

Balanced-LEACH-C: An Algorithm for Efficient Energy Consumption in WSN

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Abstract— This paper considered a balanced LEACH-C algorithm in the selection of Cluster Head (CH) that achieves equidistribution of energy and node balancing among clusters that results in delayed network disintegration. LEACH-C algorithm is replaced by Balanced LEACH-C where the size of cluster plays an important role in creating a cluster structure. The Balanced LEACH-C protocol has been compared random LEACH LEACH-C algorithm for energy equi-distribution and 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. The Balanced LEACH-C routing protocol shows improvements in respect of overall disintegration of network as well as lifetime..

Key words: Energy Consumption, Balanced-LEACH-C, WSN

I. INTRODUCTION

Since 1990s, the research on wireless sensor networks has become a hot research topic due to its distributed computing and a wide range of applications it supports. Its applications include biomedical sensing, target tracking, environmental sensing, weather forecast etc. Various design constraints in the process of finalizing various type of architecture of WSN are cost, energy, heterogeneity, deployment, mobility, resources, security, modality, infrastructure, topology, coverage, connectivity, size, lifetime and Quality of Service.

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. Nodes are small, low power devices which are deployed in different region to sense constraints like temperature, humidity, vibrations, pressure etc. Since, some regions in which the nodes are deployed are not reachable so the nodes cannot be easily replaced and thus, efforts are done to increase the lifetime of nodes. Two competing objectives in the design of WSNs are the capability to exchange large amount of data between nodes and base station and minimizing the energy consumption. We require efficient routing protocols in WSNs to manage these objectives. Therefore, many routing algorithms have been proposed due to the challenges in designing an energy efficient network. Out of these hierarchical routing protocols greatly satisfy the limitations and constraints in WSNs. Hierarchical routing protocols considers the concept of a cluster head. A cluster head (CH) is a node which is responsible for collecting data from other nodes in the cluster, aggregating or preprocess data and then sending the processed data to the base station. This paper is organized into six chapters. In Section 1,

Introduction to WSN is included. In this, we have discussed about the various characteristics of WSN and some of challenging issues in WSN. It also gives an overview of various routing protocols and brief discussion of LEACH protocol. Section 2 Reviews starts by relating the work to other available surveys in the literature. Section3 describes methodology, simulation environment and parameters used in analysis. Section4 deals with result and discussion. Section5 concludes the simulation results.

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 flat routing protocols nodes play the same role and have similar functionality in transmitting and receiving data. In this type of network all the nodes send their sensing information directly to the base station. 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.

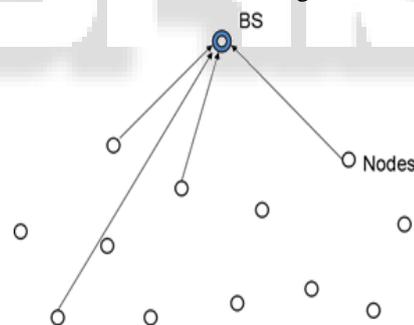


Fig. 2.1: Flat Routing

Hierarchical (Cluster-based) routing protocol is a two layer architecture. First layer involves the formation of a cluster head whereas second layer is responsible for the communication between the nodes. These 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. 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.

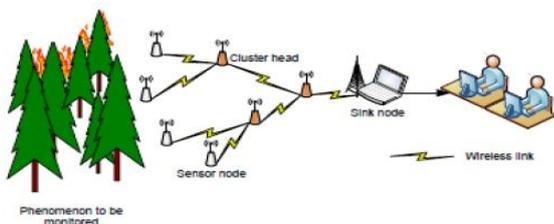


Fig. 2.2: Hierarchical Routing

Recently there has been increased interest in studying energy-efficient clustering algorithms. The main aim 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 [7]. 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.

III. PROPOSED METHODOLOGY

Low Energy Adaptive Clustering Hierarchy (LEACH) 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 [8]. LEACH assumes every node can directly reach a base station by transmitting with sufficiently high power.

LEACH protocol runs with many rounds; Cluster setup phase and Steady phase. In 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 itself by choosing a random number between 0 and 1. The threshold is set as:

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

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.

In LEACH the following steps are taken to transfer data.

- (1) First cluster heads (CHs) are selected randomly. This is called cluster head selection stage.
- (2) Then each node adds itself to a particular CH based on its distance with CH. This is called cluster formation stage.
- (3) Once cluster are formed then data is sent from non-cluster head node to CH and then CH to base station BS. This can be simulated by Energy consumption stage in simulator.

The non-cluster nodes send the message containing their IDs 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.

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 are manifolds. Neither it is fulfilling equi-space distribution nor is it fulfilling equi-energy distribution requirement for better energy efficiency. This algorithm was extended as LEACH-C 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 is advertised to all nodes in WSN to prepare them for real data communication in steady state.

LEACH protocol is achieved based on 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. The LEACH improves a lot as compared to direct transmission of data but there remain several problems in this algorithm. Because the election strategy of cluster head is random, it may lead to misdistribution of cluster head and imbalanced clusters. Thus cluster head load is not balanced consequently this may lead to high energy consumption and early death of individual cluster head.

