PSO based Energy Efficient Routing Protocol using equal size clustering approaching Wireless Sensor Network

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Abstract— This research work examines the competing issues of energy consumption efficiency in wireless sensor networks. For this purpose, we considered a multi-objective Particle Swarm Optimization (PSO) in the selection of Cluster Head (CH) in such a way so that its energy is used uniformly with load balancing among clusters for delayed disintegration of network. LEACH algorithm based random clustering approach has been replaced by PSO clustering. The improved PSO protocol has been compared with random LEACH, Max Energy LEACH and k-means algorithm, and simple PSO which cluster only for space equi-distribution not for the load balancing among clusters., Wireless sensor network (WSN) is simulated using a MATLAB programming and power consumption algorithms take into consideration all aspects of power consumption in the operation of the node. Simulating different algorithm schemes on the same network system, same initial power sources, and routing protocol, an increase of overall system lifetime is demonstrated. The performance of PSO cluster based routing protocol shows improvements in lifetime but Max Energy LEACH perform better in network disintegration criterion

Keywords: Wireless sensor Network ,PSO, Leach, Energy Efficient Routing Protocol ,equal size clustering approach

I. INTRODUCTION

Wireless sensor networks consist of numerous but very tiny electronic devices called nodes which collect data from their surrounding environment and then send it to base station for further analysis and forecasting. The analyzed data is used to take managerial or business decisions. Sensor networks have become important tool for analyzing data in different types of problems and monitoring a variety of scenarios. This has provided the remotely monitoring capability of a physical environment for a wide variety of scenarios and problem context. These tiny nodes are self organizing which provide distributing computing capability in the network. Distributing computing make network flexible to adopt variety of methods for deployment, security enforcement, routing and data dissemination. Energy efficiency is a real concern in WSN as tiny nodes have a limitation of limited battery power. Energy is a serious issue in sensor networks, as the applications display a limited set of characteristics. Therefore, there is a need to optimize the network architecture for the applications in order to minimize resources consumption. These types of requirements and limitations make WSN architecture and different protocols both challenging and divergent.

II. PROTOCOL USED IN SIMULATION

In this thesis, we have used LEACH algorithm i.e. random cluster (simply called random LEACH), max energy based clustering (called max energy LEACH), k-means LEACH and the proposed GSA based scheme in LEACH. Our main idea in this thesis is to improve energy conservation in WSN.

A. LEACH Protocol

Low Energy Adaptive Clustering Hierarchy (LEACH) first proposed by Wendi B. Heinzelman of MIT in 2002. It is a clustering-based protocol that utilizes randomized rotation of local cluster base station (CH) to evenly distribute the energy load among the sensors in the network. The 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 information that must be transmitted to base station. It rearranges the network's clustering dynamically and periodically, making it difficult for us to rely on long lasting node-to-node trust relationships to make the protocol secure. LEACH assumes every node can directly reach a base station by transmitting with sufficiently high power.

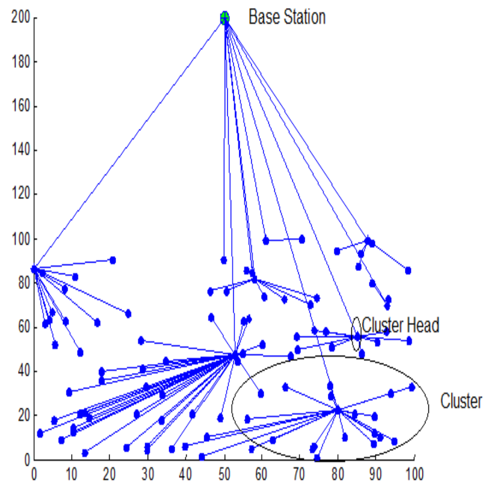

Fig. 1: Leach Routing Topology

This protocol provides a concept of round. LEACH protocol runs with many rounds. Each round contains two phases:

- Cluster setup phase
- Steady phase

1) Setup phase

Each node decides whether or not to become a cluster head for current round. The selection depends on decision made by the node by choosing a random number between 0 and 1.The threshold is set as:

$$T(n) = p/1 - p\left(rmod\left(\frac{1}{p}\right)\right) \ if\ n\ belongs\ to\ G$$

T(n)=0 otherwise

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 neighborhood 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.

