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Application of nature inspired optimization algorithm on hierarchal LEACH protocol for improved performance

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Abstract

In today's scenario Wireless Sensor Network is playing a dynamic role with the advancement in IOT for mission critical applications due to the fact that these applications are either event driven or time driven applications. Sensor network comprises of battery operated tiny sensors for sensing any change in the environment since the battery life is limited so is the sensor life. One solution to overcome this problem is the use of clustering protocol. A lot of optimization techniques are employed for performance improvement of the hierarchal LEACH routing protocol. This paper explores the three types of Foraging behavior for cluster head selection which means the process to search for food or the energy of the node so that it can be elected as CH. A fitness function is defined relating to residual energy, CH distance to Base station, position of base station. Theses algorithm progresses on the basis of the energy of sensor node in the deployed network. Here the higher energy of node is analogous to food for which the search goes on; in doing so the best CH is selected. The algorithm uses the best location of the node. The overall performance of the network is improved in terms of Energy consumption; packet delivery ratio metrics the results are compared with the existing LEACH protocol.

Subject Classification: *91A28.*

Keywords: *Wireless Networks, Clustering, LEACH, IOT, QoS.*

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1. Introduction

A Wireless sensor network is composed of tiny battery operated sensor nodes. These sensor nodes are deployed in difficult terrain to collect data related to temperature, Gas leakage, Vibrations, early landside detection, Flood detection, and surveillance etc [1]; besides this they are employed for lot of medical emergency alert, forest fire fighting alert, military operations. WSN with added technology finds its usage for IOT applications, Mission critical applications, smart city, micro and smart sensors applications. This paper utilize Hierarchal based LEACH routing protocol in which CH is selected [2] on the basis of maximum energy which is responsible for collection and aggregation of data sent by the nearby nodes within the clusters. CH finally sends the aggregated data to the base station, BS. The selection of CH plays very significant role in improving the performance of WSN. A lot of studies is going for applying optimization technique for CH selection. One such practice is the application of nature inspired optimization algorithms (NiOA) [3] such as GA-PSO[4-5], BEOLP[6].These algorithms are stimulated with the natural behaviors which are the part of our surroundings as shown in Figure 1.

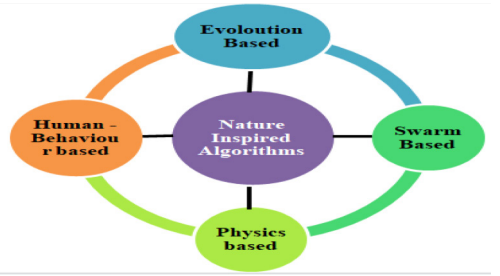


Figure 1

NiOA optimization Algorithms

The exploration of metaheurestic approach on various real time application like IoT, wireless communications, WSN has find it easy way to improve upon various parameters like latency, network life time improvement, PDR etc.This paper heighlights an hierarical LEACH protocol at the abstract level for different cluster head selection prospect. On the basis of search of higher energy node while comparing with the defined energy the decision of the best node selection is done.

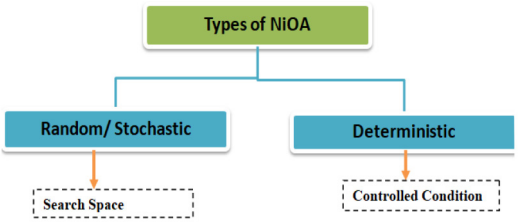


Figure 2

Grouping of NiOA Algorithm

The nature inspired optimization algorithm (NiOA) is shown is Figure 2. The proposed paper uses the bio inspired foraging approach algorithm for best selection of CH. The complete set up is divided into four stages as shown in Figure 3. The stage-I is to find the parameters of population this also represent space search randomly. Evaluation of the parameters is done in the Stage-II. The main procedure occurs in Stage-III where tuning of parameter takes place on the basis of the fitness function generation. The last stage-IV is the final result or the stop criteria. This paper proposed the Manta ray nature inspired algorithm [8] to select CH which it mimics from the manta Ray fish for the search of food. This optimization algorithm enhance network lifetime. Since network lifetime improvement plays crucial role for the Mission critical hazardous environments where a timely alert signal can avoid any adverse condition. LEACH protocol is used along with the smart swarm based manta ray approach to increase network lifetime. This method uses chain foraging, cyclone foraging and somersault foraging at different stage to solve optimization problem as shown in flow chart Figure 4. In chain foraging more than 50 nodes line-up one behind the other thus representing the intelligent strategy made by Manta ray. In this if the first nodes miss the

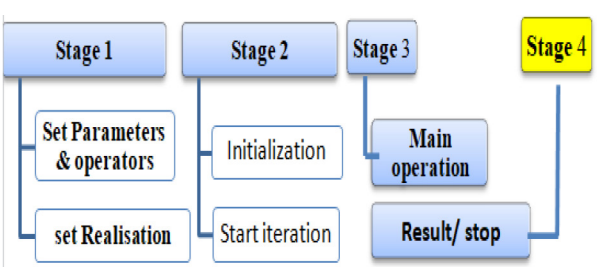


Figure 3

Behavioral Model of NiOA

chance it is gapped by the node just behind the first. While in cyclone manta ray the spiral formation of nodes is done for the maximum search of node energy. Once the final search of node is done the somersault foraging is applied. The mathematical model for the same is given in (5)-(7).