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 LEACH-C algorithm was proposed, in which CHs are chosen based on residual energy instead of random selection. LEACH-C 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.

LEACH-C 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 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.

In [5] and [6], 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 LEACH-C technique in such a way so that transmission energy of nodes used to send data to cluster head (CH) is minimized. Our algorithm will consist of the following steps:

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

Step 2: 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.

A. Experimental setup:

To simulate LEACH, we have used random 80-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 50m x 50m plot, our BS is located at (25, 150) so that the BS is at least 50m from the closest sensor node.

We use the same energy model as discussed in [3] 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/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. The initial energy of each node is 0.5 nJ. Energy for transmitting and receiving each bit is same. The energy is:

1) *Transmitting:*

TransEnergy=50 nJ/bit

2) *Receiving:*

RecEnergy=50 nJ/bit

Energy for free space is,

FsEnergy=10e-12 J/bit

and energy for multipath is,

MpEnergy=1.3e-15 J/bit

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. The total no. of rounds are 9999. 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).

B. Proposed Balanced LEACH-C Algorithm:

The above LEACH-C algorithm considers only residual energy as objective function to decide the selection of cluster head. This serves the concept of equi-energy distribution but doesn't address the concept of load balancing among clusters. For load balancing a multi-objectives criterion 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 find $p \times \text{livenodes}$ 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.

Step 3: Attach nodes to nearest CH to form cluster by finding distance matrix to form cluster. In every cluster only a fix number of nodes can have membership. This fix number is decided by dividing livenodes by total number of clusters.

So our proposed scheme involves two things; equi-energy distribution as well as load balancing in the network architecture which may ultimately improve the network life and its quality.

IV. RESULTS ANALYSIS

Following table shows the results obtained from the experimentations done as per the setup explained in the previous. Three 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. This method is called LEACH-C. In this method a fix number of CHs are selected based on the number of nodes that are living. After selection of CHs, each non-CH nodes attach itself to a particular cluster thus making a cluster structure. Another modification is made in the improved algorithm where CHs are selected based on the similar residual energy consideration but nodes are clustered based on distance and as well as balancing. Once a fixed numbers of nodes are part of a cluster further membership is restricted to that particular cluster. 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.

S R. N o.	WSN Routines 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)
1	Random LEACH	456	210	384	8702	1.29
2	LEACH-C	959	945	956	7628	1.18
3	Balanced LEACH-C	1200	1183	1196	9547	1.18

Table 1: Experimentation Results

In the table 5.1, it is clearly shown that Balanced LEACH-C performs far better as compared to random LEACH and marginally better as compared to LEACH-C for each and every criterion. The balanced LEACH-C algorithm performs nearly two times better than random LEACH and as compared to LEACH-C, performance is nearly 20%.

If we consider a network, if 50% nodes are dead then LEACH and LEACH-C are performing better than random LEACH. Random LEACH has performed worst in every situation. If we consider 75% node criterion for network life then again the BALANCED LEACH-C performs better than other two algorithms. If we compare the number of dead nodes as per our simulation results LEACH-C and the balanced LEACH-C perform better, but there nodes once start dying accelerates network decay very fast.

If we consider no of packets sent to BS then the balanced LEACH-C is clear 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 also comparable. This can be confirmed by the figures 4.1 to 4.3 which show the comparative analysis of three simulated algorithms for three different criteria.

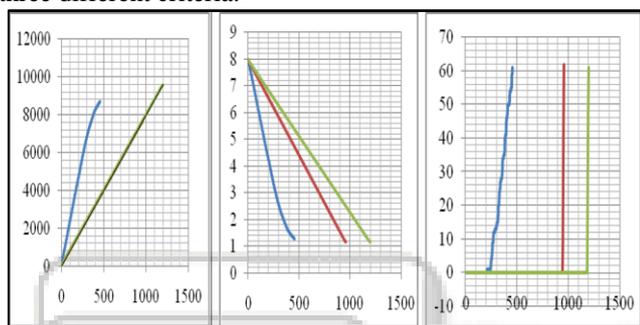


Fig. 4.1-4.3: Comparison of three algorithms for no. of packets sent to BS, residual energy, dead nodes Vs No. of Rounds

V. CONCLUSION

The performance of three algorithms is measured in these experiments. Parameters for performance measurements are Packets sent to BS, Residual Energy, Dead Nodes. These parameters are plotted against number of rounds and are shown in figures 4.1-4.3. As in fig 4.1, no. of packets sent to the base station are more in case of Balanced LEACH-C than random LEACH & LEACH-C. If we consider residual energy and total number of rounds then LEACH-C and the balanced LEACH-C perform better than random LEACH. The residual energy at the end of total number of round shows that LEACH-C and the balanced LEACH-C have most uniformly distributed energy dissipation among nodes. For network integration or dead nodes criterion Balanced LEACH-C algorithm perform far better than other algorithms.

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