Energy Efficient Protocol For Wireless Sensor Network Using Hybrid Metaheuristic Techniques

Rodali Sarma Baruah, Dr. K. Anusudha

Pondicherry University, Pondicherry

Abstract— **Energy efficiency of sensor nodes has become a primary issue in Wireless Sensor Network (WSN). WSN consists of a number of sensor nodes which are powered by a finite energy source like batteries, which imposes severe energy boundaries. So to design an energy efficient protocol for data routing is a challenging task. In this paper, a hybrid metaheuristic technique based on Artificial Bee Colony and Particle Swarm Optimization is proposed to enhance the network lifetime. The performance of this technique is analyzed and compared with hybrid technique Ant Colony and Particle Swarm Optimization.**

Index Terms— **Artificial Bee Colony, Ant Colony, Metaheuristic, Particle Swarm Optimization, WSN.**

I. INTRODUCTION

Wireless Sensor Network consists of a number of sensor nodes and a base station which can communicate wirelessly. Sensor nodes are positioned in a wide area randomly. It can sense some natural phenomena like temperature, pressure, vibration etc. and transmit it to the sink node or base station. Main work of sensor node is used for sensing of data, processing of data and transmitting the data to the base station [1][2]. Main source of energy in WSN is the battery. Energy conservation is a big issue in WSN because battery replacement in the sensors is infeasible since most of the sensors are randomly placed. So WSN has severe energy limitation which can reduce the lifetime of a network. Therefor to increase network lifetime and energy efficiency first we have to arrange the nodes into clusters i.e. grouping of nodes. Then we have to assign one Cluster Head (CH) for each cluster to transmit the data energy efficiently through the best routing path. CH reduces the number of hops which can reduce energy consumption. Nodes in a cluster send data to the CH and from CH it will send the data to the base station [3][4][5].

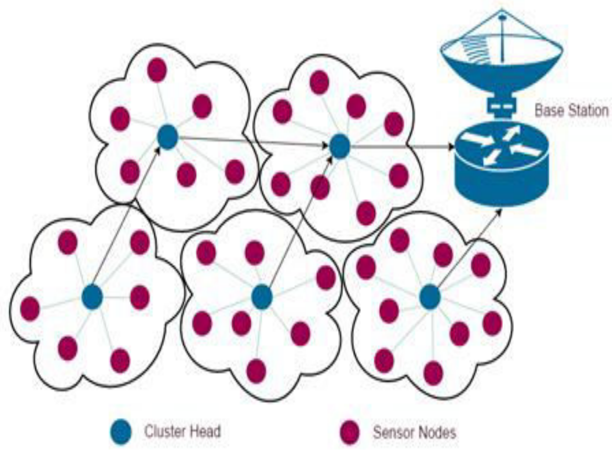

Fig 1. WSN deployment

In this paper, a hybrid metaheuristic optimization protocol based on Artificial Bee Colony (ABC) and Particle Swarm Optimization (PSO) is introduced to increase the lifetime of a network [6][7], as in Ant Colony Optimization (ACO) some challenges appears as probability distribution changes after every iteration and it takes more time to give any output if number of nodes are greater, i.e. time to convergence is uncertain. But in ABC, searching capability will improve and we will get an optimized solution with minimum hop numbers.

In this paper, Section II, briefly describes the network energy model and cluster head formation procedure. Section III describes about the proposed technique to find the energy efficient path. Section IV, presents the analysis and simulation outcomes. Section V, concluded the paper with a future scope.

II. SYSTEM MODEL

A. Energy model

When a sensor node senses some data and transmits sensed data to the sink node it has to consume more or less amount of energy. When it sends the data directly to the sink

Rodali Sarma Baruah is with the Department of Electronics Engineering, Pondicherry University, Pondicherry (e-mail: rodalisarma@gmail.com).

