Comparative Analysis of LEACH, LEACH-C, K-LEACH, Algorithms in Wireless Sensor Network for Energy Efficient Routing

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Abstract— This work elaborately compares three important clustering protocols, namely LEACH and LEACH-C (centralized), K-LEACH, using MATLAB tool for several chosen parameters, and analysis of simulation results against chosen performance metrics with throughput, network stability and network lifetime being major among them. Although K-LEACH has performed better in terms of network life but it fails on the parameters of network stability and throughput. LEACH-C has performed best for network stability and LEACH has good performance on network throughput.

Key words: LEACH, LEACH-C, K-LEACH, WSN

I. INTRODUCTION

Wireless Sensor Networks(WSN*)* have gained world-wide attention in recent years due to the advances made in wireless communication, information technologies and electronics field. A sensor network typically consists of a large number of sensor nodes densely deployed in a region of interest, and one or more data sinks or base stations that are located close to or inside the sensing region. The sink(s) sends queries or commands to the sensor nodes in the sensing region while the sensor nodes collaborate to accomplish the sensing task and send the sensed data to the sink(s). Meanwhile, the sink(s) also serves as a gateway to outside networks, for example, the Internet. Figure 1.1 represents a typical scenario of a WSN.

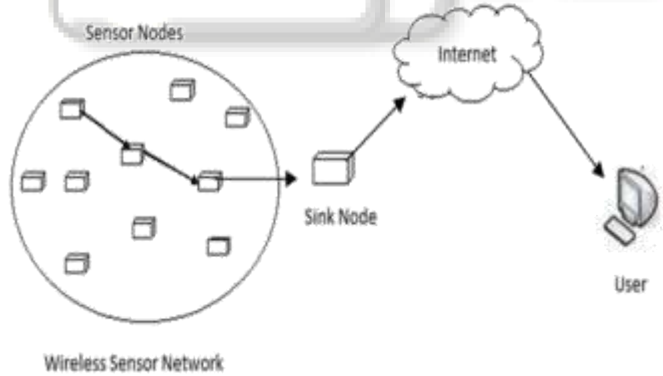

Fig. 1.1: Wireless sensor network [1]

While sensor networks share many similarities with other distributed systems, they are subject to a variety of unique challenges and constraints .like Security, Transmission Media, Production Cost, Scalability, The constraint most often associated with sensor network design is that sensor nodes energy. The key challenge in WSN is to minimize the energy consumption and enhance the network lifetime of the sensor network. Since energy is an important limited resource in WSN so we have to consider minimizing the usage of this resource. By choosing conventional routing protocols for data transmission like direct communication with BS, MTE (Minimum Energy Transmission), and energy consumption is more and lifetime of network is not hopefull. In the early days concept of Direct Communication is used .In this concept data transmitted directly between two nodes, for example node A send data to node B by using a direct path. But in this more power is consumed because power is directly proportional to the distance square. To overcome this new concept come forward that is Hop-by-Hop communication. This method Choosing routes is to use "minimum transmission energy"(MTE) routing[2],where intermediate nodes are chosen such that sum of squared distances (and.hence the total transmit energy $E_{TX}(d)$,assuming a d^2 power loss)is minimized. Thus, for three nodes A, Band C, node A would transmit to node C through node B if and only if

$$ETX(d = d_{AB}) + ETX(d = d_{BC}) < ETX(d = d_{AC}) \quad (1)$$

This approach ignores the energy dissipated in the radio to send and receive the data and, therefore, may not actually produce the lowest energy routes. Another method of wireless communication is to use clustering .In this case, nodes send their data to a central cluster head that forwards the data to get it closer to the desired recipient. Clustering enables bandwidth reuse and can, thus, increase system capacity. Using clustering enables better resource allocation and helps improve power control. While conventional cluster-based networks rely on a fixed infrastructure, new research is focusing on ways to deploy clustering architectures in an ad-hoc fashion. So clustering based routing protocols is one of the solutions of the above mentioned problem. LEACH [2] is one of the clustering based protocols where sensor nodes form clusters, they send data to cluster heads (CHs). Then CHs aggregate the received data and send it to the base station (BS). If the cluster formation, cluster heads selection and randomization of CHs are formed properly then it will help to minimize the energy dissipation and prolong the network lifetime. Our work is about to compare K-Means based cluster algorithms, with LEACH, LEACH-C, in term of performance metric, that is Network Life time, Throughput, Network Stability.

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), K-LEACH (K-means LEACH) for simulation. In all schemes LEACH is the basic algorithm. 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 In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster head. All non-cluster head nodes transmit their data to the cluster head, while the cluster head node receives data from all the cluster members, performs signal processing functions on the data (e.g., data aggregation), and transmits data to the remote BS. Therefore, being a cluster head node is much more energy intensive than being a non-cluster head node. Thus, LEACH incorporates randomized rotation of the high-energy cluster head position among the sensors to avoid draining the battery of any one sensor in the network. In this way, the energy load of being a cluster head is evenly distributed among the nodes. The operation of LEACH is divided into *rounds*. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the cluster head and on to the BS.

