WSN Energy Minimisation by Hybrid BFO-PSO

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Abstract: An energy efficient topology control using hybrid bio inspired algorithm based cluster head selection is presented in this work. Two tier architecture of WSN which consists of nodes and cluster heads is considered for simulation purpose. Residual Energy, Bandwidth and Memory Capacity are used as selection criteria for cluster head by proposed algorithm. A hybrid combination of bacterial foraging optimisation (BFO) and particle swarm optimisation (PSO) is used to select cluster head. Later on energy efficient route selection form any node to elected cluster head is also designed. Network is divided into number of clusters, which we have taken as 5% of the total numb er of no des of a network. No des are assigned to the cluster having minimum distance to the cluster head having maximum energy. The distance is calculated using Euclidean Distance Formula.

I. INTRODUCTION

Wireless Sensor Networks are composed of a large number of sensor nodes with limited resources in terms of energy, memory, and computation. They are operated by a small battery attached to it. This battery has some initial energy, and in every communication it dissipates a fraction of the energy. Many such communications take place during the network lifetime, and every time sensor node consumes some energy which makes battery exhaust eventually. When nodes are deployed in hostile environment or in a kind of environments where it is hard to reach, in most of the cases there is no way to recharge these batteries. Sensor nodes are used for monitoring physical phenomena like temperature, humidity, acoustic, seismic, video, and so on [1]. For large scale wireless sensor networks, applications exist in a variety of fields, including medical monitoring [2–4], environmental monitoring [5, 6], surveillance, home security, military operations, and industrial machine monitoring [7]. To fulfil the requirements of these applications, sensor network should have a lifetime long enough to cater for several months. How to prolong the network lifetime to such a long time is the vital question to design and manage sensor network systems. Randomly deployed sensor nodes in the field collect required data and send towards the base station after processing them. If the optimal path (in terms of energy consumption or quality of service) is chosen for each round of communications, nodes of that particular path may get drained of energy, and network can get partitioned soon. We consider the end of network life as soon as the network gets partitioned as in [8]. Many approaches have been proposed

in the literature for routing and for cluster head selection in WSN to extend the lifetime [9–13].

In this paper we have focused to minimise the energy consumption in WSN by using hybrid optimisation algorithm BFO and PSO. Work is compared with genetic algorithm too. We have chosen the approach to select the cluster head such that it has maximum residual energy, bandwidth and memory so that network life time increases.

II. PROPOSED WORK

The proposed work is based on the election of cluster heads amongst nodes randomly placed in a geographical region. For this purpose hybrid bacterial foraging optimization (BFO) and particle swarm optimization (PSO) is used because the election of cluster head is a NP hard problem and also bounded by many constraints. Once the CHs were elected, data forwarding using minimum transmission power through its CH neighbours to the sink node is done. Probability to become a CH is more for a node with maximum RE, maximum unused BW and maximum unused memory. Based on spearmen's rank correlation coefficient the objective function for the cluster head selection is represented mathematically in equation 2.1.

$$f(x) = 0.2\ x1 + 0.3\ x2 + 0.5\ x3 \qquad 2.1$$

The three parameters BW, Memory capacity and RE, considered for CH selection are represented by the variables x1, x2 and x3. Since the problem considered here is a maximization problem, the fitness function is considered to be the same as the objective function. Arbitrary weights were assigned for the variables based on its impact over the network performance. The weight assigned for the variable x3 is more compared to the other two variables. Since RE plays a vital role in the network lifetime, maximum weight is given for the variable x3 representing the RE value. For the variables considered, lower and upper bounds should be known for calculating the fitness function. The variable x1 representing BW retains between the values 0 and 250 Kbps. So the range for the variable x1 is given as $0 < x1 < 250$, and a total of 8 bits is required for the binary encoding of the variable x1 ($27 + 26 + 25 + 24 + 23 + 22 + 21 + 20 = 255$). For representing the Memory capacity, the lower bound is 0 and upper bound is 128 Kb ($0 < x2 < 128$) and it requires a total of 7 bits for binary encoding ($26 + 25 + 24 + 23 + 22 + 21 + 20 = 127$). The maximum RE assumed for

each node is 1000 mJ. So the range is from 0 to 1000 mJ ($0 < x3 < 1000$) and it requires a total of 10 bits for the process ($2^9 + 2^8 + 2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0 = 1024$).

