i) **Initialization:** Initially a feasible search area is considered in which a population of seeds is dispread randomly. Each weed's position in the area represents a solution. Thereafter an objective function is considered after which the fitness value of each weed could be calculated and its position would be introduced into the function.

ii) **Reproduction:** Depending on the fitness value of the respective weed and also the lowest and highest fitness values of the population, it is allowed to produce seeds that guarantee the linear production of number of seeds from a minimum value for the worst weed to a maximum value for the best weed.

iii) **Spatial Dispersal (SD):** The property of spatial dispersal could be easily identified due to random distribution of generated seeds over the dimensional search space d. It leads to a local search in the region of the weed. Also it could be observed that the distance property obeys normal distribution with zero mean but varying Standard Deviation (SD). Here the distance is between a seed and its parent weed.

The Standard Deviation is determined as per (3.10), where σ_{max} and σ_{min} represents maximum and minimum SD respectively.

$$\sigma_i = \left(\frac{t_{max} - t_{min}}{t_{max}}\right)^{pow} (\sigma_{max} - \sigma_{min}) + \sigma_{min} \qquad (3.10)$$

σ_t is the standard deviation (SD) at current iteration t, t_{max} and t_{min} are the maximum and minimum iteration number. pow is a nonlinear modulation index.

Then, the position S_{ij} of a seed j produced by the respective weed i is given as per (3.11),

$$S_{ij} = W_i + \sigma_i . \text{randn}(0,1) \qquad (3.11)$$

Where W_i represents the parent's position and randn(0,1) returns a random number that obeys the standard normal distribution.

iv) **Competitive exclusion:** As the number of weeds hold by a particular environment is limited, it is indispensable during the evolution to introduce the competitive exclusion process. Initially, all the weeds are allowed to reproduce as step (2) and then all the seeds are allowed to spread over the search area according to step (3). As mentioned in step (2), this mechanism gives a chance to plants with lower fitness to reproduce, and if their offspring has good fitness in the colony then they can survive. The population control mechanism is also applied to their offspring to the end of a given run, realizing competitive exclusion. This process continues until the maximum number of plants is reached.

3. Proposed Approach

We know that ES is a two-stage approach in which the intended algorithms could be used at respective stage. The first stage which involves search process could use randomization via L´evy flights. In the perspective of meta-heuristics, L´evy distribution is a distribution of the sum of N identical and independent random variables. During the latter stage, differential evolution could be used for the local search.

We know that IWO is a global search algorithm which could easily be tuned to perform the local search effectively for the confined new solutions which are local to the most promising region. In our proposed solution which will be demonstrated in the succeeding section, we are combining both the techniques basing on the idea that the combined approach may produce even better results rather than with single technique. It is obvious and vital to achieve the balance of local as well global searches which means the intensification at former stage and diversification during latter stage respectively.

In nature, better individuals propagate their genetic material more likely resulting in the evolution that is mostly determined by natural selection process. The encoding of genetic information seems to admit asexual reproduction resulting in offspring's those are genetically identical to the parent. However, the variants of IWO algorithm most probably avoids the advantages of IWO like low efficiency of search strategies, premature convergence, and standard deviation. A clustering strategy to be deployed in the pre reproduction stage had been introduced in this work so as to disperse the solution regions. In case of multimodal problems the aforementioned feature is required with which new individuals could be located in different regions, and also avoids over-explored and premature convergence. Depending on the inter distance of cluster centre and the individual, Clustering algorithm categorizes them into to a set of solution regions basing on the distance between the individual and cluster centre. After clustering certain fittest individuals shall be selected from the respective cluster basing upon the cluster size. Further the seeds of each chosen weed are to be distributed basing on the fitness factor. In this approach, the standard deviation value calculated from fittest individuals is based on statistical information. In this manner, the standard deviation could be more accurate and representative in nature. The computational consumption might increase but not the time consumption. As per the study it is identified that research on incorporating clustering into ES-IWO has not been done so far. As per the experimental results, there seems to be a significant increase in the performance.

