Improved Performance on Wireless Sensor Network using Fuzzy Clustering Algorithms

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Abstract— Clustering in wireless sensor network faces several challenges such as selection of an optimal group of sensor nodes as cluster, optimum selection of cluster head, energy balanced optimal strategy for rotating the role of cluster head in a cluster, maintaining intra and inter cluster connectivity and optimal data routing in the network. In this paper, we study a protocol supporting an energy efficient clustering, cluster head selection and data routing method to prolong the lifetime of sensor network. Simulation results demonstrate that the proposed protocol prolongs network lifetime due to the use of efficient clustering, cluster head selection and data routing. The results of simulation show that at the end of some certain part of running the EECS and Fuzzy based clustering algorithm increases the number of alive nodes comparing with the LEACH and HEED methods and this can lead to an increase in sensor network lifetime. By using the EECS method the total number of messages received at base station is increased when compared with LEACH and HEED methods. The Fuzzy based clustering method compared with the K-Means Clustering by means of iteration count and time taken to die first node in wireless sensor network, as the result shows that the fuzzy based clustering method perform well than k-means clustering methods.

Key words: WSN, Fuzzy Clustering Algorithms

I. INTRODUCTION

A. *Wireless Sensor Networks*

Wireless sensor network is a collection of sensor nodes interconnected by wireless Communication channels. Each Sensor node is a small device that can collect data from its surrounding area, carry out simple computations, and communicate with other Sensors or with the base station (BS).[2], [4].

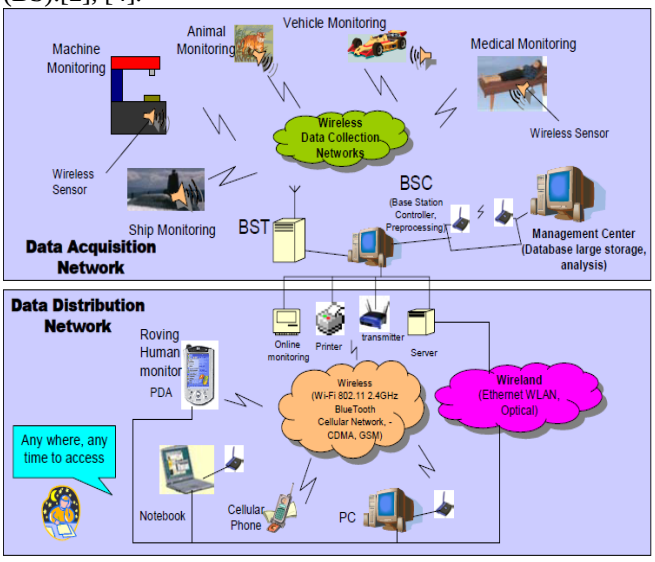

Fig. 1: Wireless Sensor Network

II. CLUSTER ANALYSIS

A. *Clustering in Wireless Sensor Network*

In clustering, the sensor nodes are partitioned into different clusters. Each cluster is managed by a node referred as cluster head (CH) and other nodes are referred as cluster nodes.

1) Sensor Node

It is the core component of wireless sensor network. It has the capability of sensing, processing, routing, etc.

2) Cluster Head

The Cluster head (CH) is considered as a leader for that specific cluster and it is responsible for different activities carried out in the cluster, such as data aggregation, data transmission to base station, scheduling in the cluster, etc.

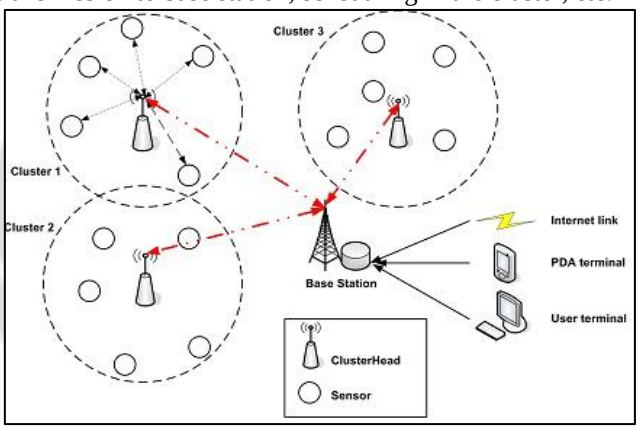

Fig. 2: Clustered Sensor Network

3) Base Station

Base station is considered as a main data collection node for the entire sensor network. It is the bridge (via communication link) between the sensor network and the end user. Normally this node is considered as a node within power constraints. Cluster: It is the organizational unit of the network, created to simplify the communication in the sensor network.