The application of smart Manta ray optimization gives the better selection of cluster head on the formulation of minimum value fitness function. Therefore, this optimization approach work for the minimization problem.

2. Literature Review

The advancement in the felid of integrated circuits has brought the revolution in field of WSN. Now a day's every application involves the use of sensors and automation of the system. So the need of optimization of the system in WSN also becomes the research challenge. Authors in [1] discuss about the design issues of WSN in practical scenario.[2] discuss the most commonly used protocol for WSN being the low power protocol. There are few shortcomings in this protocol which are reformed well with the use of various NiOA as discussed in [3]. [4] Discussed an additional preparation phase to LEACH. The CH selection is done by GA algorithm. The data analysis for the sensor nodes is done with unsupervised and supervised machine learning algorithms as discussed in [5-6]. M.Malik *et al.* applied [7] ABO optimization approach to improve the LEACH performance. A nature inspired feature of Manta Ray fish is discussed in [8]. [9] Discuss about the bandwidth and energy usage and reduction for WSN. [10] T.Behera *et.al.*discussed the role of LEACH protocol for IOT applications. Authors in [11] represent the comparison of benchmark functions with Manta Ray functions.[12] discuss about design issue of 5G with IOT and WSN. Authors in [13] discuss the CH selection approach with Fuzzy logic. The selection of CH is done using few parameters like distance, node density. [14] Discuss about the performance analysis of WSN with Machine learning. The real time application for gas leakage detection is represented [15]. [16] Authors depicted various optimization technique used for wireless sensor networks. Authors in [17] discussed K-means clustering for MapReduce .[18] uses the MAC protocol for mission critical application.[19] Gives the use of optimization algorithm based features of plankton for Manta ray fish. Foraging concept used for relating to fish nature with nodes. Kumar *et. al*.[20] discussed the framework for the MQTT protocol for smart city model. [21] Used the

combination of firefly algorithm and fuzzy logic to the performance improvement of the hierarchal clustering Protocol.

3. Overview of the Proposed Work

LEACH protocol as given in Figure 4 is energy efficient hierarchal protocol. It works on the basis of selection of cluster head node among the randomly deployed nodes with same initial energy. The CH is selected by comparing energy of each node with the threshold energy $T_h(n)$ (1), here 'p' denotes preferred percentage of sensor nodes that can develop into CH, r denotes the present round and G is the set of non-CH nodes The clusters are formed with the non-CH nodes which later join the CH according to minimum distance criteria as given by Eq. (2).

$$T(n)=\begin{cases}1/\ (1-p\ (r\ \bmod(1/p))\\ 0;\ \text{otherwise}\end{cases}$$

$$d(x,y)=\sqrt{(x2-x)^2}\text{-}(y2-y)^2) \quad (2)$$

The WSN model uses the radio communication model [11] considered for transferring K bits of data from transmitter to a receiver located at 'd' distance is given by Eq. (3).

$$E_{Trans}(k,d) = E_{Trans}\text{- elec}(k)+E_{Trans}\ \text{–amp}(k,d) \quad (3)$$

$$= k^* E_{elec}+k^*\varepsilon_{fs}^*d^2,\ d<d_0$$

$$= k\ ^*E_{elec}+k^*\varepsilon_{mp}^*d^4,\ d>d_0$$

Where, k bits of message, d is the distance, d_0 is the threshold distance, $\varepsilon_{fs}d^2$ for free space, $\varepsilon_{mp}d^4$ for multipath

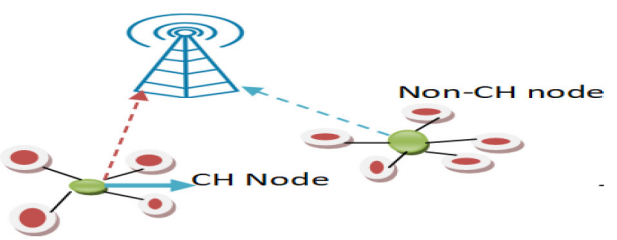


Figure 4

LEACH Protocol

In Chain Foarging a regulated line of Manta ray is formed one behind the other thus making the line of search space.The search for higest energy of the node occurs from head to tail and the node with higest energy gives

the best fitmess function as given by Eq(4). In this approach the first node acts as the reference and the chain start from second till last node[8].

