A Weighted Leach Algorithm for Energy Efficiency in WSN

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Abstract— This research work is related to energy consumption efficiency in wireless sensor networks. Here, we have considered a weighted or Hybrid LEACH-C algorithm in the selection of Cluster Head (CH) in such a way so that its energy is used uniformly with efficient CH selection among clusters for delayed disintegration of network. LEACH-C algorithm based clustering approach has been replaced by multi-objective CH selection method where we not only considered the residual energy of nodes but the position of CH in cluster structure and distance of CH from BS. The Hybrid LEACH-C protocol has been compared with random LEACH and Max Energy LEACH or existing LEACH-C algorithm for energy equi-distribution, network life, stability and throughput. 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 hybrid LEACH-C routing protocol shows improvements in lifetime but at the cost of network stability criterion.

Key words: LEACH-C, CH

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. Since WSNs are restricted in terms of bandwidth, battery and power consumption, a major goal in the design of WSNs is prolonging network lifetime. There are many challenges in WSN which should be considered and several should be addressed. Some of the major limitations facing the existing protocols are to fulfil the modern WSNs requirement can be listed as the following:

1) Limited energy resources: With the absence of a fixed infrastructure, wireless sensor nodes are forced to manage the small amounts of battery power, thus energy aware protocols are highly desired. Working only on battery power, also means, that after a certain life span, a sensor node will die, because the battery is empty. Among other things, this fact leads to serious security issues (see point 4), that have to be kept in sight.
2) Lower data rates: One of the major struggles of wireless networks in general is the low data rates. The quantity of data that can be transmitted in a period of time depends on the frequency that is used. A high frequency results in higher data rates, as a result interference issues are more prevalent. This proves that wireless networks cannot be as quick as the wired networks.
3) Communication failures: Wireless Networks have a higher error rate than their wired equivalent. They use electronic waves to transmit packets and these waves can be affected by unexpected occurrence event like reflection, refraction, diffraction or scattering. These events can splinter or corrupt the package, and that way produce error in transmission.
4) Security issues: Wireless Networks in general are much easier to attack from the outside, than wired systems. The wireless channel is accessible to unwanted listeners and several passive and active attacks can be accomplished. Methods like encryption are also limited by the energy resources that tend to be small in WSNs, which makes the problems stronger.

A. Flat and Hierarchical Routing Protocols:

Network routing protocols are in charge of routing scheme as well as maintaining the network structure in WSNs. There are three types of network structure: flat routing, hierarchical routing and location-based routing. However, in order to focus in our area of research, we present further discussion of only flat and hierarchical routing protocols.

1) 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 assign a global identifier to each node due to large number of nodes. Therefore, base station send queries to different part of the field and waits for the data from sensors in selected parts of the field. This approach is called data centric routing. SPIN (Sensor Protocols for Information via Negotiation) and DD

(Direct Diffusion) are two examples of the data centric routing protocols that save energy by data negotiation and omitting the redundant data.

2) 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 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.

Hierarchical Routing is a feasible solution for reducing energy consumption in WSNs. Within a cluster, cluster head manages the member nodes and assigns them tasks which lead to reduction in redundant data transmission. Moreover, cluster head has some responsibilities such as data collection and data aggregation from their respective cluster members. Energy consumption greatly reduced in this kind of routing method since the total data messages sent to the base station is minimized by data aggregation.

Hierarchical Routing effectively assigns each node different task according to the ability of that sensor node. This approach offers balanced distribution of energy in the network. It can achieve by selecting higher energy nodes to perform the responsibility of cluster heads while lower energy perform sensing duties in the target area. Hierarchical Routing can easily achieve collision free network by applying a proper MAC protocol. After creating clusters, it is the responsibility of the cluster heads to create a transmission schedule for the member nodes and broadcast it to all the nodes in its respective cluster. Sensor nodes send, receive and listen data based on the assigned time slot and sleep other times in order to conserve energy in the system. By using the hierarchical routing protocol the number of data collision between the nodes would be reduced.

3) 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 to evenly distribute the energy load among the sensors in the network [1]. 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.

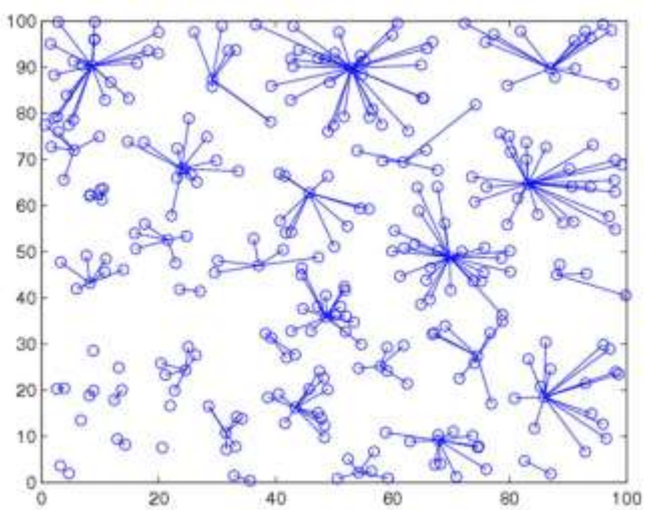

Fig. 1: Cluster Head Formation in LEACH Topology

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

1) Cluster setup phase
2) Steady phase

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:

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \quad if\ n \in G \tag{1}$$

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.