3.1 ALGORITHM :

Step 1. Load function and the associated parameters

Step 2. Random Generation of initial population

Step 3. While ‖minimum $(k+1)-$ minimum $f(k)$‖ ≤ tolerance

or k>maximum iterations,

perform random global search using Levy Flight $x^{k+1} = x^k + \alpha L(s,\lambda)$,

(= 1.5, α=1, and step length s set as s=5)

To find a promising solution

Step 4. Determine a random number and Set p the switching parameter so as to control the global and local searches. (Here p = 0.2)

If p< rand

go to Step 5

else

go to Step 6

Step 5. Calculate the Num seed(i) for each weed.

$$\text{Numseed(i)} = \left[S_{min} + (S_{max} - S_{min}) \frac{f - f_{worst}}{f_{best} - f_{worst}} \right]$$

$$\sigma_i = \left(\frac{t_{max} - t}{t_{max}} \right)^{pow} (\sigma_{max} - \sigma_{min}) + \sigma_{min}$$

$$S_{ij} = W_i + \sigma_i . \text{randn}(0,1)$$

Step 6. $k=k+1$

Step 7. Look for the Stopping criterion,

Set tolerance as 1.0000e−9for reactive power optimization problem

Step 8. If criterion is observed

stop the algorithm

else go to Step 3

Step 10: Apply the best to select the CH

Step 11: Calculate the parameters like Dead nodes, alive nodes, and average residual energy, etc..

4. Simulation Results

The overall objective of the experimentation results in performance evaluation of each protocol. Here, a round is defined as one complete cycle of CH selection, data aggregation from the member node, and transmission of aggregated data to BS. Performance evaluation is done basing on the three metrics mentioned below.

Number of Dead nodes

The performance of network solely relies on the lifetime of all nodes kept together. Higher the nodes’ lifetime, lesser the dead nodes. Consequently the network performance stands high in terms of data transmission and other factors.

Network Residual Energy

The residual energies of the network associated with the number of nodes is analyzed for different. An algorithm is said to perform better if their residual energy is greater and the energy graph is more smooth and flatter and in such case the respective algorithm is known as an energy-optimized algorithm.

Throughput of the network

Throughput in terms of a network is said to be the number of bits transmitted by the live nodes during the round process. As mentioned earlier higher the number of live nodes, higher the network throughput.

Table 1 Simulation Environment parameters of Research Contributions.

Parameter	Value

Network Coverage	300m x 300m
Number of Sensor Nodes	200
Initial Energy E_0	0.5J
E_{elec}	50nJ/bit
E_{fs}	10pJ/bit/m^2
E_{amp}	0.0013PJ/bit/ m^4
d_0 [d_0= Sqrt(E_{fs}/E_{amp})]	87.7058m
EDA	5nJ/bit
Data Packet Size	4096 bits
Control packet size	200 bits
Number of Rounds	1000
Mutation Coefficient Damping Ratio	0.98

Results and Analysis

The Energy Efficient Hybrid Eagle Strategy and Invasive Weed Optimization algorithm are proposed for the cluster head selection using Eagle Strategy and Invasive Weed Optimization algorithms. From the simulation result analysis of Hybrid ES-IWO, it is found that lifetime of the network is better than the individual Eagle Strategy and Invasive Weed Optimization algorithms. The comparison of the number of dead nodes in the network versus the number of simulation rounds for various algorithms like LEACH, ES, IWO, and hybrid ES-IWO is shown in figure 2.

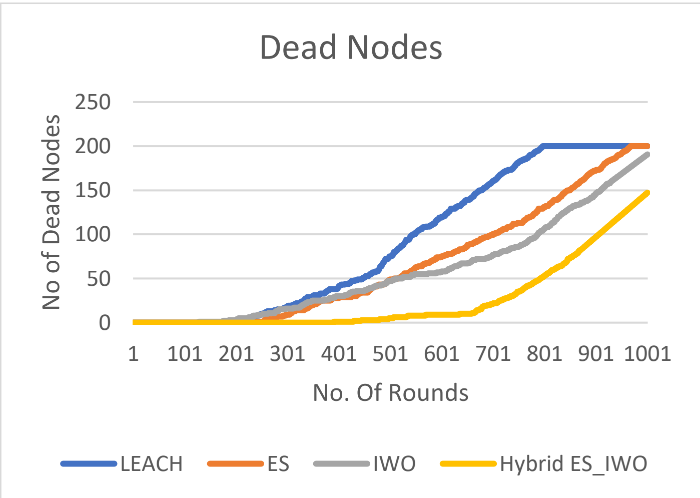

Fig.2 Comparison of no. of dead nodes vs. No. of simulation rounds for various algorithms LEACH, ES, IWO, and hybrid ES-IWO.

Initially, there are 200 nodes. The above graph (Fig.2) specifies round wise dead node count in the network for LEACH, ES, IWO and proposed hybrid ES-IWO algorithms. After 1000 rounds of simulation, the number of dead nodes is very less in case of the algorithm proposed when compared to the mentioned algorithms. The network that has the least number of dead nodes for a longer time will have a long network lifetime. Hence, the hybrid ES-IWO algorithm is better than LEACH, ES, IWO algorithms.