Dr. K. Anusudha is with Department of Electronics Engineering, Pondicherry University, Pondicherry.

node it is called free space propagation model and if it is multihop transmission then it is called multipath fading channel model. When distance 'd' is less than threshold value 'd_0' then free space model is used else multipath fading channel is applied. Mathematical model for finding energy consumption is given as,

$$E_n T_{rx}(L, D) = \begin{cases} LE_{n(elec)} + L \in_{fres} D^2, d < d_0 \\ E_{n(elec)} + L \in_{mpat} D^4, d \geq d_0 \end{cases} \quad (1)$$

Here, L is the data packet size. $E_{n(elec)}$ is the energy spend by the electronics circuit to transfer data. $\in_{free}$ is free space energy loss. $\in_{mpat}$ is multipath energy loss. d_0 represents threshold value, is computed as follows:

$$d_0 = \sqrt{\frac{\in_{fres}}{\in_{mpat}}} \quad (2)$$

Energy consumed to receive L bit energy is given by,

$$E_{rec}(L, D) = LE_{n(elec)} \quad (3)$$

B. Cluster Head Formation

One node from each cluster will be chosen as cluster head collects data from each node and send the aggregate data to the sink node. Generally, a node with the maximum residual energy will become a cluster head. For every round, each node will generate a random number between 0 and 1. If this random value is less than the threshold value, T(i) it will become the cluster head [8]. T(i) is given as,

$$T(i) = \frac{P_{opt}}{1 - P_{opt}\left(r.mod\left(\frac{1}{P_{opt}}\right)\right)} * \frac{E_i(r)}{E_{avg}(r)} \text{ for all nodes if } E_i(r) > 0 \quad (4)$$

Here, P_{opt} is the probability of selecting nodes as cluster head, r represents the current round in WSN, $E_i(r)$ is the present energy of given node i. $E_{avg}(r)$ symbolizes average remaining energy which is given as,

$$E_{avg} = \frac{\sum E_i(r)}{N} \text{ for every node i} \quad (5)$$

N is the total number of nodes

III. Proposed Algorithm

A. Artificial Bee Colony Algorithm

Artificial Bee Colony (ABC) algorithm was proposed by Karaboga and Akay in 2009. It is a swarm intelligence based protocol which is inspired by the searching behavior of honey bees. There are three types of bees in nature: Employee, Onlooker and Scout bee. In ABC, employee bees exploit sources of food and share information about route, quality of food, distance etc. to onlooker bees using waggle dance. Onlooker bees will select a food source based on the quality of food source. Scout bees will explore new food source around their hives [9]. In the following, three main features of the bee colony are discussed that can be applied to find the best routing path.

i. Management of work division: For each bee, work division is already decided and they can adjust according to the requirement and environment. Such as when a source is found by scout or onlooker bee, it becomes an employee again whereas when a food source is fully exploited employee bee becomes scout bees.
ii. Multiple interactions: Employee bee can interact with many bees at a time using waggle dance.
iii. Stochastic flower-site choice. Bee colony always finds for multiple food sources rather than the best food source. In ABC, a number of employee bee is proportional to the quality of flower site.

B. Particle swarm optimization

Russell Eberhart and James Kennedy invented Particle Swarm Optimization (PSO) in 1995. This swarm intelligence protocol is motivated by flocking and schooling behavior of birds and fish. PSO is initialized with a group of random particles and each particle is initialized with random velocity and position. It searches for optima by updating its velocity and position after every iteration. After every iteration, particle will be updated with two best values. The fitness value of a current particle is called pBest. The best solution among the generated solution is called gBest [10]. Velocity updating rule is given as,

$$new_v = \omega * old_v + \omega_1(lBest_p - cBest_p) + \omega_2 + (gBest_p - cBest_p) \quad (6)$$

ω represents the inertia weight. $\omega 1$ and $\omega 2$ are user defined PSO parameters. v signifies the velocity and p is the position value.