B. *Clustering Algorithms in WSN [5],[10]*

1) Low Energy Adaptive Clustering Hierarchy (LEACH)

Low Energy Adaptive Clustering Hierarchy is designed for sensor networks here an end-user wants to remotely monitor the environment. LEACH includes distributed cluster formation, local processing to reduce global communication, and randomized rotation of the cluster-heads. Together, these features allow LEACH to achieve the desired properties. Initial simulations show that LEACH is an energy-efficient protocol that extends system lifetime.

2) Hybrid Energy-Efficient Distributed Clustering (HEED) [7]

Nodes in LEACH independently decide to become cluster heads. While this approach requires no communication

overhead, it has the drawback of not guaranteeing that the cluster head nodes are well distributed throughout the network. While the LEACH-C protocol solves this problem, it is a centralized approach that cannot scale to very large numbers of sensors. Many papers have proposed clustering algorithms that create more uniform clusters at the expense of overhead in cluster formation. One approach that uses a distributed algorithm that can converge quickly and has been shown to have low overhead is called HEED. HEED uses an iterative cluster formation algorithm, where sensors assign themselves a "cluster head probability" that is a function of their residual energy and a "communication cost" that is a function of neighbor proximity.

3) EECS: Energy Efficient Clustering Schemes [3],[6]

Authors proposed an algorithm in which cluster formation is different from LEACH protocol. In LEACH protocol cluster formation takes place on the basis of a minimum distance of nodes to their corresponding cluster head. In EECS, dynamic sizing of clusters takes place which is based on cluster distance from the base station. The results are an algorithm that addresses the problem that clusters at a greater distance from the sink requires more energy for transmission than those that are closer. Ultimately it provides equal distribution of energy in the networks, resulting in network lifetime. Thus main advantage of this algorithm is the full connectivity can be achieved for a longer duration. So we can say it provides reliable sensing capabilities at a larger range of networks for a longer period of time. It provides a 35 percent improvement in network life time over LEACH algorithm.

III. CLUSTERING TECHNIQUES ON WIRELESS SENSOR NETWORK

A. Clustering and Cluster Head Selection using LEACH METHOD [10]

The operation of LEACH is broken up into rounds, where each round begins with a setup phase, when the clusters are organized, followed by a steady state phase, when data transfers to the base station occur.

1) Cluster Setup Phase

After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits this information back to the cluster-head again using a CSMAMAC protocol. During this phase, all cluster-head nodes must keep their receivers on.

2) K-means Clustering

K-Means Training starts with a single cluster with its center as the mean of the data. This cluster is split into two and the means of the new clusters are iteratively trained.

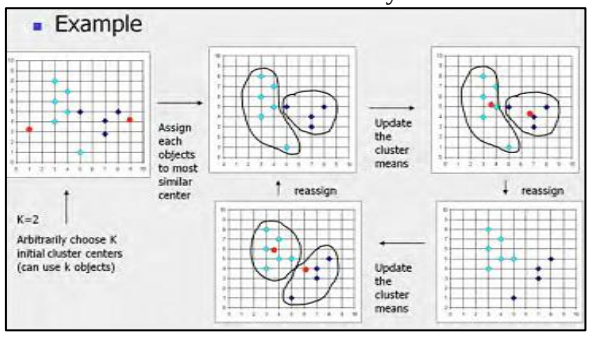

Fig. 3: K means Clustering Process

These two clusters are again split and the process continues until the specified number of clusters is obtained. If the specified number of clusters is not a power of two, then the nearest power of two above the number specified is chosen and then the least important clusters are removed and the remaining clusters are again iteratively trained to get the final clusters. When the user specifies random start the algorithm generates the k cluster centers randomly and goes ahead by fitting the data points in those clusters. This process is repeated for as many random starts as the user specifies and the Best value of start is found. The outputs based on this value are displayed.

The distance between the nodes is calculated using the Euclidean distance.