2) 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. The problems of LEACH Algorithm:

- Because the election strategy of cluster head is random, it may cause misdistribution of cluster head in the network making each cluster head load unbalanced, and which ultimately results in early death of cluster heads.
- LEACH arrangement can only be used for small wireless sensor networks. Between base station and cluster head use the single route choice model.
- LEACH protocol has many assumptions, such as assuming that all nodes in the network have the same structure and start with the same energy, and nodes can be aware of their residual energy, and so on.

In this method, the cluster head consumes more energy for receiving, processing and directly sending this data to the BS node. So for increasing the life time of the network it is necessary to replace role of cluster head between network nodes.

In our simulation we have used LEACH-C which is again proposed by Heinzelman et al. in 2002 in which Base station takes the role of deciding about cluster heads (CHs) and cluster formation. As from the starting node locations are fixed and can be fed to BS for calculation a lot of energy can be saved by WSN in such computation by nodes. Once CHs are calculated and clusters are formed this information in advertised to all nodes in WSN to prepare them for real data communication in steady state.

III. OBJECTIVE OF DISSERTATION:

The proposed work is about to use some metaheuristic based technique as a cluster algorithm such as Particle Swarm Optimization (PSO) for finding an optimal clustering scheme instead of using some random method, thus using less energy and more rounds of transmission to BS. For this, it will combine few parameters such as Distance and balanced clusters as basis parameter for clustering. The proposed system is supposed to increase the overall network life time of WSN. The proposed scheme will use plain aggregation of data.

So, we set following objectives for our thesis work:

- To propose own modified algorithm of PSO based equal clustering.
- To simulate the proposal.
- To verify and validate the results by comparing it with different LEACH algorithms.

IV. SIMULATION METHODOLOGY & ENVIRONMENT

A. Proposed Methodology:

Wireless sensor networks (WSNs) are composed of a massive number of cheap battery-powered sensor nodes with wireless communication capability. They sense environmental information such as humidity, temperature, sound, light and motion, and special nodes referred to as sink nodes collect the sensed data to produce useful analysis outputs. The performance of a WSN is limited by battery power, low computing capacity, short wireless transmission range and hostile environments. In wireless sensor networks, sensor nodes are capable of not only measuring real world phenomena, but also storing, processing, and transferring these measurements. Many techniques have been proposed for disseminating sensing data. However, most of them are not efficient in the scenarios where a huge amount of sensing data are generated, but only a small portion of them are queried. WSNs are widely used in various applications for tracking or surveillance purposes. Border security monitoring and terrorist attack prevention are just two of many crucial homeland security applications which rely upon WSN technologies.

B. Experimental Setup:

To simulate LEACH, we have used random 100-node networks for our simulations with similar parameters used in [9]. We placed the BS at a far distance from all other nodes. For a 100m x 100m plot, our BS is located at (50, 200) so that the BS is at least 100m from the closest sensor node.

1) Energy Model for LEACH

We use the same energy model as discussed in [6] which is the first order radio model. In this model, a radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and E_{amp} = 100 pJ/bit/m^2 for the transmitter amplifier. The radios have power control and can expend the minimum required energy to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions. The equations used to calculate transmission costs and receiving costs for a *k*-bit message and a distance *d* are shown below:

2) Transmitting

E_{Tx} (k, d) = E_{elec}*k + E_{amp} * k* d^2 ………………..(1)

3) Receiving

E_{Rx}(k)=E_{elec}*k…………...………………………..(2)

Receiving is also a high cost operation, therefore, the number of receives and transmissions should be minimal. LEACH also uses the same constants (E_{elec}, E_{amp} , and k) for calculating energy costs, therefore the LEACH achieves its energy savings by minimizing d and the number of transmissions and receives for each node.

In our simulations, we used a control packet length *k* of 200 bits to send information from non-CH node to CH node. Size of packet length *K* of 6400 bits is fixed to send information from CH node to BS. With these radio parameters, when d^2 is 500, the energy spent in the amplifier part equals the energy spent in the electronics part, and therefore, the cost to transmit a packet will be twice the cost to receive. It is assumed that the radio channel is symmetric so that the energy required to transmit a message from node *i* to node *j* is the same as energy required to transmit a message from node *j* to node *i* for a given signal to noise ratio (SNR).