Position updating rule is given as,

$$new_p = old_p + new_v \quad (7)$$

C. Hybrid Algorithm

In this section, two metaheuristic techniques ABC and PSO is combined to get an optimum solution. It is inspired by foraging behavior of ABC and velocity update nature of PSO Algorithm:

1. 'N' number of sensor nodes are randomly distributed in graphical area XxY, each sensor has a communication range R.
2. Define a bidirectional link between two nodes.
3. Initialize parameters.
4. Define cluster heads from the nodes.
5. DmaxS defines the maximum distance between one nodes to another which can be calculated by the Euclidean distance between them.
6. Find the maximum distance between a sensor node and BS using the Euclidean distance between them.
7. Define maximum distance between a sensor node and cluster head by Euclidean distance.
8. Define maximum distance between a cluster head and BS by Euclidean distance.
9. Energy required to transmit k bits over d distance is given as,

$$E_n T_{rx}(L,D) = \begin{cases} LE_{n(elec)} + L \in_{fres} D^2, d < d_0 \\ E_{n(elec)} + L \in_{mpat} D^4, d \geq d_0 \end{cases} \quad (8)$$

10. Set ABC control parameters.
11. Employee Bee's phase.
    In ABC, initial population number are randomly produced through D-dimensional real set of vectors. Let x_{ij} is the ith food source. Generate new food position vi from xi using the following equation [11],

$$vi = x_{ij} + \emptyset_{ij}(x_{ij} - x_{kj}) \quad (9)$$

where j = {1, 2,. . . ,*D*} and $\emptyset_{ij}$ generates uniform random number between [−1, 1].

12. Calculate waggle dance number [12],

$$DN_p = \frac{n - H_p * (\omega_2(E_{initial} - E_{avg}) + (1-\omega_2).E_{min})}{\delta} \quad (10)$$

where ω_2 is the weight value, n and δ are user-defined parameters, $E_{initial}$ and E_{min} are preliminary energy of node and lowest residual energy in the path respectively, E_{avg} is the average remaining energy of nodes in the path, and H_p is the hop number between source to destination node.

13. Onlooker Bee's phase
    Probability of selecting a path

$$pi = \frac{DN_i}{\sum_{j=1}^{n} DN_j} \quad (11)$$

14. Choose a food source depending on pi.
    Updating new velocity,

$$new_v = \omega * old_v + \omega_1(lBest_p - cBest_p) + \omega_2 + w_1(gBest_p - cBest_p) \quad (12)$$

Updating new position,

$$new_p = old_p + new_v \quad (13)$$

15. Fitness value is compared for both old and new particle and the better one is selected for the next observation.
16. Store the best solution until cycle = maximum cycle number (MCN).
17. Scout Bee's phase
    After completion of MCN, if the quality of selected path is not improved, then it will go under self-destruction and scout will search for new option again by equation vi.

IV. EXPERIMENTAL SETUP AND RESULTS

In this experiment, MATLAB is used as a simulation tool. Performance evaluation is done with existing protocol Hybrid ACO-PSO based energy efficient protocol. We are considering network lifetime, throughput and residual energy as performance matrices for the experiment. Here the whole network is consists of 100 nodes in a 100x100 m^2 area. All nodes are randomly deployed and the base station is taken at the center. Table 1 gives the parameters considered for the simulation.

TABLE I
Parameters for WSN

Parameter	Value
Monitoring Area	100,100
Base station position	50,50
Number of Nodes (n)	100
Probability (p)	0.1
Initial energy	0.5J
Transmitter energy	$50 * 10^{-9}$J
Receiver energy	$50 * 10^{-9}$J
Free space loss	$10 * 10^{-13}$J
Multipath loss	$0.0013 * 10^{-13}$J
Effective data aggregation	$5 * 10^{-9}$J
Data packet size	4000 bits

A. Network Lifetime

This is defined as the maximum period of time during which located sensors have the ability to observing the area of interest. Fig 2(a) and 2(b) represents network lifetime of the existing network and the proposed network respectively. From comparison, we can say that the proposed one is enhanced than the existing one.