The Euclidean distance between two data points, X1 = (x11, x12… x1n) and X2 = (x21, x22… x2n)

$$\mathbf{Dist(X_1, X_2) = \sqrt{(\Sigma(x_{1i} - x_{2i})^2)}} \quad (1.1)$$

This distance is used to calculate the distance between all the nodes.

3) Clustering based on Fuzzy Logic

A fuzzy logic approach to cluster-head election is proposed based on three descriptors - energy, concentration and centrality. Depending upon network configuration a substantial increase in network lifetime can be accomplished as compared to probabilistically selecting the nodes as cluster-heads using only local information. For a cluster, the node elected by the base station is the node having the maximum chance to become the cluster-head using three fuzzy descriptors - node concentration, energy level in each node and node centrality with respect to the entire cluster, minimizing energy consumption for all nodes consequently increasing the lifetime of the network.

a) Fuzzy Based Clustering Algorithm

Input

D = {d1, d2, d3... di... dn }// Set of n data points.

k =Number of desired clusters

Output

Objects in belongs to more than one groups or class.

b) Methods

1) Choose a number of clusters and assign randomly to each point coefficients for being in the clusters.
2) Assign each points di to the cluster which has the highest membership values.
3) Compute the centroid for each cluster using the below formula.

$$c_j = \frac{\sum_{i=1}^{n} {u_{ij}}^m . x_i}{\sum_{i=1}^{n} {u_{ij}}^m} \quad (1.2)$$

4) For each point, compute its membership values of being in the clusters, using the below formula

$$u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{||x_i - c_j||}{||x_i - c_k||} \right)^{\frac{2}{m-1}}} \quad (1.3)$$

5) Repeat step 3 to 4 until the algorithm has converged

4) Data Transmission

When all the data has been received, the cluster head node performs signal processing functions to compress the data into a single signal. For example, if the data are audio or seismic signals, the cluster-head node can beam form the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base

station is far away, this is a high energy transmission. This is the steady-state operation of LEACH networks.

After a certain time, which is determined a priori, the next round begins with each node determining if it should be a cluster-head for this round and advertising this information. In our work, we assume a simple model where the radio dissipates Eelec = 50 nJ/bit to run the transmitter or receiver circuitry and _amp = 100 pJ/bit/m2 for the transmit amplifier to achieve an acceptable *Eb/No*. These parameters are slightly better than the current state of the-art in radio design1. We also assume an r2 energy loss due to channel transmission. Thus, to transmit a k-bit message a distance d using our radio model, the radio expends and to receive this message, the radio expends:

Our proposed system makes use of a combination of the concepts of LEACH protocol and EECS method with Fuzzy based clustering Algorithm. The concepts of the fuzzy based clustering are used to grouping the sensor networks and finding the better cluster head, ect.

a) The Proposed System

Initially all the nodes broadcast their probability to be the CH. The ones with the maximum probability are chosen as the CHs. This concept is the initial stage of the LEACH protocol. These behave as the initial CHs chosen for the K means clustering.

In the next step, the two nearest nodes to the CH get grouped with the respective chosen CHs. Then we can form a connected weighted graph with these nodes. The weight here for each edge between each node is the Euclidean distance between them. By this weighted connected graph, we can form a minimum spanning tree.

For finding the center using the concept of eccentricity, the pendant vertices are removed until a vertex is obtained whose eccentricity is zero. The vertex with eccentricity zero is the center of the tree. This center will be the center of the cluster and this node is considered as the CH. Pendant vertices are the vertices with degree one.

This concept is repeated until all the nodes have been grouped in a cluster. In this manner, the whole data set or the nodes are divided into k clusters. So, this proposed system overcomes the drawback of k means clustering, i.e. finding the center of the system at each iteration.

IV. Experimental Results and Discussion

A. Implementation and Simulation

1) Simulation Set up

We simulated the proposed algorithm in NS 2.29 [8]. We found results for placing the cluster heads with minimum distance separated as well as placing the cluster heads randomly over the grid.

2) Simulation Results

As per mentioned, 5% of total number of cluster gives the better performance in the network. We have clustered the network in same number of clusters. We have found the intra cluster distance and inter cluster distance of the cluster.

