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Hybrid PSO based Leach Algorithm for Reducing Energy Consumption in Wireless Sensor Networks

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ABSTRACT: An evolutionary algorithm for reducing energy consumption in wireless sensor networks (WSNs) is presented in this paper. Metaheuristic particle swarm optimization (PSO) algorithm and its variants is used for the selection of Cluster Head (CH) in such a manner so that its energy used uniformly with the delayed disintegration of the network. For this purpose, the LEACH algorithm, random clustering approach has been replaced by PSO clustering. The PSO variants G_{best} and L_{best} are used for clustering .A new hybrid PSO is also proposed for node clustering for which improved performance has been achieved. Simulation results show the improvement in energy conservation if we employ Hybrid PSO.

Keywords: Metahurastic Algorithm, Partical Swarm Optimization, LEACH Algorithm, Cluster head, Hybrid PSO

I. INTRODUCTION

Sensor networks have become valuable tool for monitoring a variety of scenarios. Energy is a serious issue in sensor networks, as the applications display a limited set of characteristics. Thus, there is a need to optimize the network architecture for the applications in order to minimize resource consumption. The requirements and limitations of sensor networks make their architecture and protocols both challenging and divergent from the needs of traditional Internet architecture. A sensor network [1] [2] is a network of many small, low power devices, called nodes, which are distributed in order to perform a global task. The sensor nodes, which consist of sensing, on board data processing component, and communicating components, directly influence the architecture WSNs [3] [4].

In WSN, tiny, low cost and low power sensor nodes are able to communicate with their environment by sensing or controlling physical parameters within a short range and work together to form a sensor network for gathering data from a field. The major concern in WSN is economic usage of energy of tiny and energy deficient nodes. A node collects data from its vicinity and then transfers it to base stations (BS). Communication is the most energy expensive activity of a node. Energy required to transmit varies exponentially with transmission distance therefore, it is advisable to use multi-hop communication in WSNs. A WSN's life-time largely depends on how efficiently it carries a data packet from its source to its destination.

The rest of paper is organized as follows.the brief description about routing protocols and LEACH Protocol is given in section 2 and section 3.Section 4 summarises the assumption and energy model used in this paper. In section 5, the brief overview of PSO and types of PSO is explained that are used in this paper. In section 6 results and detailed analysis of the changes carried out to PSO Algorithms.Finally we conclude the paper.

II. ROUTING PROTOCOLS

Routing Protocols in Wireless Sensor Networks can be classified as categorical and hierarchically based on the network topology. In flat routing, all nodes are assigned equal roles and similar functionality whereas in hierarchical routing, they exhibit different roles [5]. Hierarchical Protocols are based on the formation of clusters.

A.Flat Routing

In flat routing protocols nodes play the same role and have similar functionality in transmitting and receiving data. In this type of network it is not possible to specify a global identifier to each node due to a large number of nodes. Therefore, the base station sends queries to different parts of the field and waits for the data from sensors in selected parts of the field. This approach is called data centric routing [6]. SPIN (Sensor Protocols for Information via Negotiation) [7] and DD (Direct Diffusion) [8] are two examples of the data centric routing protocols that save energy by data negotiation and omitting the redundant data.

B.Hierarchical (Cluster-based) Routing

In this kind of routing method, nodes play different roles in transmitting and receiving data. Some of the nodes are responsible for processing and communication, while other nodes can be used for sensing the target area. Hierarchical routing is mainly considered as two layer architecture where one layer is engaged in cluster head selection and the other layer is responsible for routing. Cluster head in hierarchical routing is the node which is responsible for collecting data from other nodes in the cluster, aggregating

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all data and transmitting the aggregated data to the base station. Creating clusters and assigning communication task to cluster heads contributes to a more scalable and energy efficient network [6]. The main goal of all the hierarchical routing protocols is to appropriately create clusters and choose cluster heads in order to reserve energy in the network.
In this paper, we have used LEACH algorithm i.e the proposed PSO based scheme in LEACH.