$$X_i^{(t+1)}=X_i^{(t)}+r*(X_{i-1}^{(t)}-X_i^{(t)})+\alpha*(X^{(t)}_{best}-X_i^{(t)}) \quad (4)$$

Here $x_i^{(t)}$ is the first node, $x_{best}^{(t)}$ is the position of best individual, r is the random vector and α is weighted coefficient given as Eq.(5).

$$\alpha=2*r*\sqrt{|\log(r)|} \quad (5)$$

The next search is in spiral formation position of nodes called as Cyclone foraging. The first individual in the chain relocate its position according to the superior node Eq. (6).

$$X_i^{(t+1)}=X_{best}^{(t)}+r*(X_{best}^{(t)}-X_i^{(t)})+\boldsymbol{\beta}*(X^{(t)}_{best}-X_i^{(t)}) \quad (6)$$

Where β represents weight position as given by Eq. (7)

$$\beta=2e^{r1\,T-t+1/T}.\sin(2\pi r1) \quad (7)$$

T is upper limit of iteration; r1 is random value [0, 1].The last technique is somersault search in which the best energy node is at the center and all the other nodes circle around and accordingly relocate their position as given by Eq. (8)

$$X_i^{(t+1)}=X_i^{(t)}+S*(r_2\,X_{best}^{(t)}-r_3*X_i^{(t)}) \quad (8)$$

Algorithm for Nature Inspired Manta Ray Optimization
Input –{ set of sensor nodes= n}
Output-{defined position of CH}
Step1: Initialize population size(N): no of sensor nodes Step2:define Maximum no. of Rounds(R) Step3: Compare the fitness value for each search agent Step3: find current best solution in the population. Step 4: Check for the stop criteria(current round<=Max R) Step5:for i=1 to population size If rand<0.5 Then cyclone foraging technique equation (6) Else chain foraging technique equation(5) Step 6: Compute fitness of each individual Step7: select current best node Step 8:perform somersault foraging technique to find the best fitness function Step9:select best among all Step10: end For

Figure 5

LEACH with nature inspired Algorithm

Here S is the somersault factor and r1 =r2=random value between [0, 1]. The algorithm for all the three technique for best selection of CH is given in Figure 5. Here the chain and cyclone test for the CH selection on the basis of threshold energy value finds for best fitness function.

The flowchart of Manta Ray for CH selection is shown in Figure 6. The next step in the set up phase is the formation of clusters and joining the non CH member nodes to the CH selected from the best fitness function. The last phase steady state phase is as followed in the LEACH protocol. Table 1 give the fitness function values obtained for using Foraging techniques.

Table 1

Fitness Function value for CH

Foraging Technique	No of nodes(n)	Fitness Function Value
Chain	n=50	0.084692
		0.4237
		0.00699
		0.00699
Cyclone	n>50	0.00699
		0.00699
		0.003045
		0.00253
		0.0007

As given in flow chart the decision to accept the line formation of nodes or the spiral formation of nodes is decided by comparison of rand value with the threshold value. The node with minimum fitness function value is taken as CH. Table 2 show the various parameters value taken for the algorithm.

4. Result and analysis

The Implementation of Manta ray foraging optimization technique has improved the network lifetime. Initially the sensor nodes are deployed in the area of (300,300) defined area as shown in Figure 6 with the flow chart in Figure 7.

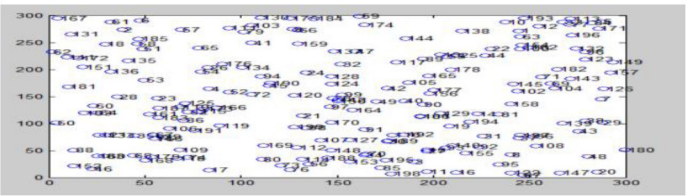


Figure 6

Nodes deployed in WSN with 300X 300 Field

The Cluster head and packets to BS are shown in Figure 8 after maximum no. of iterations of R=1000. The packets received to the base station shows improvement as shown in Figure 8.The various values evaluated for CH fitness function shown in Figure 9. The improvement of network life with this optimization scheme is shown in Figure 10.