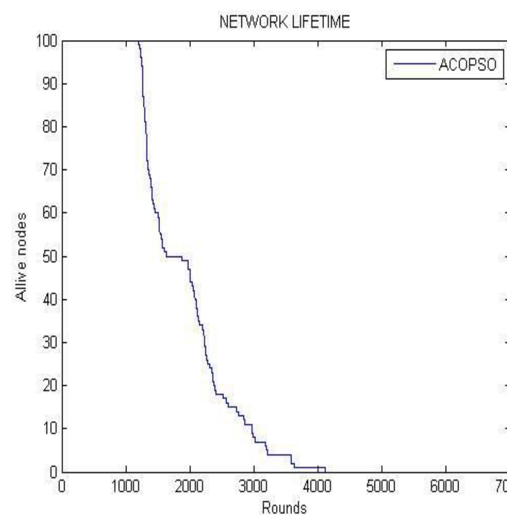

Fig 2(a). Network lifetime of existing protocol

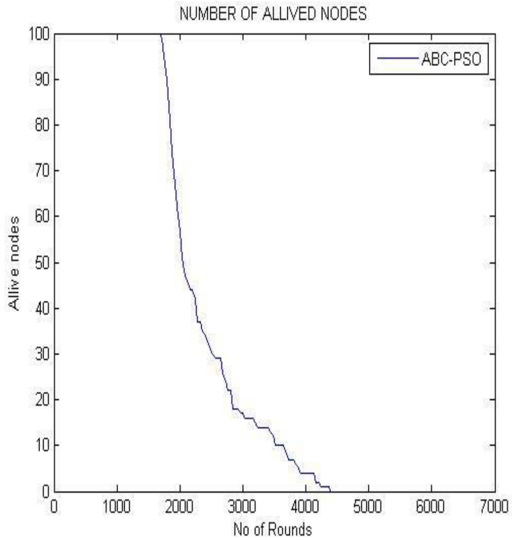

Fig 2(b). Network lifetime of proposed protocol

For fig 2(a) and 2(b) first node dies after 1205 rounds and 1731 rounds respectively and last node dies after 4117 rounds and 4426 rounds respectively.

TABLE II

Last dead node comparison

Protocol	100x100
Existing	1
Proposed	1.08

Considering existing as benchmark, we compared the lifetime of proposed one with last dead node and it is found that the proposed one is 1.08 times improved than the existing one.

B. Throughput

Throughput is defined as the number of packets which can be delivered successfully to the destination. Fig 3(a) and 3(b) represents throughput of the existing network the proposed network respectively. These figures clearly show that the throughput of the proposed network is better than the existing one.