III. LEACH PROTOCOL

LEACH (Low Energy Adaptive Clustering Hierarchy) is first proposed by Wendi B. Heinzelman of MIT. LEACH is a clustering-based protocol that uses a randomized rotation of the local cluster base station (CH) to evenly distribute the energy load among the sensors in the network [7]. LEACH uses localized coordination to enable scalability and robustness for dynamic networks, and incorporates data fusion into the routing protocol to reduce the amount of data that must be transmitted to base station. LEACH rearranges the network's clustering dynamically and periodically, making it difficult for us to rely on long lasting node-to-node trust relationships to create the protocol secure. LEACH assumes every node can directly contact a base station by transmitting with sufficiently high power. This protocol provides a concept of round. LEACH protocol runs with many rounds. Each round contains two phases:

A. Cluster Setup phase

Nodes that are clustered heads in round r shall not be selected in the next 1/p rounds. The node whose number is larger than the threshold will be selected as a cluster head. In a setup phase each node decides whether or not to become a cluster head for current round. The choice depends upon decisions made by the node by choosing a random number between 0 and 1. The threshold is set as:

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \, if \; n \in G \qquad (1)$$

Where,

p is the probability of the node being selected as a cluster-head node
r is the number of rounds passed
G is the set of nodes that have not been cluster-heads in the last 1/p rounds mod denotes modulo operator
Nodes that are cluster heads in round r shall not be selected in the next 1/p rounds. The node whose number is bigger than the threshold will select itself as the cluster-head. Then the CH will broadcast an advertisement message to inform their neighbourhood that it is the new cluster-head. The non-cluster nodes send the message containing their IDs by using CSMA (carrier sensing multiple access) to join a cluster with strongest signal strength.
After that, each CH knows its own member nodes information including the numbers and IDs. Based on the message, the CH creates TDMA schedule table and broadcasts it to the cluster members. So all the member-nodes know their idle slots, and then the steady-state phase starts.

B. Steady State phase

During the Steady-state phase, each node can turn off its radio until it senses the necessary data. The member nodes can send their data to CH during their allocated schedule table created during the set-up phase. As for the CHs, they have to keep up their communication status at all times so as to receive the data from their member nodes. When the CH receives all the data sent by their members, it will aggregate them at first and then send the aggregating data packets to BS in order to save energy.

IV. SIMULATION METHODOLOGY

A. Experimental setup:

To simulate LEACH, we have used random 100-node networks for our simulations with parameters used in [10]. We placed the BS at a far distance from all other nodes. For a 50m x 50m plot, our BS is located at (25, 150) so that the BS is at least 100m from the closest sensor node.

B. Energy model for LEACH

100 pJ/bit/m2 have power control and can expend the minimum required energy to reach the intended recipients. The equations used to calculate transmission costs and receiving costs for a k-bit message and a distance d are shown below:
Equations written as:
(i) Transmitting

$$ETx\,(k,d) = Eelec * k + Eamp * k * d2 \qquad (2)$$

(ii) Receiving

$$ERx(k) = Eelec * k \qquad (3)$$

C. Parameter selection for simulation:

Following is the list of parameters required for the simulation of LEACH with encryption strategies.
The corresponding value of each parameter is also specified.

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Vol. 3, Issue 1, January 2014

Table 1. Parameter setting for simulation.

Length	Length of the field Area	100 m
Width	Width of the field Area	100 m
Num_Nodes	Total number of nodes	100
bsX	x coordination of base station	50 m
bsY	y coordination of base station	200 m
max_Round	No. of Max Round	9999
ctrPacketLength	Length of packet that sent for nodes to CH	200 bits
PacketLength	Length of packet that sent for CH to BS	6400 bits
initEnergy	Initial energy of each node	0.5nJ
transEnergy	Energy for transferring of each bit (ETX)	50 nJ/bit
recEnergy	Energy for receiving of each bit (ETX)	50 nJ/bit
fsEnergy	Energy of free space model	10e-12 J/bit
mpEnergy	Energy of multi path model	1.3e-15 J/bit
aggrEnergy	Data aggregation energy	5e-9 J/bit

D.Node deployment

In node Deployment,100 nodes positions are generated randomly in a 100*100 m2 area and a BS is also placed at (50, 200) position