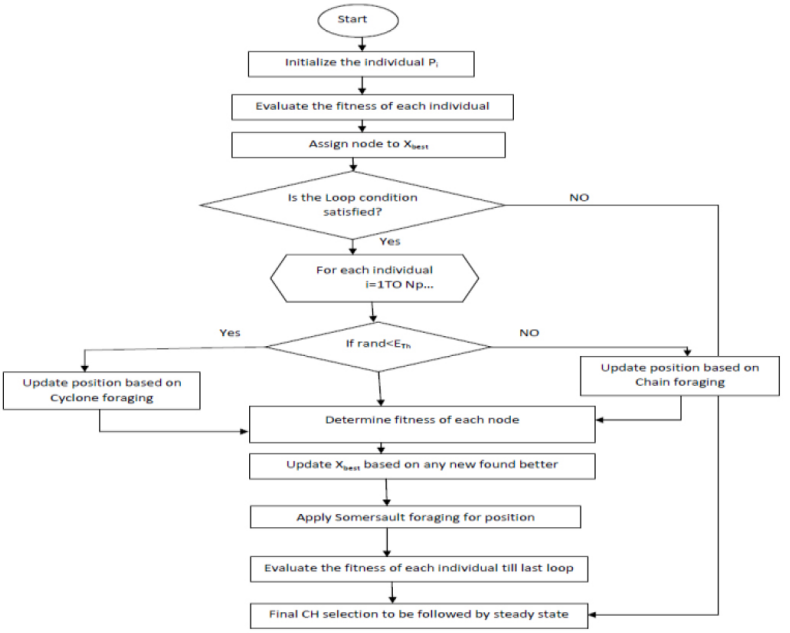


Figure 7

Flow Chart for CH selection using Manta Ray technique

All these graphs shows improvement in LEACH protocol performance while using nature inspired Manta Ray Foraging technique for CH election.

Table 2

Symbol Representation for equations

Parameters used for Dual Controllers	Parameters
Total deployed nodes	N=50,100
distance to the base station	d_{BS}
network area	M
amplification factors	E.free, E.multipath
Controller node cluster head	CNCH
Member nodes	MN
Nodes-(N)	100
Initial node energy E_i (Joules)	0.50 J
CH probability (p)	0.10
Channel Bandwidth (BW)	1Mbp/s
small distance Amplifier energy	$10\text{-}^3 pJ/bit/m^2$
Large distance Amplifier energy	$1.3*10\text{-}^3$ $pJ/bit/m^4$
E_{elec}	50.00nJ/bit
Foarging Technique	Chain, cyclone

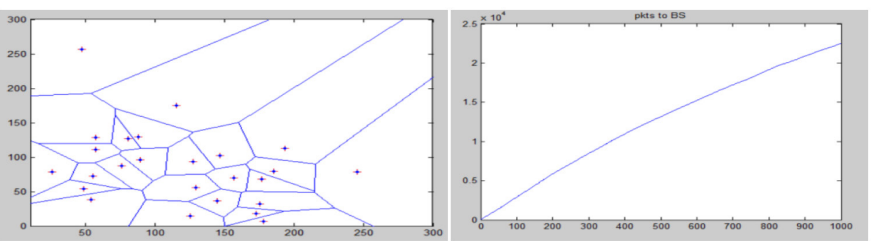


Figure 8

CH Selection and Packet to Base Station

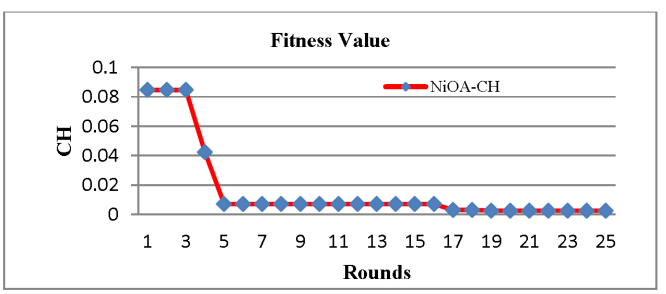


Figure 9

Fitness function of CH

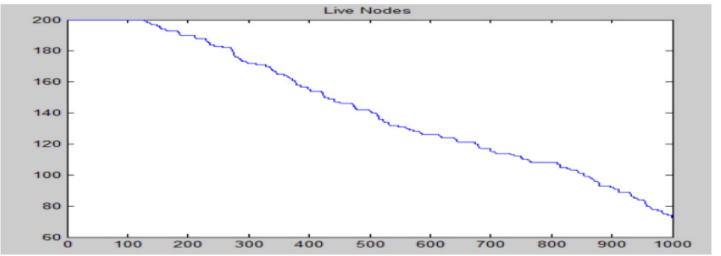


Figure 10

Alive Nodes with no. of rounds

5. Conclusion and future work

The use of nature inspired algorithm, Manta ray Foraging technique for selection of cluster head showed improvement in network lifetime as this is one of the most important parameter for working with mission critical application as node remains in the deployed environment for longer duration. MATLAB 2022b is used for performance testing. The alignment of nodes in search of energy of node for CH election makes this algorithm suitable for WSN real time applications.

Conflicts of Interest

The authors declare that they have no competing interests.

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