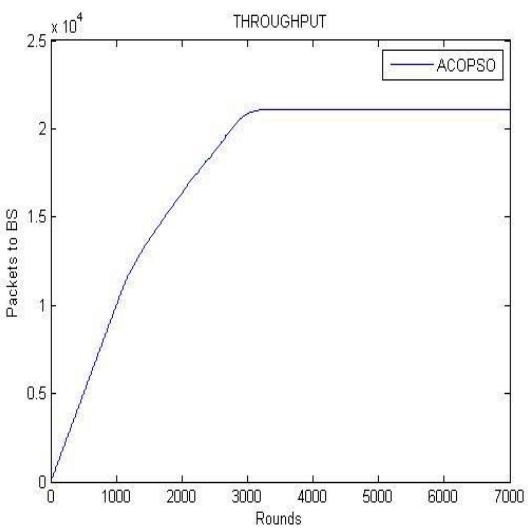

Fig 3(a). Throughput of existing protocol

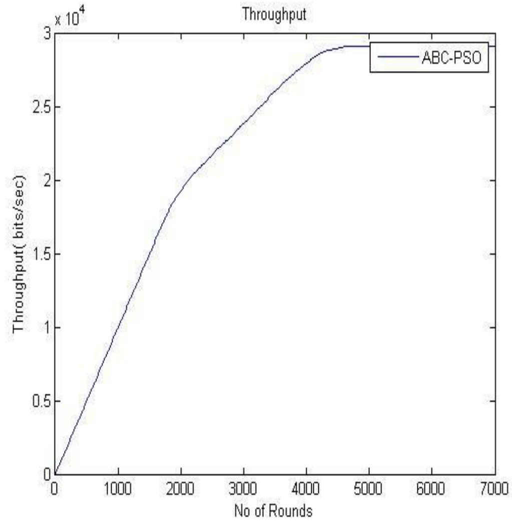

Fig 3(b). Throughput of the proposed protocol

TABLE III

Throughput comparison

Protocol	100x100
Existing	1
Proposed	1.10

Higher traffic causes more collisions and more packet loss. But Bee Colony has more control over traffic so packet delivery rate is more in ABC-PSO. In ABC-PSO maximum throughput is 29206 and in ACO-PSO maximum throughput is 26508. Considering existing as benchmark, we get that proposed one is 1.10 times efficient than existing one.

C. Residual Energy

Residual energy is the remaining energy of the node after every round. Fig 4(a) and 4(b) represents the residual energy of the existing network and the proposed network respectively. It can be said that the residual energy of the proposed protocol is improved than the existing one.

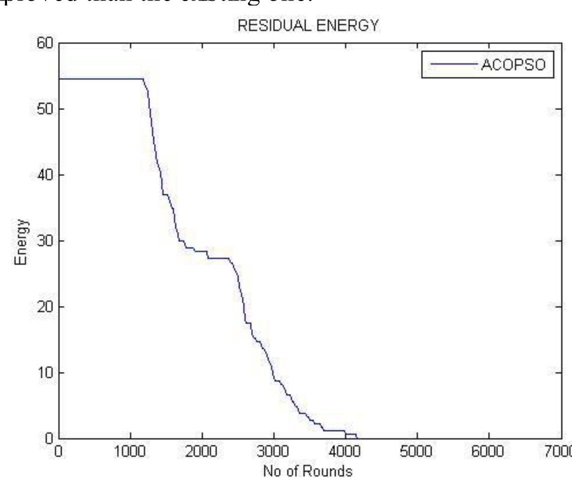

Fig 4(a). Residual energy of existing protocol

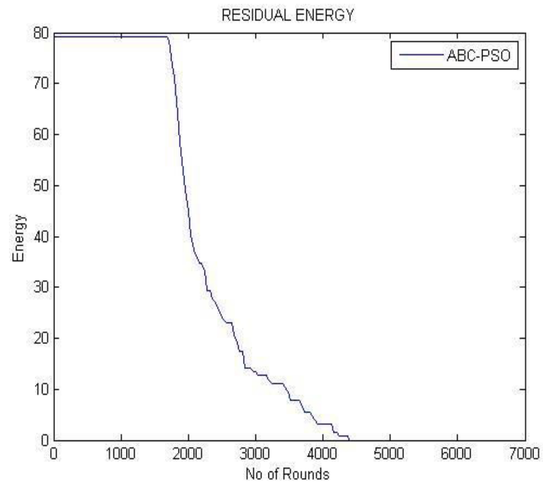

Fig 4(b). Residual energy of proposed protocol

TABLE IV
Residual Energy comparison

Protocol	100x100
Existing	1
Proposed	1.06

Residual energy is evaluated for number of rounds and it is found that residual energy of nodes becomes zero after 4426 rounds for the proposed one and it is 4185 rounds for existing one. Considering existing as benchmark, we get that proposed one is 1.06 times better than existing one.

V. CONCLUSION

In this paper, a hybrid metaheuristic technique ABC-PSO protocol is implemented and analysed with existing protocol ACO-PSO based metaheuristic technique using MATLAB. This paper describes the procedure to choose the appropriate CH. ABC-PSO multipath routing protocol gives fast searching features in the routing process. In the proposed method the behaviour of sensor nodes as an employee bee, onlooker bee, scout bee are described to achieve shortest path to the sink node. Network lifetime, residual energy and throughput analysis is compared with existing one and simulation show that the proposed one is better than the existing one. In future, we can implement other metaheuristic techniques which can increase the lifespan of a network.

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