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GA Based Balanced Clustering Approach for Energy Efficiency in WSN

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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 modified Genetic Algorithm (GA) 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 LEACH algorithm based random clustering approach has been replaced by GA clustering. The improved GA protocol has been compared with random LEACH, Max Energy LEACH and k-means algorithm, and simple GA 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 GA cluster based routing protocol shows improvements in lifetime but Max Energy LEACH perform better in network disintegration criterion.

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. WSN has evolved as a completely different technology as compared to standard traditional Internet architecture.

II. ROUTING PROTOCOLS IN WSN

Two main classes of routing protocols in Wireless Sensor Networks can be named as flat and hierarchical. In flat routing, all nodes are assigned equal roles and similar functionality whereas in hierarchical routing, they are assigned different roles. In hierarchical protocols clusters are formed. 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 all data and sending 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. 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.

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LEACH Protocol

Low Energy Adaptive Clustering Hierarchy (LEACH) first proposed by Wendi B. Heinzelman of MIT 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 [3]. 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.

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

A. 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:

$$T(n) = \frac{p}{1-p*\left(r \bmod \frac{1}{p}\right)} \text{If } n \in G$$

$$T(n) = 0 \text{otherwise}$$

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 neighbor-hood 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.

B. Steady 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.

The surveys dealing with WSN clustering protocols can be found in [1,4]. N. M. Abdul Latiff, C. C. Tsimenidis, B. S. Sharif [2] presented an energy-aware cluster based protocol for wireless sensor networks using Particle Swarm Optimization (PSO) algorithm. He had defined a new cost function that takes into account the maximum distance between the non-cluster head node and its cluster head, and the remaining energy of cluster head candidates in the cluster head selection algorithm. Ayon Chakraborty, Kaushik Chakraborty, Swarup Kumar Mitra, M.K. Naskar [5] presented An Energy Efficient Scheme for Data Gathering in Wireless Sensor Networks Using Genetic Algorithm. In this paper a novel data gathering protocol was proposed for enhancing the network lifetime by optimizing energy dissipation in the nodes. To achieve the design objective it uses applied particle swarm optimization (PSO) with Simulated Annealing (SA) to form a sub-optimal data gathering chain and devised a method for selecting an efficient leader for communicating to the base station.

Buddha Singh, D. K. Lobiyal [7] presented particle swarm optimization (PSO), a technique which is known for its easy implementation and fast convergence. In this paper, it has applied PSO for optimizing the cluster heads location on the basis of our objective function. The PSO ultimately reduces the communication distance by locating optimal position of the cluster head nodes in the cluster. The proposed technique is implemented within the cluster rather than base station, which makes it a semi-distributed approach. The proposed technique shows better performance in terms of network lifetime, average number of packets sent and energy consumption.

M. Natarajan, R. Arthi, K. Murugan [6] presented Energy Aware Optimal Cluster Head Selection in Wireless Sensor Networks. The proper organization of nodes becomes one of the major techniques to expand the life span of the whole network through aggregating data at the cluster head(CH). LEACH (Low Energy Adaptive Clustering Hierarchy) and particle swarm optimization (PSO) are applied for producing energy-aware clusters with optimal selection of cluster head. The work is simulated using NS-2 and the performance metrics are analyzed. Energy aware cluster head selection using LEACH and PSO are implemented in the wireless sensor networks. The selection of a cluster head using PSO minimizes the intra cluster distance between cluster head and the cluster member, and the optimization of energy management of the network. From the simulation results, it is seen that Energy-aware Optimal cluster head selection using PSO approach increases the network lifetime of the cluster in such a way by reducing the total energy consumption than LEACH implementation.

Choon-Sung Nam [8] presents a method to divide unequal cluster size into equal cluster size for balance of energy consumption in a local cluster. In case the number of member nodes per a local cluster is more or less than average number of member nodes, this cluster could be an unequal cluster. To solve unfairness among local clusters, it re-selects cluster heads using by distance between cluster heads and between member nodes and a cluster head.

At present routing in routing in WSNs is a hot research topic, with a limited but rapidly growing set of efforts being published? In this thesis we have conducted a survey of the various latest routing protocols in WSNs assuming underlying base of these protocol as LEACH and PEGASIS. We considered a comparison of the routing protocols discussed in the thesis in terms of clustering manner, intra-cluster topology, and cluster head selection. Although the performances of these protocols are encouraging for improving scalability of large-scale WSNs, some issues remain to be considered. For clustering in data mining several meta-heuristic techniques such as GA, PSO are being used actively. These can be effectively used in clustering of nodes in WSN environment where equi-distribution of space and energy are the real concerns for enhancing the lifetime of network. Embedding these algorithms in the routing design is desirable.