In order to understand the necessity of routing protocols and their benefits we briefly describe the power consumption model for WSN devices. The communications channel can be modeled by using the long distance path loss model and ignoring more complex effects such as fading and multi-path. Thus, the power required by a node to transmit over a distance of d meters can be expressed as:

PT(d)=P0×(d0/d)α.. (3)

Where P0 represents the power of the signal received at distance d0 from the source and α is the path loss exponent which is dependent on the propagation environment and can take values between 2 and 5. Also, using the path loss model and the Friis model the power received at distance d from the node can be expressed as:

PR(d)=Ptx/(β×dα)……………………………….(4)

where Ptx is the RF power delivered to the antenna of the transmitting node and β is parameter specific to the characteristics of the transmitting and receiving antennas. Therefore we can determine that the power required to make a single hop transmission between two nodes is equal to PT + PR. The power required to make a multi hop transmission between n nodes is
(n-1) × (PT + PR).

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

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
ctrPacketLen.	Length of packet that sent for nodes to CH	200 bits
PacketLen.	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/b
recEnergy	Energy for receiving of each bit (ETX)	50 nJ/b
fsEnergy	Energy of free space model	10e-12 J/b
mpEnergy	Energy of multi path model	1.3e-15 J/b
aggrEnergy	Data aggregation energy	5e-9 J/b

Table. 1: Parameter setting for simulation.

D. Random LEACH in WSN:

In Random LEACH, each node has equal opportunity to be selected as cluster head (CH) with a probability *p*. The probability function is normal distribution function spread over every 10 rounds. It doesn't care about the energy a node is having. To become cluster head a node must be live and should have sufficient energy to send data to BS. After selection of cluster heads every node selects its cluster head on the basis of distance. Node selects its cluster head which is closest to its position. The following algorithm specifies the concept of random LEACH.

Step 1: Find the nodes that are alive Nodes that are not of type dead nodes are alive.

Step 2: In alive nodes randomly find whether a node is selected as a CH. Probability of selecting a node as CH is pre decided.

Step3: Attach nodes to nearest CH to form cluster by finding distance matrix to form cluster.

E. Max Energy LEACH Algorithm:

In contrast to Random LEACH, Max Energy LEACH selects cluster head (CH) to those nodes which as the maximum energy. In this algorithm first all nodes are sorted as per their energy status in each round and then first k nodes are selected as CH. After selection of cluster heads every node selects its cluster head on the basis of distance. Node selects its cluster head which is closest to its position. The following algorithm specifies the concept of maximum LEACH.

Step 1: Find the nodes that are alive. Nodes that are not of type dead nodes are alive.

Step 2: In alive nodes find p*livenodes number of node which have maximum energy in nodes architecture is selected as a CH. Probability p of selecting a node as CH is pre decided.

Step3: Attach nodes to nearest CH to form cluster by finding distance matrix to form cluster.

F. K-Means LEACH Algorithm:

K-means is a simple algorithm that has been adapted to many problem domains. As we are going to see, it is a good candidate for extension to work with fuzzy feature vectors. The following code snippet gives an idea of implementation of k-means in WSN environment. The algorithm for this is given below:

Step 1: Find the nodes that are alive. Nodes that are not of type dead nodes are alive.

Step 2: In alive nodes using some standard clustering algorithm such as k- means or k-medoid for spatial distribution of nodes in clusters.

Step 3: In the next step, from each cluster CH is chosen on the basis of surplus energy, its position in cluster and its distance from Base Station, a node is having. So this scheme involves both things spatial distribution as well as energy distribution in the network architecture which may ultimately improve the network life and its quality.

G. Particle Swarm Optimization (PSO) based 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.

$$v_{id}^{t+1} = w \times v_{id}^{t} + r_1 \times c_1 \times \left(p_d^g - x_{id}^t\right) + r_2 \times c_2 \times \left(p_{id}^l - x_{id}^t\right) \text{---------} \quad (1)$$

$$x_{id}^{t+1} = x_{id}^{t} + v_{id}^{t+1} \text{-------------------------} \quad (2)$$

Where

- v_{id}^{t+1} is a velocity vector at t+1 time for i particle in dth dimension.
- x_{id}^{t+1} position vector at t+1 time for ith particle in d dimension.
- $r_{1,}r_2$ are random number generators.
- $C_1$and C_2 are learning rates governing the cognition and social components.
- p_d^g represents the particle with best p-fitness.
- W is the inertia factor that dynamically adjust the velocities of particles gradually focusing the PSO into a local search.