S. No	No. Item Description Parameter	No. Item Description Parameter
1	Simulation Area	1000x 1000
2	No. of Nodes	100
3	Radio Propagation Model	Two ray ground
4	Channel Type	Channel/ Wireless channel
5	Antenna Model	Antenna/Omni antenna
6	Interface Queue Type	Queue/Drop Tail/PriQueue
7	Link Layer Type	LL
8	Energy Model	Battery
9	Min Packets inifq	30

Table 1: Simulation Parameters

B. Execution of Clustering Schemes

The execution of a clustering algorithm can be carried out at a centralized authority (e.g., a base station) or in a distributed way at local nodes. Centralized approaches require global. The performance of the schemes is evaluated considering network lifetime as a parameter which is defined as the time until the last node dies in the network. Network lifetime is measured using two different yard-sticks:

1) Number of nodes alive in the network - more number of nodes alive implies network lifetime lasts longer.
2) Number of messages received at BS - more number of messages received at BS implies more number of nodes is alive in the network leading to longer network lifetime.

C. Network Performance Analysis

We tracked the rate at which the data packets are transferred to the BS and the amount of energy required to get the data to the BS. When the nodes use up their limited energy during the course of the simulation, they can no longer transmit or receive data. For these simulations, energy is consumed whenever a node transmits or receives data or performs data aggregation.

The number of nodes alive in over time for different method is obtained and listed in the below table.

S. No	Number of nodes alive over time. (In sec)	Number of nodes alive		
		Leach	HDDP	EECS
1	100	100	100	100
2	200	100	100	100
3	300	88	96	100
4	400	75	86	93
5	500	40	51	75
6	600	23	30	64
7	700	8	15	31
8	800	0	3	7
9	900	0	0	0
10	1000	0	0	0

Table 2: Number of Nodes Alive in Over Time

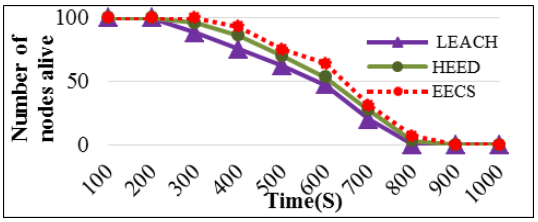

Fig. 4: Comparison chart for Total number of alive nodes in the LEACH, HEED, EECS

The improvement increased through EEPSC compared to LEACH and HEED is further showed in Figure 4 which specifies the lifetime of network is extended and the overall number of messages received at base station is

increased. With LEACH and HEED, all nodes remain alive for 245and 270 seconds before the first node dies, while in EECS, all nodes remain alive for 360 seconds, which is 39% more than LEACH and HEED. Figures 10clearly indicates the advantages of EEPSC over LEACH and HEED in terms of increasing network lifetime.

D. Messages received at base Station

The total number of messages received at base station with three different methods LEACH, HEED and EECS are obtained and depicted in the below table.

S. No	Time (in Sec)	Number of Messages received at BS		
		LEACH	HEED	EECS
1	70	3005	5487	6647
2	140	5741	7845	9974
3	210	9561	16578	22478
4	280	16245	30458	40578
5	350	23054	37845	55174
6	420	29595	44578	59428
7	490	34289	53541	64825
8	560	39648	59864	67845
9	630	46254	60247	70458
10	700	51540	60564	72894
11	770	55800	63584	74589
12	840	56250	64875	75415
13	910	56252	66455	75412
14	980	56250	66453	75415
15	1000	56250	66458	75415

Table 3: Message Received At Base Station (Bs)

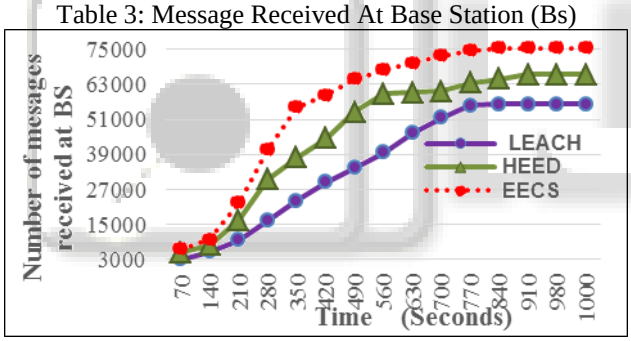

Fig. 5: Comparison chart for message received at Base Station (BS).