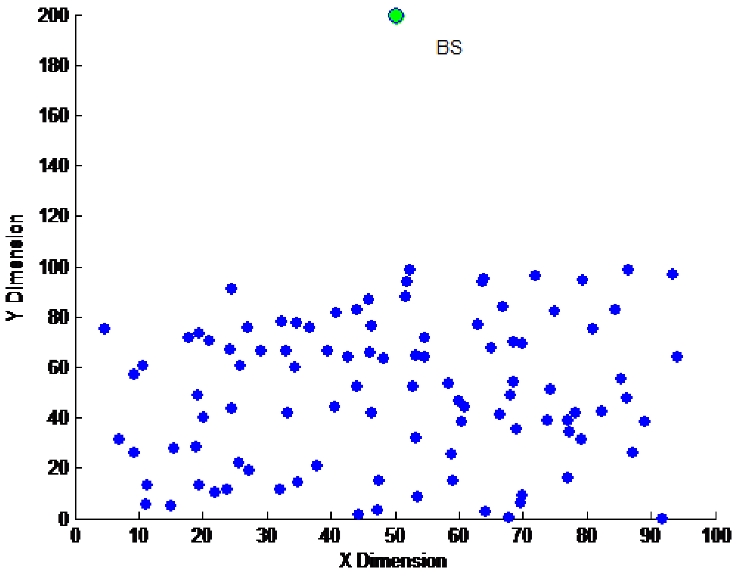

Fig 1: WSN Node Deployment

V. Particle Swarm Optimization(PSO) based LEACH Protocol

LEACH-PSO is a population-based a biologically inspired algorithm which applies to concept of social interaction to problem solving where each individual is referred to as particle and represents a candidate solution. Each particle in PSO flies through the search space with an adaptable velocity that is dynamically modified according to its own flying experience and also flying experience of other particles using the following equations.

$$v_i^d(t+1) = w \times v_i^d(t) + \varphi_1 \times rnd() \times (p_i^d - x_i^d(t)) + \varphi_2 \times rnd() \times (p_g^d - x_i^d(t))$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \quad (4)$$

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Where

$v_i^d(t+1)$ is a velocity vector at t+1 time for i particle in $\boldsymbol{d}$ dimension

$x_i^d(t+1)$ position vector at t+1 time for i particle in $\boldsymbol{d}$ dimension

$\boldsymbol{rnd}()$ is random number generator.

φ_1 and $\varphi_2$are learning rates governing the cognition and social components.

$\boldsymbol{g}$ represents the index of particle with best p-fitness.

$\boldsymbol{w}$ is the inertia factor that dynamically adjusts the velocities of particles gradually focusing the PSO into a local search.

A.Algorithm

1.Initialize the particle population by randomly assigning locations (X-vector for each particle) and velocities (V-vector with random or zero velocities- in our case it is initialized with zero vector)
2. Evaluate the fitness of the individual particle and record the best fitness Pbestand update P-vector related to each P_{best}.
3. Also find out the individuals' highest fitness Gbest and record corresponding position page.
4. Modify velocities based on P_{best} using eq3.
5.Update the particles position using eq4.
6.Terminate if the condition is met
7.Go to Step 2.

B.Types of PSO

1) G_{best}PSO:

In equation (5) above, new velocity at t+1 is generated with the help of global fitness which all the particles have achieved till iteration t. This equation is reproduced for easy understanding.

$$v_i^d(t+1) = w \times v_i^d(t) + \varphi_1 \times rnd() \times (p_i^d - x_i^d(t)) + \varphi_2 \times rnd() \times (\boldsymbol{p_g^d} - x_i^d(t)) \quad (5)$$

In this equation, p_g^d (given in bold) is position given by the global best fitness in dimension d. Usually, global best fitness concept is expected to present a global search exploration possibilities in the search space.

2)L_{best} PSO:

A good optimization algorithm is expected to have both types of search capabilities i.e. global as well as local. Local search capability is provided in PSO by p_i^d which is i[th] individual best fitness based position till iteration t+1; this is expected to give a local search capability. Another concept of local search capability is L_{best} PSO in which instead of taking global best fitness till iteration t+1 we take local best fitness based position in above equation in place of p_g^d. And above equation become

$$v_i^d(t+1) = w \times v_i^d(t) + \varphi_1 \times rnd() \times (p_i^d - x_i^d(t)) + \varphi_2 \times rnd() \times (\boldsymbol{p_l^d} - x_i^d(t)) \quad (6)$$

3) Hybrid PSO:

A new PSO is proposed here which contains the concept of both types of PSO i.e G_{best} and L_{best}. In this for having both types of search capabilities, we have divided social learning rate into two parts φ_2 *and* φ_3 and velocity at t+1 is determined by three components i.e individual best positions, global best position and last iteration best position.

$$v_i^d(t+1) = w \times v_i^d(t) + \varphi_1 \times rnd() \times (p_i^d - x_i^d(t)) + \varphi_2 \times rnd() \times (\boldsymbol{p_g^d} - x_i^d(t)) + \varphi_3 \times rnd() \times (\boldsymbol{p_l^d} - x_i^d(t)) \quad (7)$$