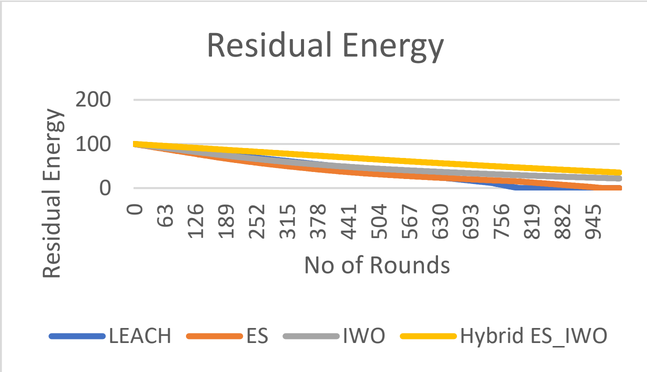

Fig.3 Comparison of Residual Energy vs. No. of simulated rounds for LEACH, ES, IWO, and hybrid ES-IWO algorithms.

Fig.3 shows the residual energy of the sensor node in the network after applying the Hybrid ES-IWO, Eagle Strategy, IWO and Leach algorithms for cluster head selection. The simulation was carried out for1000 rounds. The residual energy of the network is more optimal in the case of the proposed hybrid algorithm than other algorithms. In the LEACH, Eagle Strategy, IWO and the hybrid algorithms, the residual energy of the network relatively differs in a close manner. As the best features of Eagle and IWO algorithms are chosen for the proposed hybrid algorithm, the residual energy of the whole network has increased.

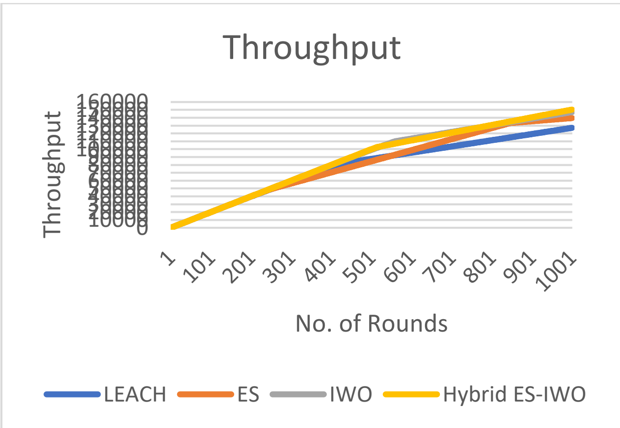

Fig. 4 Comparison of Throughput vs. No. of simulated rounds for LEACH, ES, IWO, and Hybrid ES-IWO algorithms.

Fig.4 shows the Throughput comparison of Hybrid algorithm in the single sink along with Eagle Strategy, IWO, and LEACH. The graph indicates that during the initial rounds the throughput seems to be high in case of ES algorithm but after few rounds the number of data bits transmitted is high in case of the proposed hybrid algorithm. Not only is the performance high when compared with ES, but also with the other algorithms. Thus it could be affirmed that the hybrid algorithm registers better performance than all other algorithms in terms of sending more bits of data i.e. throughput. In addition the energy is also optimized alongside the increase in overall network lifetime when hybrid algorithm is used. It is achieved only through utilizing the salient features from the Eagle and IWO algorithms.

4.1Comparison of Implemented Algorithms

Table.2 Comparison of Network Parameters between Hybrid ES-IWO Algorithm and Existing Algorithms

S.No	Algorithm	FND	LND	Energy(J) after 500 Rounds	Throughput (bits/round) after 1000 rounds
1	LEACH Protocol	197	796	39.694	127180
2	ES	240	967	31.681	139601
3	IWO	128	1087	44.099	147292
4	Hybrid ES-IWO	361	1445	65.057	150355

From Table.2, it is clear that the performance of Hybrid ES-IWO algorithm is better when compared to the other algorithms. The simulation was run for 1000 rounds. The results are compared for LEACH, IWO, ES, and Hybrid algorithm. From the table it is obvious that Firefly algorithm increases the FND but, more nodes are alive for a longer period in the proposed hybrid algorithm. The ES includes not only self-improvement within the current space, but also shows improvement in terms of own space from the earlier stages. Therefore, the lifetime of the network is increased in the case of the proposed hybrid algorithm because the LND is high in the case of the proposed hybrid algorithm. Hence, finally it can be concluded that the hybrid algorithm presents promising solutions in WSN.

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