We have optimised the equation 2.1 by hybrid BFO and PSO algorithm. BFO algorithm is based on the food searching process of E.Coli bacteria and PSO is based on behavior of swarms as discussed in previous chapter. The counterpart of Bacteria and particles in BFO and PSO respectively in our work is the tuning variables and is shown in table 1.

Table 1: Technical counterpart of bio inspired variables

	Variable in Bio Inspired Algorithm	Terms in our technical concept
1	Position of bacteria/swarms	Values of three parameters in binary format
2	Number of dimension of searching space	Total number of number of binary strings
3	Update in positions	Change in binary string of three parameters

The hybrid BPSO algorithms work in the manner that PSO becomes alive to update the direction in the BFO algorithm. The update in position requires knowledge of step size and direction and in BFO the direction of movement of bacteria is random. Due to it, it takes time to converge of to reach at an optimal solution. This random direction is controlled by the PSO algorithm in our work. This make the convergence faster with each minima point checked. Initialization of direction is random but later on once for every bacteria, fitness function is evaluated, the direction is controlled by PSO. The step by step algorithm is defined as:

STEP1.   Initialize the random positions and directions of bacteria.

STEP2.   Consider the searching space dimension as number of total binary digits for bandwidth, energy and memory

STEP3.   Initialize the chemotactic, swarming, reproduction and dispersion steps. The initial step size of bacteria is taken as 0.1.

STEP4.   Initialize the weighting parameters of PSO as 0.2 and 0.5.

STEP5.   In each chemotactic step, for every bacteria fitness function is evaluated (fitness function is discussed in next column) and position of bacteria is updated by position updation formula defined in previous chapter. It is

$$new\ pos = old\ pos + step\ size \times \frac{direction}{\sqrt{direction * direction'}}$$

STEP6.   In swarming step the previous fitness function output is compared with the next position output of same bacteria. If found less then position of bacetria is updated again by formula given in step 5.

STEP7.   The present position of bacteria is termed as current position of particle for PSO and output of fitness function is Jlocal for the PSO.

PSO Starts here:

STEP8.   Take out the minimum value index from the J local and corresponding bacteria's position is termed as the local best position of particle for each bacteria.

STEP9.   The velocity of each particle is further updated from random initial velocity to a PSO tuned velocity by using the formula:

$$new\ velocity = 0.9 * old\ velocity + c1 \\ * R1(local\ best\ position \\ - current\ posiiton) + c2 \\ * R2(global\ best\ position \\ - current\ posiiton)$$

Where c1,c2 and R1,R2 are initialized initially.

STEP10.   This new velocity is the direction of bacteria in BFO as

$$direction = velocity$$

PSO ends here

STEP11.   The chemotactic and swarming loop continues till all initialized steps are completed. In each loop PSO updates the direction of bacteria and move the bacteria into the direction of fast convergence.

STEP12.   Reproduction steps take place for bacteria with high fitness function values.

STEP13.   To disperse or kill the weak bacteria, a probability of 0.25 is defined as the deciding probability. If random probability is higher than it, bacteria is dispersed or vice versa.

STEP14.   Result will be positions of bacteria with minimum fitness function output. These positions are binary digits for remaining bandwidth, memory and energy for cluster heads.

