Comparative Analysis of Single Objective & Multi-Objective Cluster-Head Selection in K-Means Algorithm For Energy Efficiency In WSN

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Abstract—Limited energy is a serious issue in sensor networks. Therefore, there is a need to optimize the network architecture for the applications in order to minimize resources consumption. This paper compares the strategies of cluster-head selection in K-means algorithm in wireless sensor network when applied as a routing algorithm. The single-objective cluster-head selection takes account of only inter cluster distance of nodes and cluster head while multi-objective strategy considers cluster head position in cluster and distance between base station and cluster head besides inter cluster distance. The later strategy fails to provide equal distribution of energy among nodes and the results confirm our hypothesis proving single objective function as a better strategy.

Key Word:- Clustering, K-means, LEACH, WSN

I. INTRODUCTION

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 but has limited capabilities of computing, storage and power source, unreliable type of communication. The sensor nodes sense the conditions in which they are surrounded and transfer their data to the base station (BS) through electronic signals transmitted over radio waves. In WSNs, all nodes is fed by a small battery making energy saving as primary goal in designing WSN structure with an objective of maximizing network lifetime as it is impractical to change or replace exhausted batteries [2]. In fact, there are two competing objectives in the design of WSNs. The first objective is the capability to exchange large amount of data between the nodes and the base station. The second constraining objective is minimizing the energy consumption. The two competing objectives reveal the importance of efficient routing protocol in WSNs. Therefore, many routing algorithms have been proposed due to the challenges in designing an energy efficient network. Among all the proposed methods, hierarchical routing protocols greatly satisfy the limitations and constraints in WSNs [6]. Hierarchical routing protocols, also known as cluster-based routing, is mainly considered as a two layer architecture where one layer is engaged in cluster head selection and the other layer is responsible for routing. A cluster head (CH) 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.

The proposed work is about to compare K-Means based cluster algorithms for finding an optimal clustering scheme instead of using some random method, thus using less energy and more rounds of transmission to BS. Two CH selection methods are evaluated for performance. This paper is organized into six sections. In section I, Introduction to WSN is included. The IInd section will give an overview of various routing protocols and brief discussion of LEACH protocol. Section III relates the work to other available surveys in the literature. Section 4 gives the information about methodology, Simulation Environment and parameters used in analysis. Section 5 deals with result and discussion. Finally Section 6, concludes the simulation results and shows some of the future work which can be followed up.

II. PROTOCOL USED IN SIMULATION

In this paper, we have used Low Energy Adaptive Clustering Hierarchy (LEACH) algorithm i.e. random LEACH, max energy LEACH), Single-objective K-means LEACH and multi-objective K-means based scheme for simulation. In all schemes LEACH is the underlining protocol. The LEACH proposed by Wendi B. Heinzelman of MIT. 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 [3]. 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. 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 make the protocol secure. LEACH assumes every node can directly reach a base station by transmitting with sufficiently high power.

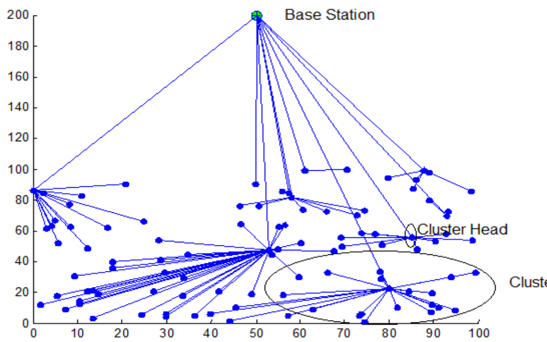


Fig. 1: Leach routing topology

The algorithm for above deployment is given below:

Step 1: Create the network architecture with desired parameters

Step 1.1 Create the field Area

Step 1.1.1 x and y Coordinates of the base station

bsX=x coordination of BS

bsY=y coordination of BS

Step 1.1.2 Create the node model randomly

x coordination of nodes

y coordination of nodes

Step 1.1.3 initially there are no cluster heads, only nodes 1 for 'N' =non-CH node, 2 for 'C' = CH node,3 for 'D'= Dead node

Step 1.2 Energy Model (all values in Joules)

- Specify Initial Energy of node
- Specify Energy for transferring/receiving of each bit (ETX)
- Transmit/receive Amplifier types
- Energy free space;
- Energy multi path
- Data Aggregation Energy

Step 2: plot field area with its nodes and bs
Step 3: for each round
Step 3.1 Create the new node architecture using random_leach/ max_enrgy_Leach/ K_Mean_leach algorithm in beginning of each round. Probability of selection of a node to be selected as CH if selected randomly. Random leach algorithm in which nodes are selected CHs randomly and number of CHs is also variable. Max_ energy leach algorithm in which max. Energy nodes are selected as CHs and CH is also fixed as p*liveNodes
Step 3.2: if (any cluster is formed during round)
Find Energy dissipation patterns for nodes (Ref section 4.10)
End if
End for
Step 4: Display number of packets sent from CH, energy dissipation per round and dead node pattern for each round

III. 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. It selects its cluster head which is closest to its position.
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

IV. Related Works

Recently there has been increased interest in studying energy-efficient clustering algorithms in the context of both ad hoc and sensor networks. The surveys dealing with WSN clustering protocols can be found in [10]. 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. The EEHC [11], EECS [12], and HEED [13] fall in the probabilistic class and PEGASIS [14], and TASC [15] are categorized in the deterministic class.