After that, each CH knows its own member nodes information including the numbers and IDs. Based on the message, the CH creates Time Division multiple Access (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.

The problems of LEACH Algorithm:

1) 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.
2) LEACH arrangement can only be used for small wireless sensor networks. Between base station and cluster head use the single route choice model.
3) 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.

MaxEnergyLEACH (LEACH Centralized) is a kind of improved LEACH. In MaxEnergyLEACH, the location information and the residual energy value of all the nodes will be sent to the base station at the beginning of each round. After receipting this information, the base station calculates the average energy value of all nodes, the nodes with residual energy higher than average are considered as the candidate, then the base station will select a group of cluster heads from the candidate using the simulated annealing to minimize the objective function. Finally the cluster head group will be broadcasted to the network. If the node's own ID is included in the cluster head group it received, the node will put itself as a cluster head; if not, the node will establish the contact with the corresponding cluster head, and transfer data to the cluster head in the corresponding TDMA slot.

In our simulation we have used MaxEnergyLEACH [1] 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. Related Work

Recently there has been increased interest in studying energy-efficient clustering algorithms in the context of both ad hoc and sensor networks. The main aim of clustering protocols in ad hoc networks is to generate the minimum number of clusters while maintaining network connectivity. In these algorithms the election of CHs is based mainly on the identity of nodes, the degree of connectivity or the connected dominating set. These techniques are discussed in depth in [2]. In the case of WSNs, the main objective of clustering protocols is to minimize energy consumption by the network in order to extend the network lifetime. The surveys dealing with WSN clustering protocols can be found in [3]. The WSN clustering protocols can be classified into two categories: probabilistic and deterministic. In probabilistic clustering protocols a node becomes a CH with a certain probability, which requires an exchange of overhead messages for the CH's election. In [Yunjie 2012] k-means based clustering technique is used and then CH is selected on the basis of residual energy, spatial position of nodes in the cluster.

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 two routing protocols namely LEACH and MaxEnergyLEACH discussed in the thesis in terms of clustering manner, intra-cluster topology, cluster head selection. Although the performances of these protocols are comparable, some issues remain to be considered. Till now no research have been made for finding the optimized density for WSN applications which uses LEACH based protocols. This thesis will make an effort toward this.

IV. Problem Formulation

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. MaxEnergyLEACH 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. The clustering algorithm while choosing its CH should pay attention toward the residual energy of nodes and distance it is having from base station. If we can consider position of cluster head and distance with residual energy that it may lead to better energy efficiency. This is our hypothesis.

V. Methodology

To simulate LEACH and MaxEnergyLEACH, we have used random number of node networks for our simulations with similar parameters used in [1]. We placed the BS at a far distance from all other nodes. For a 50m x 50m plot, our BS is located at (25,100) so that the BS is at least 50m from the closest sensor node.

We use the same energy model as discussed in [19] which is the first order radio model. In this model, a radio dissipates Eelec = 50 nJ/bit to run the transmitter or receiver circuitry and Eamp = 100 pJ/bit/m2 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.

A. Proposed Weighted or Hybrid LEACH Algorithm:

In contrast to Random LEACH and Max Energy LEACH, the Weighted LEACH selects cluster head (CH) to those nodes which gives least cost as three aggregated component averaged by three weights W1, W2 and W3. The sum of all the weight are 1. The cost component are position of node in cluster, energy consumed and distance from BS. In this algorithm first all nodes are clustered using minimum distance method and then from each cluster least cost node is selected CH. The following algorithm specifies the concept of Weighted LEACH.

1) Step 1: Find the nodes that are alive

Nodes that are not of type dead nodes are alive.

2) Step 2: Cluster the alive nodes in num_nodes/10 clusters.
3) Step3: For each node in every cluster compute three costs. COMP1, COMP2 and COMP3 by following equations
   comp1=sqrt((meanX-nodes.LocX(cluster(i).node(j)))^2+ (meanY-nodes.LocY(cluster(i).node(j)))^2); --------------(2)
   comp2=1-nodes.Energy(cluster(i).node(j))/0.5;-----------(3)
   comp3=sqrt((bs.x-nodes.LocX(cluster(i).node(j)))^2 +(bs.y-nodes.LocY(cluster(i).node(j)))^2);----------------(4)
4) Step 4: cost(node)=W1*comp1+W2*comp2+W3*comp3; -----(5)
5) Step 5: Select least cost nodes from each cluster as CH.
6) Step 6: for each cluster simulate energy dissipation.

VI. RESULTS ANALYSIS

If we take the weights where W1= 0.1, W2=0.4 and W3=0.5 where only energy is being considered it can be clearly understood that despite using energy effectively as it is having least remaining energy of all the combinations and best stability as first node is dead at more than half of total round and best network throughput as it has sent highest number of packets, its network life is Least of all. So if life is main factor then we should consider weighted LEACH or Hybrid LEACH. As far as weights are considered these can't be decided until we fix clustering.