We have developed a different MATLAB module which is called for each bacterium in each iteration. In the objective function module, the binary strings of each parameter is converted to decimal by using the equation

$$x_i \frac{x^u - x^l}{2^\beta - 1} \sum_{j=0}^{\beta} \gamma_i 2^j \quad ; i = 1,2,3$$

Where x^l is the lower bound of the variable x_i, x^u is the upper bound of the variable x_i, ß is the length of the string representing the variable and γj represents the bit value of the jth position. For the obtained variables x1, x2 and x3,the

fitness function is calculated for maximizing the function given in equation 2.1.

III. RESULTS

To simulate the WSN in MATLAB we have selected the geographical region of 100*100 m² area with 100 nodes randomly placed in it. Form the literature review 5% of nodes are used as cluster heads for minimum energy consumption and optimum path selection. So there are 5 number of cluster heads and BFO +PSO optimisation will be used to select these 5 cluster heads from 100 nodes which are having highest remaining values of bandwidth, memory and energy. Every node is initialised with these parameters as shown in table 2.

Table 2: initialisation values of WSN nodes parameters

Bandwdith	Memory	Energy
250 (Kbps)	128 Kb	1024 J

Every optimisation algorithm runs for certain number of iterations and settle to either maximum or minimum value depending upon number of iterations. Early it settles to a minimum value as in our case, good is the optimisation. Figure 3.1 shows the figure for objective function values with number of iterations. It can be checked that after 3rd iteration, no decrease in objective function value if visible since it gain the minimum level. The minimum value in this curve is -589 and to compare it, we used genetic algorithm from the base paper which is giving the minimum value of -575 which is higher than proposed work as shown in figure 3.2 for GA.
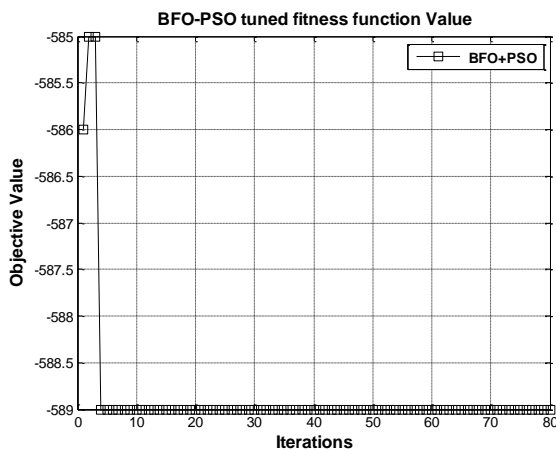

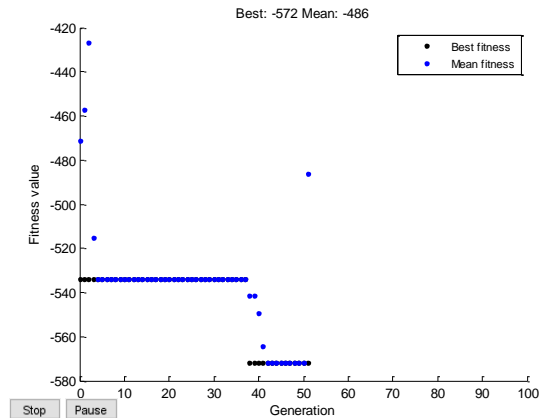Figure 3.1: Optimisation curve for proposed algorithm

Figure 3.2: optimisation curve for Genetic algorithm for cluster head selection

optimisation five cluster heads are selected are 57, 58, 9, 41, 47. Path formed form these cluster heads with a transmission range of 40 meter is shown in figure 3.3.
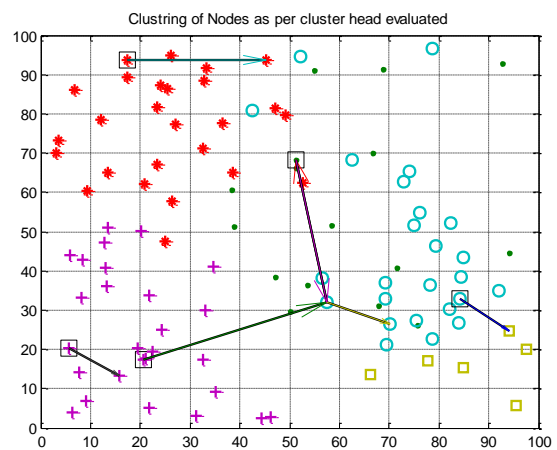

Figure 3.3: Efficient path formation for chosen cluster heads

Table 3 shows the optimised values of bandwidth, memory and residual energy for each cluster head for both BFO+PSO and GA optimisation for comparison purpose.