From the above figure 5, it clearly shows that the overall number of messages received at base station is increased in EECS method for all different timeline, the EECS obtain the better performance than LEACH and HEED method.

E. Clustering Performance Analysis

The two different clustering methods are involved and compared in the process of time taken for first node to die in WSN, the results are obtained from the two different methods and listed in the below table 4.

S. No	Rounds	Time taken for first node dies	
		K means	Fuzzy Method
1	R1	1584	1348
2	R2	1862	1574
3	R3	2075	2104
4	R4	1727	1384
5	R5	1973	1754
6	R6	2485	2754
7	R7	2155	2014
8	R8	1687	1548
9	R9	2457	2105
10	R10	1824	1687

Table 4: Times Taken for First Node to Die In WSN

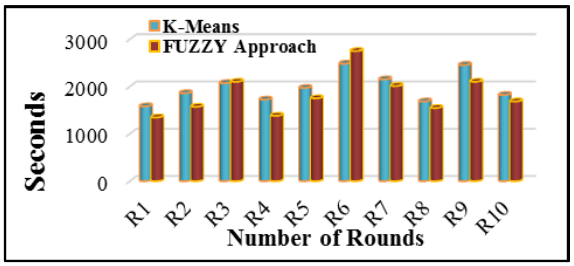

Fig. 6: Comparison chart of Time taken for first node to die in WSN

As seen from Table 4 the times taken for first node to die are comparable in the case of the fuzzy logic approach and the Kmeans approach. As seen from Figure 6, the fuzzy approach leads to the time steps after which the first node dies to be much later than that of Kmeans method. Also all the nodes die almost at the same time as opposed to the random fashion in which nodes die as in the case of Kmeans method. The death of the last node in Kmeans occurs much later than that in the fuzzy logic approach. Therefore a clustering algorithm allows the system to work for longer time although the performance of the system may reduce. Whereas in case of fuzzy logic approach the system gives the maximum performance till the end and dies instantly.

F. Iteration Level Analysis

Different Clustering algorithms are compared for their performances using the time required to cluster the nodes in wireless sensor network. The obtained results are depicted in the following Table 5.

S. No	Cluster Head	Number of iterations	
		Kmeans	Fuzzy Method
1	10	15	13
2	20	10	6
3	30	22	13
4	40	18	10
5	50	13	7
6	60	9	13
7	70	15	10
8	80	10	8
9	90	4	7
10	100	9	5

Table 5: Execution Level for Kmeans and Fuzzy Based Clustering Method.

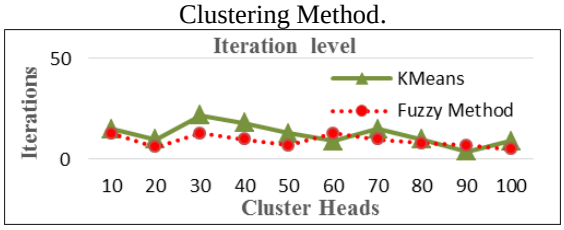

Fig. 7: Iteration level chart for k-means and Fuzzy based clustering methods

From the above figure 7, it clearly shows that the fuzzy based clustering algorithm is executed very faster than Kmeans clustering methods.

V. CONCLUSION

In this study, we have classified the different clustering approaches according to the clustering criteria and the entity responsible for carrying out the clustering process included the study of wireless sensor network, clustering, cluster head selection and other energy efficient communication protocols for WSN. We study and implement the three different cluster head selection methods LEACH, HEED and EECS which is compared the performance of each of the clustering methods. It was found that EECS give a much reduced network lifetime as compared to LEACH and HEED. The experimental results shows that the EECS with Fuzzy based clustering method received more number of messages at Base Station (BS) than LEACH and HEED. However the proposed Fuzzy based clustering method along with the EECS method of cluster head selection provides a much increased performance with a faster convergence as compared to other techniques. Our algorithm tries to change the cluster head of the nodes if the CH is running out of the energy; it helps to minimize the dropped packets. Different types of cluster head selection methods and different clustering methods are used to improve the network life time, messages received at base station and its performance in wireless sensor network is our future work.

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