Table 2 : PSO parameters for experiment

Sr. No.	Type of PSO	Parameters
1	G_{best} PSO	Population Size =30,
2	L_{best} PSO	Population Size =30,
3	Hybrid PSO	

VI. Simulation Results and Analysis

Following table shows the result obtained from the experimentations done as per the setup .In this setup ,three algorithm based on PSO and its varients are used and efficiency of algorithm are measured by assessing total no .of rounds up to which network surives and find out that the hybrid PSO is better than that of two i,e G_{best} PSO and L_{best} PSO. Here we are using three objectives i,e no.of packets sent to BS From cluster head , No of dead nodes per round and Nodes Remaining Energy pattern in WSN and then the efficiency of network has been checked and we find out that the hybrid PSO is better.

Table 3: Experimentation Results

WSN Routing Algorithm	**Network Life (in rounds)**	**Rounds in which first Node Dead**	**Rounds in which 50% Node Dead**	**No of packets sent in total rounds**	**Remaining Energy after 70% node is dead (Joules)**
G_{best} PSO LEACH	1795	556	1255	11811	2.42
L_{best} PSO LEACH	1826	563	1271	11819	2.39
Hybrid PSO LEACH	2148	596	968	12338	1.81

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We have shown these statistics in the following figures.

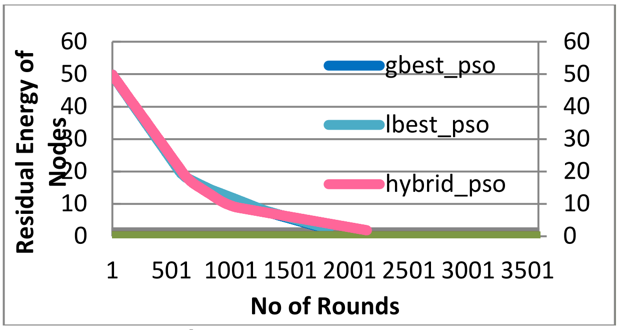

Fig 2. Nodes Remaining Energy pattern in WSN

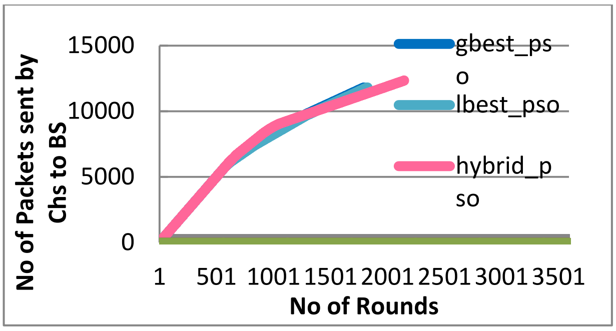

Fig 3. Number of Packets Sent to BS by CHs

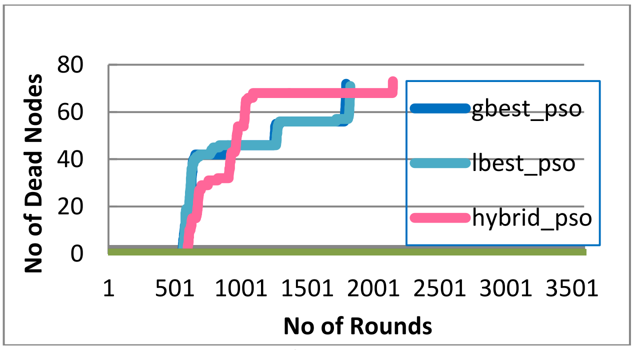

Fig 4. Number of dead nodes per round

VII. CONCLUSION AND FUTURE SCOPE

In this paper, the network life, number of dead nodes and number of packets are considered to sent BS affect performance of routing algorithm in WSN. The performance of the cluster based routing protocol shows some differences by varying life pattern among nodes and the number of dead nodes. From our experimental analysis, we conclude that Hybrid PSO based LEACH algorithm gives better performance in network life overall but could not restrict early network disintegration. . We have improved the network life but one thing; we have observed that node starts dying early which is an area of concern in PSO LEACH. This can be addressed by considering other parameters of nodes characteristics such as remaining node energy in addition to distance between them while clustering them. This technique may delay early node death problem.

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