III. PROBLEM FORMULATION

Clustering is the main factor responsible for the energy conservation in LEACH algorithm. Main objectives of clustering are equal distribution of energy and equal distribution of nodes in space so that less energy is consumed and early deaths of nodes can be delayed. In LEACH both of these objectives can't be achieved. Further to achieve these objectives a Max-Energy LEACH was proposed, in which CHs are chosen based on residual energy instead of random selection. Max-Energy LEACH steps are shown below:

1. **Cluster head selection stage:** CHs are chosen based on residual energy. Highest energy nodes are selected to work as CH.
2. **Cluster formation stage:** similar to LEACH.
3. **Energy consumption stage** in simulator.

Max-Energy LEACH is able to achieve energy equi-distribution but not space equi-distribution because CH can be selected from one region only leading to large energy consumption by nodes to send data to CHs. To achieve second objective some data clustering algorithm such as Genetic Algorithm (GA) can be used. The following steps can show GA based clustering in WSN routing.

1. **Cluster formation stage:** First nodes can be clustered using some heuristic techniques such as GA.
2. **Cluster head selection stage:** CH is chosen from each cluster based on residual energy. Highest energy node is selected to work as CH for the cluster.
3. **Energy consumption stage** in simulator.

Space equi-distribution and energy equi-distribution both objectives can be achieved by this method but still there can be scope for improvements. The clustering algorithm while doing its work should pay attention toward the number of nodes a cluster is having. If we can equi distribute all nodes to cluster then we assume that it may lead to better energy efficiency. This is our hypothesis. The cluster head is elected by obtaining the energy consumption in Intra-cluster and Inter-cluster, and then we could find the average energy of overall network. Finally, we proposed the re-electing cluster heads method for balancing local clusters. This method uses the information which the cluster heads have. This information is the number of member nodes and distance between the member nodes and the cluster head. This is called balanced energy based clustering. We propose to balance clustering in terms of number of nodes in clusters. We hereby propose to make efficient clustering of WSN nodes by using GA metaheuristic technique in such a way so that transmission energy of nodes used to send data to cluster head (CH) is minimized.

Choon-Sung Nam [8] presents a method to divide unequal cluster size into equal cluster size for balance of energy consumption in a local cluster. In case the number of member nodes per a local cluster is more or less than average number of member nodes, this cluster could be an unequal cluster. To solve unfairness among local clusters, it re-selects cluster heads using by distance between cluster heads and between member nodes and a cluster head. This method first select Ch and then readjust CH in such a way that load balancing occurs in clusters. Here we propose a method in which fitness function of GA is made in such a way so that it minimize the distance of limited nodes which will be part finally of the cluster. Our algorithm consists the following steps:

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

Step 2: In live nodes use GA for spatial distribution as well as equal distribution of nodes in clusters.

Step 3: In the next step, from each cluster CH is chosen on the basis of surplus energy. So our proposed 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.

IV. PROPOSED METHODOLOGY

To simulate LEACH, we have used random 100-node networks for our simulations with similar parameters used in [3]. 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. We use the same energy model as discussed in [3] which is the first order radio model.

Genetic Algorithm (GA) based LEACH

Genetic algorithms (GAs) are optimization technique initially inspired from the processes of natural selection and is considered good for searching nonlinear and discrete search spaces. Algorithm is started with a set of solutions (represented by chromosomes) called population. Solutions from one population are taken and form a new population through repetitive application of mutation, crossover, inversion and selection operators. This is motivated by a hope, that the new population will be better than the old one. Solutions which are selected to form new solutions (offspring) are selected according to their fitness – the more suitable they are the more chances they have to reproduce. This is repeated until some condition (for example number of populations or improvement of the best solution) is satisfied. The workflow of the algorithm is shown in the following figure.

1. Generate the M number of solution string known as parent population.
2. Evaluate fitness to each of the solution.
3. Select some of the best fit chromosomes from parent population according some selection criteria.
4. Crossover partial solution between pair of selected solution with some probability value to generate child population.
5. Change the value of an allele of child with some small probability value.
6. Evaluate child population and replace parent population.
7. Go to step 3 and repeat the process until termination criteria satisfies.