Another observation we have made about Network stability. The network stability is measured by counting the number of rounds in which first node is dead called FND, Half node dead called (HND) and Last node dead (LND). If more than 75% nodes are dead then it is assumed that network is dead and so criterion of full node dead occurs, when 75% of nodes are dead. Max Energy LEACH has performed better than random LEACH in every situation may be it is first node dead or half node dead or full node dead. In fact, Max Energy LEACH doesn't start disintegrating untill 99% of rounds. But once it starts disintegrating it accelerates very fast and within a span of 20 or 30 rounds all the nodes expires their energy. This shows that Max Energy LEACH provides almost complete stability to the network.

WSN Routing Algorithm	Res. Energy	FND	HND	LND	PTBS
RandomLEACH	0.57	249	418	470	5903
MaxEnergyLEACH	0.49 1022 1030	1022 1035	1030	1035 5147	5147
HybridLEACH W1= 0.1, W2=0.4 W3=0.5	0.86	156	947	1475	4735

Table 1: Experimentation Results

Third criterion we have taken for observation is network throughput which is measured using number of packets sent to BS and percentage packets loss and number of packets sent per round and per node. There is no incident of packet loss. Packets loss occurs specially when network size is very large and that is also in LEACH. There is no incidence of packet loss in Max Energy LEACH. LEACH sent more packets as compared to Max Energy LEACH for the same densities however the numbers of rounds are double in Max Energy LEACH. This disparity may be due to variable and high number of CH selection in LEACH. This may be the reason which explains the high ratio of number of packets per round per node in LEACH as compared to Max Energy LEACH.

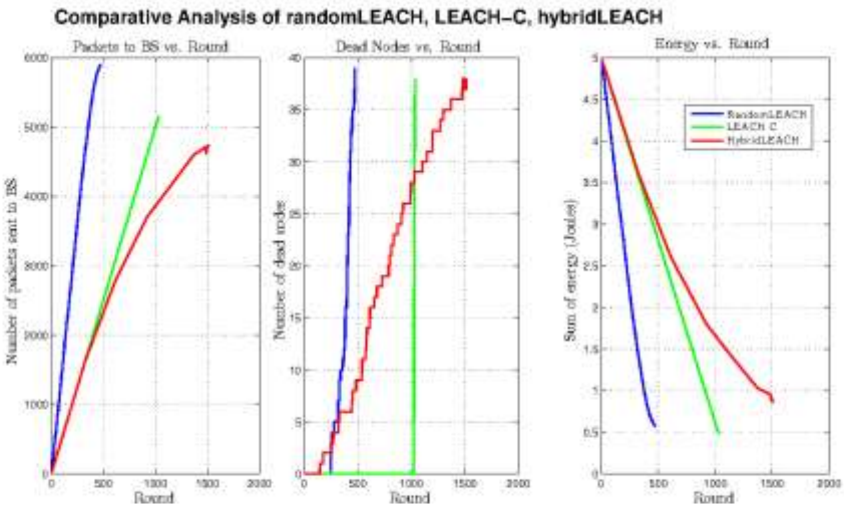

Fig. 2: Experiments Results for Network Throughput, Stability and Life for Three Algorithms

Figure 2 shows the comparison of energy efficiency, network stability and network throughput of all the three algorithms. Figure 2(a) shows the packets sent per round per node which is high for LEACH for all density perhaps due to uneven number of clusters made in LEACH.

Figure 2(b) shows the network stability in terms of process of nodes death by giving percentage number of rounds in which first node is dead and so on, which is given by FND, HND and LND in short. The FND for Max Energy LEACH is much higher than other two methods. HND and LND are also highest for this algorithm.

Figure 2(c) shows the % residual energy after completion of network simulation. It clearly shows that Max Energy LEACH is better than other algorithms. One more fact from figure 5.1 can be deduced that Max Energy LEACH gives consistent performance for this attribute. However Energy expanded per round is more for Hybrid or weighted LEACH taken from sr. no. 40. This again shows that better energy efficiency can be achieved by weighted LEACH.

VII. Conclusion

We have measured performance of LEACH, Max Energy LEACH and Hybrid LEACH algorithms for different node deployment densities. 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 Hybrid LEACH perform better than random LEACH and Max Energy LEACH. The residual energy at the end of total number of round shows that Hybrid LEACH most uniformly distributes energy dissipation among nodes. However different weights can't be determined until we fix clustering. For network integration or dead nodes criterion again Max Energy LEACH outperforms other algorithm. However, for number of packets sent to BS criterion the LEACH outperforms other algorithms. It may be due to uneven number of clusters made. .

One area where improvement can be made is equi-distribution of space in the nodes for better clustering and this need to be tested for different densities. This can be achieved by employing some clustering algorithm such as k-means or some heuristic algorithm. Uneven number of cluster formation can't be prevented but low throughput of algorithm need to be investigated further.

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