The selection of cluster head is done with a probability function, each node selects a random number between 0 and 1 and if the number is less than T(n) , the node is elected as a cluster head for current round:

$$T(n) = \frac{p}{1-p(r\ mod\frac{1}{p})} \quad n \in G \qquad (2)$$

Where, p is the probability of node being selected as a cluster –head node r is the number of current round,G is the set of nodes that have not been cluster-heads in last 1/p rounds. Mod denote a module 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. During the steady-state phase, each node turn off its radio until it senses the necessary data. The member's node can send their data to CH during their allocated schedule table created during the set-up phase. The cluster –head will keep its receiver on to receive all data from the nodes in the cluster. 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 all the data has been received, the cluster-head performs data fusion to compress all data into a signal .After that the composite signal is sent to base station directly by the cluster-head. Since the base station is far away, this is a high energy transmission. This is the steady phase operation of LEACH networks. After a certain time, which is determined priori, the next round begins. While there are advantages to using LEACHs distributed cluster formation algorithm, this protocol offers no guarantee about the placement and/or number of cluster head nodes. LEACH has a problem of Space distribution and equi-distribution of energy. The subsequent protocols, such as LEACH-C [3] were designed to solve these. Therefore using a centralized clustering algorithm would produce better results. However, using a central control algorithm to form the clusters may produce better clusters by dispersing the cluster head nodes throughout the network. This is the basis for LEACH-centralized (LEACH-C), a protocol that uses a centralized clustering algorithm and the same steady-state protocol as LEACH. During the set-up phase of LEACH-C, each node sends information about its current location and energy level to the BS. In addition to determining good clusters, the BS needs to ensure that the energy load is evenly distributed among all the nodes. To do this, the BS computes the average node energy, and whichever nodes have energy below this average cannot be cluster heads for the current round. Once the cluster heads and associated clusters are found, the BS broadcasts a message that contains the cluster head ID for each node. If a node's cluster head ID matches its own ID, the node is a cluster head; otherwise, the node determines its TDMA slot for data transmission and goes to sleep until it is time to transmit data. The steady-state phase of LEACH-C is identical to that of LEACH. LEACH-C solve the problem of Space distribution but not the problem of energy distribution. According to the deficiency of the LEACH, LEACH-C and LEACH K-Means are almost improved based on the LEACH agreement. Among them LEACH K-Means algorithm improves the performance of network by the optimal number of cluster head and the mechanism of cluster head selection, making node energy consumption reduced and extending the network life cycle. This simulation result shows that K-Means LEACH have obvious advantage over LEACH and LEACH-C agreement in overall performance but K-means LEACH has a problem as it can have unbalanced number of nodes in cluster.

A. 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 [4] is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem.

1) Place K points into the space represented by the objects that are being clustered. These points represent initial group centroids.
2) Assign each object to the group that has the closest centroid.
3) When all objects have been assigned, recalculate the positions of the K centroids.
4) 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. The distance between the data points is calculated using Euclidean distance as follows. The Euclidean distance between two points or tuples, $X=\{x_{11}, x_{12}, x_{13}......x_{1n}\}, Y=\{y_{11}, y_{12}. y_{13}.....y_{1n}\}$..

$$dis(x,y) = \sqrt{\sum_{j=1}^{n}(x_{ij} - y_{ij})} \qquad (3)$$

III. EXPERIMENTATION SETUP AND SIMULATION

A. Experimental Setup

To simulate LEACH, LEACH-C, K-LEACH we have used random 100 nodes network for our simulation. We placed the base station at a far distance from all the nodes. For a 50×50 plot, our base station is located at (25,100). All the nodes in the network have limited energy and homogenous. The initial energy of all the nodes is same.

B. Energy Model for LEACH

This paper adopts the same energy consumption model [5]. Thus, to transmit *l*-bit message a distance *d*, the radio expends

$$E_{TX} = E_{elec}*L+E_{amp}*L*d^2 \quad (4)$$

The energy consumed by received by k bit is:

$$E_{RX} = E_{elec} * L, \quad (5)$$

E_{elec} is the energy used in transmitting electronics and receiving electronics. E_{amp} is the amplification factor of amplifier. In equation (5) , $L *E_{elec} << L* E_{elec} + L *E_{amp}* d$ means that the shorter distance the less energy will consume.

C. Parameter Selection for Simulation

Table 1: Simulation Parameters

Parameter	Value
Network area	50×50 m^2
No. of nodes	100
No .of rounds	9999
No. of cluster	10% of the live node
Initial energy	0.5J
Base station length	X=25,Y=100
Data aggregation Consumption(E_{DA})	5e-9 J/b
Energy for transferring of each bit (ETX)	50 nJ/b
Energy for receiving of each bit (ERX)	50 nJ/b/m
Energy of multi path model (mpEnergy)	1.3e-15 J/b/m
Free space Energy(E_{fs})	10e-12 J/b
Data packet size(L_{ch})	6400bits
Ctr packet length(L_{non-ch})	200bits

IV. SIMULATION RESULTS AND ANALYSIS

Following table shows the result obtained from the experimentation done as per the setup. The performance of the K-LEACH protocol is evaluated and compared with existing LEACH, MAX-LEACH in terms of number of rounds, packet sent to the base station, energy and number of nodes. The result for simulation is taken by considering some metric. The metric used for performance Check as follow

1) Network stability**:** is the time interval from the start of network operation until the death of the first sensor node. We also refer to this period as "Network stability region."
2) Network life time: Network lifetime is the number of round from the start of operation until the death of the last alive node.
3) Network throughput**:**We measure the rate of data sent from cluster heads to the sink.