LEACH protocol randomly selects a few nodes as cluster heads based on a probability model. The probabilistic approach leads to the formation of unequally sized clusters which leads to imbalance in energy consumption across the network and thereby reduces the efficiency and network lifetime. Various new improvements such as LEACH-F[4], LEACH-C[5], H-LEACH[8], E-LEACH[9], V-LEACH[1] have been proposed in LEACH for network life elongation. The Power-Efficient Gathering in Sensor Information Systems (PEGASIS) proposed in [14] is also an improvement over the LEACH protocol. It is a near optimal chain-based protocol. The idea of cluster formation and cluster head is discarded in PEGASIS. Instead of multiple nodes, a single node in the chain communicates with the base-station.

V. Proposed Methodology

The protocol plays important role, which can minimize the delay while offering high energy efficiency and long span of network lifetime. LEACH (Low Energy Adaptive Clustering Hierarchy) and PEGASIS (Power-Efficient Gathering in Sensor Information System) are such typical hierarchical-based routing protocols. As we have already explained the various flavors of LEACH algorithm proposed in the last decade. Clustering is the main factor responsible for the energy consumption and energy conservation in LEACH algorithm. Our hypothesis also points to the same concept. We hereby propose to make efficient clustering of WSN nodes in such a way so that transmission energy of nodes used to send data to cluster head (CH) is minimized.

VI. Experimental Setup:

To simulate LEACH, we have used random 100-node networks for our simulations with similar parameters used in [5]. 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 [4] 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.

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 the starting every node is having equal energy i.e. 0.5Joules and all nodes are live nodes.

VII. K-MEANS LEACH ALGORITHM

In this algorithm idea is to select cluster in such a way that their intra distance is minimum which ensures that less communication energy is consumed and WSN can run more rounds. K-means [7] is one of the simplest unsupervised learning algorithms that solve the well known clustering problem.

– Place K points into the space represented by the objects that are being clustered.
  These points represent initial group centroids.
– Assign each object to the group that has the closest centroid.
– When all objects have been assigned, recalculate the positions of the K centroids.
– Repeat Steps 2 and 3 until the centroids no longer move. This produces a separation of the objects into groups from which the metric to be minimized can be calculated.

Fig. 2: K-means Algorithm

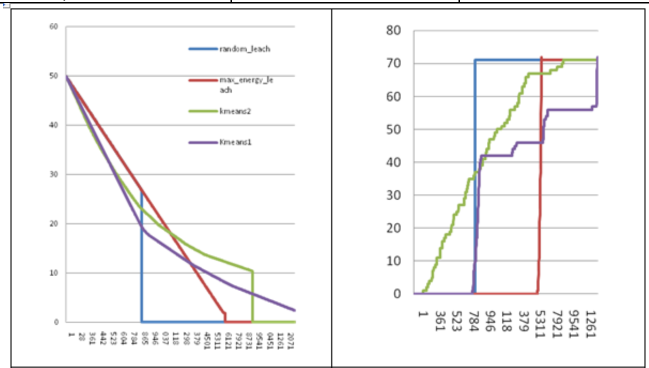
VIII. V RESULTS ANALYSIS

Following table shows the results obtained from the experimentations done as per the setup explained in the previous section. Six 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. The Third algorithm "k-means2" where nodes are clustered based a multi-objective criterion such as inter distance as used by a standard algorithms K-means, remaining energy while selecting CH and CH's distance from each cluster node and its distance from BS is also considered. Our contention is that in this case, it will invite skewed distribution of energy. The fourth algorithm is proposed a single objective plain k-means algorithm based clustering is called *"k-means1"* where, while selecting CH only remaining energy of node is considered. The node which is having largest energy in the cluster is selected as a CH for that 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 30% nodes are alive with total energy greater than zero.

In the table it is clearly shown that plain k-means clustering based *"k-means1"* LEACH algorithms perform far better as compared to other methods if we consider the no of rounds covered by the algorithms. *"k-means1"* algorithm perform nearly four time better than random LEACH and nearly 50% better than max energy LEACH and nearly 20% better than k-means2. If we consider a network, dead if 50% nodes are dead then Max Energy LEACH is performing better than K-means based LEACH *"k-means2"* and nearly equal to *"k-means1"* based LEACH. Random LEACH has performed worst in every situation. If we consider 70% node criterion for network life then *"k-means1"* variants performs better.

Table 1. 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	Rema-ining Energy after 70% node is dead (Joules)
Random LEACH	589	100	410	11222	26.755
Max Energy LEACH	1234	1229	1229	12249	1.816
Paper [16] based k-means LEACH (K-means2)	1448	89	802	8535	10.385
Plain k--means LEACH (k-means1)	1777	565	1255	11813	2.414



Remaining Energy pattern | No of dead nodes

Fig. 3: Experimentation Result

From table1 and figure3 it can be conclusively inferenced that *"k-means1"* based algorithms are much better than random LEACH and max energy LEACH. Nearly 400% network life improvement is recorded for over simple LEACH and 50% over max Energy LEACH. If we compare the no 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 Kmeans-LEACH algorithms are lacking i.e. network disintegration in this front. In these algorithms, first node is dead very. Even *"k-means1"* based algorithm is not performing well if we consider this parameter. 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 *"k-means1"* is clearly winner. The former has sent highest no 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.

IX. CONCLUSION

We have measured performance of four 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 *"k-means1"* based algorithm performs better than *"k-means2"*, Max Energy LEACH and random LEACH. But residual energy at the end of total number of round shows that Max Energy LEACH most uniformly distributed energy dissipation among nodes and then *"k-means1"* based LEACH performs. For network integration or dead nodes criterion Max Energy LEACH performs better than other algorithms. For number of packets sent to BS criterion *"k-means1"based* and Max Energy LEACH performs better than other algorithms.

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