Figure 1. Genetic Algorithm Workflow

In software testing, objective of GA is to find the appropriate inputs which can execute the program for the target path. An individual input in program becomes the genes in a chromosome and a string of all input values is a probable solution to the problem and which is also called as an individual in GA.

Proposed Modified GA Algorithm

The above GA algorithm considers only inter-cluster distance as objective function. This serves the concept of equi-space distribution but doesn't 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 GA 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.

V. RESULTS

The following table shows the results obtained from the experimentation done as per the setup explained in the previous section. Five algorithms have been implemented in this thesis. In first algorithm i.e. Random LEACH algorithm is implemented where 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 meta-heuristic algorithm namely GA 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 GA also called GA-LEACH. Further an improvement has been made in GA-LEACH by measuring fitness based on distance as well as number of nodes in the clusters. This is called MOD-GA-LEACH. We measure algorithms' efficiency by assessing total no. 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.

Table 1 Experimentation Results

WSN Routing Algorithm	Remaining Energy after 75% node is dead (Joules)	Rounds in which first Node Dead FND	Rounds in which 50% Node Dead HND	Network Life (in rounds)	No of packets sent in total rounds
Random LEACH	8.0155	90	335	541	10293
Max_Energy LEACH	4.8305	1158	1192	1198	11878
K-means LEACH	14.3158	20	873	1596	9371
GA- LEACH	11.3362	20	938	1754	10150
MOD-GA-LEACH	1.2898	448	1047	1825	12618

In the table it is clearly shown that modified GA based clustering based LEACH algorithms perform far better as compared to other methods if we consider the number of rounds covered by the algorithms. Modified GA-LEACH algorithm performs nearly four times better than random LEACH and nearly double of max energy LEACH i.e. LEACH-C. If we consider a network, dead if 50% nodes are dead then Max Energy LEACH is performing better than K-means based LEACH and nearly equal to GA variants LEACH. Random LEACH has performed worst in every situation. If we consider 75% node criterion for network life then GA variants performs better than other three algorithms.