Table 2: Simulation Results

WSN Routing Algorithm	Residual energy	Rounds in which first Node Dead	Rounds in which 50% Node Dead	Round in which 75% Node Dead	Total Packet Send to BS
Random LEACH	6.0293	748	2403	2976	67355
LEACH-C	4.9775	5826	5839	5843	58382
K-LEACH	13.9648	114	4588	8710	49477

A. Analysis

The K-LEACH scheme is compared with the LEACH.LEACH-C protocol in terms of network lifetime and throughput, and stability.

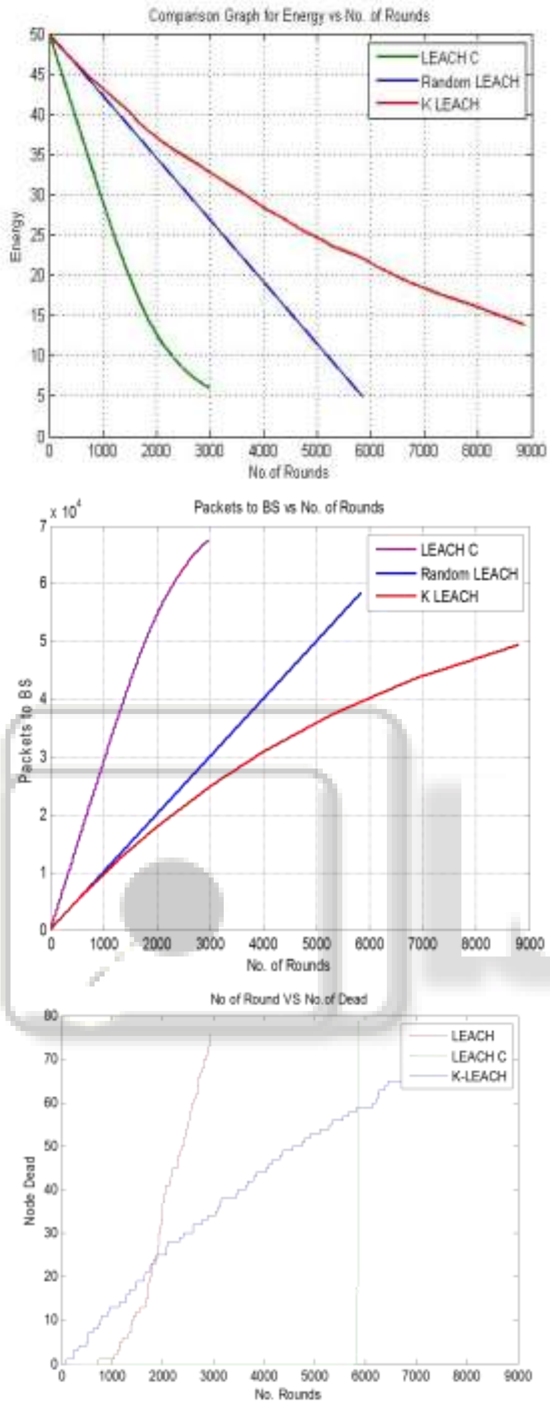

Figure 1.2 Simulation Result a) Comparison of Energy VS No of Rounds b) Comparison of Packets VS No. of Rounds c) Comparison of No of Rounds VS No. of Dead Nodes

To compare the energy efficiency, the remaining energy of the network as the round proceeds is shown in Figure 1.2(a). It can be seen from this Fig, the K-LEACH is better than the LEACH, Max-LEACH with respect to energy efficiency. It can be clearly seen from the Fig. that little energy is left after 2000 rounds with the LEACH protocol. Same case with the Max-LEACH the little energy is left over 5998 Round .However, the network still has some residual energy even after 8000 rounds with the K-LEACH. K-LEACH Inc. the network life time. Figure 1.2(b) shows the data sent to BS during the simulation, the data sent to BS during the simulation time is increased by in K-LEACH, than normal LEACH. This is due to the fact that the network life time is increased in LEACH compare to K-LEACH, which demonstrates the significant improvement in the network performance LEACH approach.It is observed from Figure 1.2(c) that Death rate of sensor nodes in the LEACH is much faster than the K-LEACH, Max-LEACH. It means that Max-LEACH can transmit data more accurately for a longer period .As shown in this Figure after 1000 rounds, almost all the nodes are dead in the LEACH, but in case of Max-LEACH after 5998 rounds nodes are dead.so in case of stability Max-LEACH has a higher stability as compared to the other two.

V. Conclusion

We have measured performance of three 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-means LEACH" based algorithm performs better than, LEACH-C 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 LEACH-C performs better than other algorithms. For number of packets sent to BS criterion Random LEACH performs better than other algorithms.

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