Table 3 (a): Optimised parameters for cluster head by BFO+PSO

Cluster head	String 1(8 bits)	String2 (7 bits)	String 3 (10 bits)	BW (Kbps)	Memory (Kb)	RE (J)
1	1 1 1 1 1 0 0 1	1 1 1 0 1 1 1	1 0 1 1 1 1 1 1 1 0	249	124	999

Cluster head	String 1	String 2	String 3	BW (Kbps)	Memory (Kb)	RE (J)
2	1 1 1 1 1 0 0 1	1 1 1 0 1 1 1	1 0 1 1 1 1 1 1 1 0	249	124	999
3	1 1 1 1 1 0 0 1	1 1 1 0 1 1 1	1 0 1 1 1 1 1 1 1 0	249	124	999
4	1 1 1 1 1 0 1 0	1 1 0 1 1 0 0	1 0 1 1 0 1 1 1 1 1	250	125	1003
5	1 1 1 1 1 0 1 0	1 1 0 1 1 0 0	1 0 1 1 0 1 1 1 1 1	250	125	1003

Table 3 (b): Optimised parameters for cluster head by GA

Cluster head	String 1(8 bits)	String2 (7 bits)	String 3 (10 bits)	BW (Kbps)	Memory (Kb)	RE (J)
1	1 1 1 1 1 0 0 1	1 1 1 0 1 1 1	1 0 0 0 1 0 0 1 0 0	243	121	974
2	1 1 1 1 1 0 0 1	1 1 1 0 1 1 1	1 0 0 0 1 0 0 1 0 0	243	121	974
3	1 1 1 1 1 0 0 1	1 1 1 0 1 1 1	1 0 0 0 1 0 0 1 0 0	243	121	974
4	1 1 1 1 1 0 1 0	1 1 0 1 1 0 0	1 0 0 0 1 0 0 1 0 0	243	121	974
5	1 1 1 1 1 0 1 0	1 1 0 1 1 0 0	1 0 0 0 1 0 0 1 0 1	251	125	1006

Form above table it is clear that though for cluster heads residual parameter values are same for some but their binary strings are different. There is more bandwidth, memory and energy is left in BFo+PSO optimised cluster heads selected rather than GA.

IV. CONCLUSION

Our work is based on reducing the energy consumption in WSN. We have considered two tier topology of WSN in which nodes transmit their data to cluster head and which is forwarded to base station by their cluster heads. This way energy consumption is reduced and nodes can live long life even with bounded by battery available. It can be done either done by selecting the cluster head such that energy consumption in making communication with nodes is very less or selecting the optimum path with minimum distance to travel for data packets. In our work we have combined both approaches to reduce energy consumption. This is done by using optimisation as it is a work of non linear mathematical problems bounded by many constraints. A hybrid bio inspired optimisation algorithm is used which is a combination of bacterial foraging optimisation (BFO) and particle swarm optimisation (PSO). Results are compared with previously used genetic algorithm (GA). Simulation environment of WSN is tested for 100 nodes and three parameters: bandwith, memory and energy, all are assigned equal to every node. By choosing the cluster head by proposed optimisation, remaining values of these three parameters for cluster heads is noted since the node with highest of remaining quantities of these will be elected as cluster head.

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Special Issue - 2017

International Journal of Engineering Research & Technology (IJERT)
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NCIETM - 2017 Conference Proceedings

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