1) PSO Algorithm

- 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)
- Evaluate the fitness of the individual particle and record the best fitness P_{best} for each particle till now and update P-vector related to each P_{best}.
- Also find out the individuals highest fitness G_{best} and record corresponding position p_g.
- Modify velocities based on P_{best} and G_{best} position using eq3.
- Update the particles position using eq4.
- Terminate if the condition is met.
- Go to step 2

In equation (1) above, new velocity at *t+1* is generated with the help of global fitness which all the particles have achieved till iteration *t*. In this equation, position given by the global best fitness in dimension d. Usually, global best fitness concept is expected to give a global search exploration possibilities in the search space.

The following parameters have been taken for PSO:

Sr. No.	Type of PSO	Parameters

1	G_{best} PSO	Population Size =20 W=0.7 C1=2.8 C2=1.8 Total generation=150

Table. 2: PSO parameters for experiment

H. Proposed Algorithms:

The above PSO algorithm consider only inter-cluster distance as objective function. This serves the concept of equi-space distribution but does not address the concept of load balancing among clusters. For better clustering and load balancing a multi-objectives fitness function is required. The following steps show this concept:

Step 1: Find the nodes that are alive

Nodes that are not of type dead nodes are alive.

Step 2: In alive nodes using PSO clustering algorithm for spatial distribution and load balancing among nodes in clusters.

Step 3: In the next step, from each cluster CH is chosen on the basis of surplus energy only a node is having. So our proposed scheme involves both things spatial distribution as well as load distribution in the network architecture which may ultimately improve the network life and its quality.

I. Energy Dissipation in WSN:

Finally when clusters are formed then packets are sent from non-CH nodes to CH nodes and finally CHs nodes sent their packets to BS. The CHs also consumes energy in data aggregation and receiving. All nodes consume transmitting energy. This is shown below:

Energy dissipation for nodes is a factor of distance from BS. This decides whether to use free space or multipath transmitter. In our simulation we take a distance d0 as d0 = sqrt(Efs/Emp). This becomes the criterion for using free space energy or multipath energy scenario. Every cluster node consumes its energy for transmission of data in circuitry, receiving of data from non cluster head nodes, data aggregation and data radiating to BS.

nodes.Energy(k) = nodes.Energy(k) -((ETX+EDA) * packetLength + Emp * packetLength * (dist ^ 2)); for free space

nodes.Energy(k) = nodes.Energy(k) -((ETX+EDA) * packetLength + Emp * packetLength * (dist ^ 4)); for multipath

While for non-CH nodes energy is consumed in sending data to CH.

V. SIMULATION RESULTS & ANALYSIS

A. Results Analysis:

Following table shows the results obtained from the experimentations done as per the setup explained in the previous section. Four algorithms have been implemented in this thesis. In first algorithm i.e. Random LEACH algorithm is implemented where Cluster Heads (CHs) are selected randomly based on a probability function. We have taken this probability as 10%. It is further improved by using a fair distribution of energy by selecting maximum energy nodes to be CHs. In this method a fix number of CHs are selected based on the number of nodes that are living. Another modification is made in third algorithm where nodes are clustered based on inter distance by using a standard algorithm such as K-means algorithm. The problem with K-means is that its performance is based on initial centers chosen by the algorithm. To alleviate this we have further used a metaheuristic algorithm namely PSO (Particle swarm optimization) in which fitness of particles are found based on sum of the distance measures of each nodes from its cluster head in order to provide effective optimization or clustering. We need to minimize this distance. This is called single objective PSO also called SOP-LEACH. Further an improvement has been made in SOP-LEACH by measuring fitness based on distance as well as number of nodes in the clusters. This is called multi-objective PSO also called MOP-LEACH. We measure algorithm efficiency by assessing total number of rounds up to which network survives. A network is assumed to be live if more than 25% nodes are alive with total energy greater than zero.