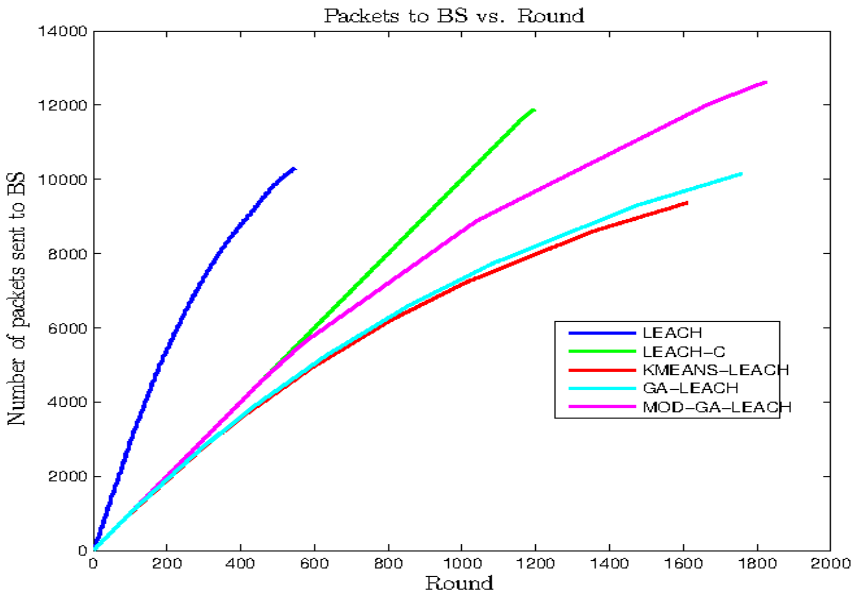

Figure 2: Experimental Results for Network Throughput

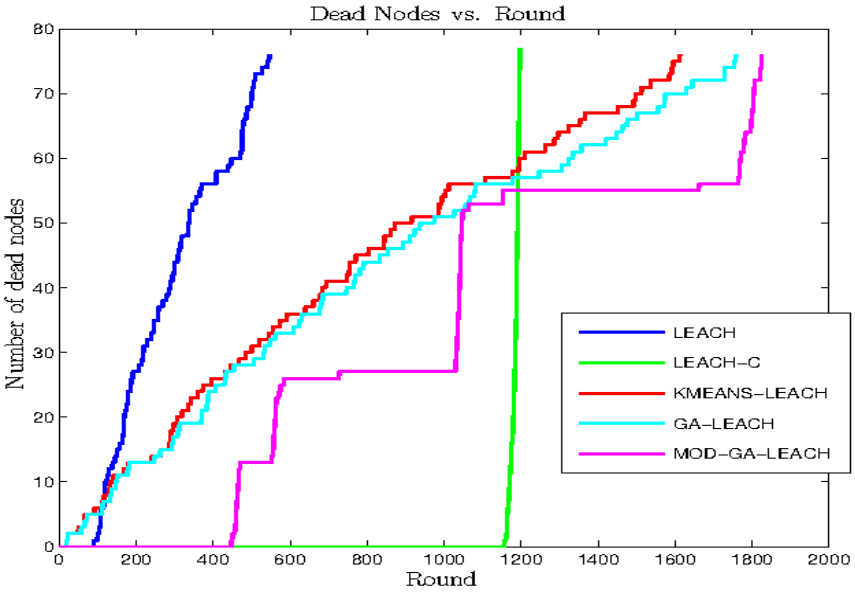

Figure 3:**Experimentation Results for Network Stability**

If we compare the number of dead nodes as per our simulation results Max energy LEACH seems to perform better, but there nodes once start dying accelerates network decay very fast. On one front random LEACH and K-means based LEACH algorithms are lacking (i.e. network disintegration) in this front. In these algorithms, first node is dead very early. Even MOD-GA is not performing well if we consider round number of first dead node. This is the grey area which needs to be addressed in future research.

If we consider no of packets sent to BS then Max Energy LEACH and MOD-GA-LEACH is clearly winner. Later has sent highest number of packets to BS but if we consider the ratio between packet sent and no. of rounds performed by the algorithm then Max Energy LEACH is clear winner in this. This can be confirmed by the following figures.

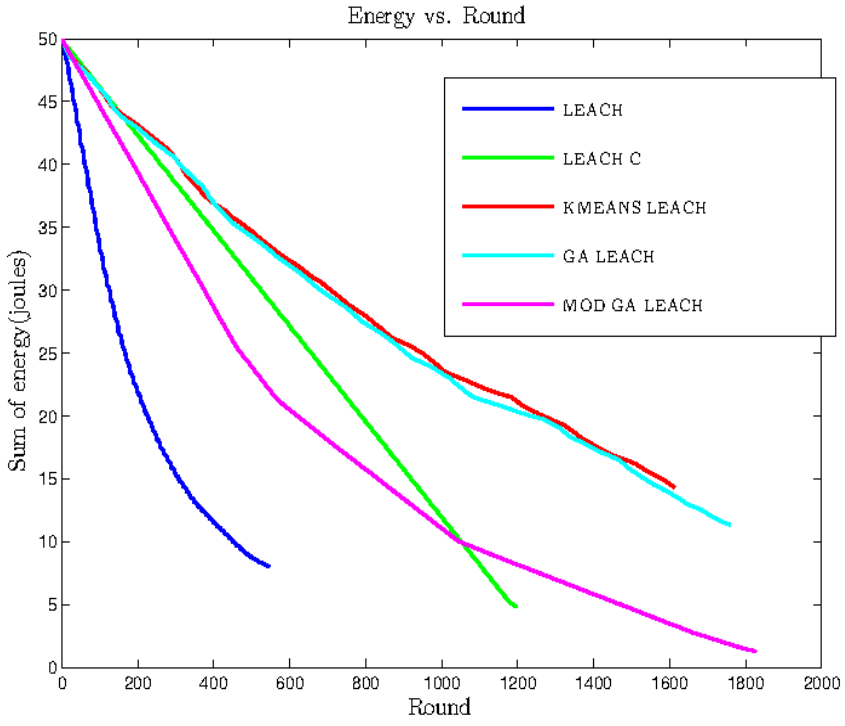

Figure 4: E**xperimentation Results for Network Energy and Life**

VI. CONCLUSION AND FUTURE SCOPE

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 MOD-GA-LEACH performs better than GA-LEACH, K-means LEACH, Max Energy LEACH and random LEACH. But residual energy at the end of total number of round shows that MOD-GA-LEACH, Max Energy LEACH most uniformly distributed energy dissipation among nodes and then GA based 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 hybrid GA and Max Energy LEACH performs better than other algorithms.

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