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 75% node is dead (Joules)
Random LEACH	626	108	380	11501	3.21
Max_Energy LEACH	1292	1267	1292	12895	0.0087
K-means LEACH	1842	21	978	10519	9.57
SOP	1615	12	878	9144	9.72
MOP	4958	50	1642	22152	0.013

Table. 3: Experimentation Results

B. Figures:

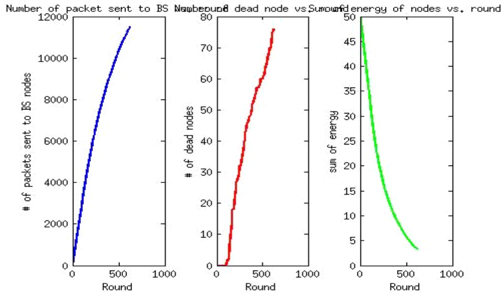

Fig. 5.1: Experimentation Results for Random LEACH

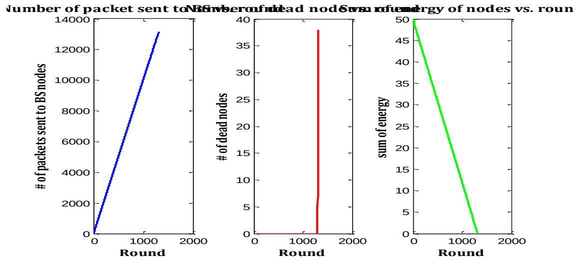

Fig. 5.2: Experimentation Results for Max Energy LEACH

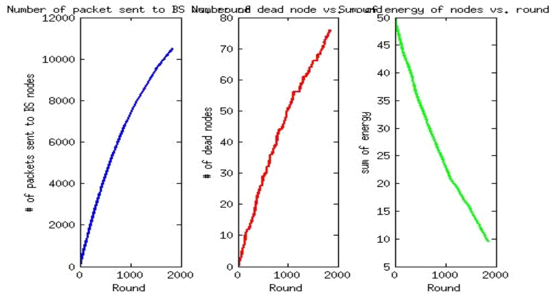

Fig. 5.3: Experimentation Results for Max Energy LEACH

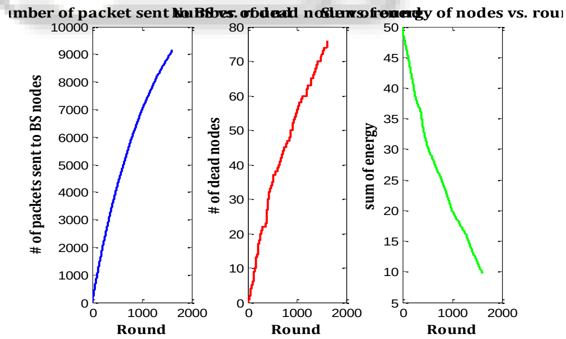

Fig. 5.4: Experimentation Results for Single Objective PSO-LEACH (SOP)

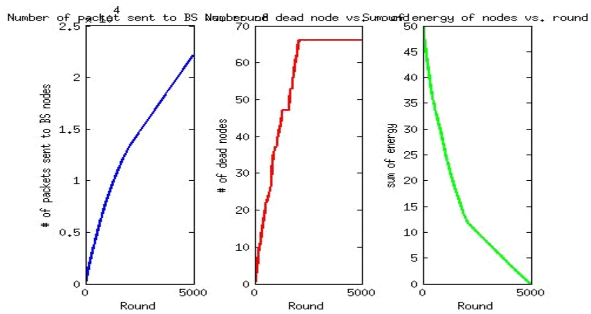

Fig. 5.5: Experimentation Results for Multi Objective PSO-LEACH (MOP)

VI. CONCLUSION FUTURE DEVELOPMENTS

We have measured performance of five algorithms in these experiments. Parameters for performance measurements are Residual Energy, Dead Nodes, Packets sent to BS. These parameters are shown in above figures and are plotted against number of rounds. If we consider residual energy and total number of rounds then MOP-LEACH performs better than SOP-LEACH, K-means based LEACH, Max Energy LEACH and random LEACH. But residual energy at the end of total number of round shows that MOP-LEACH and Max Energy LEACH most uniformly distributes energy dissipation among nodes than SOP-LEACH performs. For network integration or dead nodes criterion Max Energy LEACH performs far better than other algorithms. For number of packets sent to BS criterion MOP-LEACH performs better than other algorithms. gray area which remains a point of concern is early death of nodes in MOP-LEACH. It needs to be addressed by systematic assignment of variable number of nodes to clusters.

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