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SELECTION OF CLUSTER HEAD USING FUZZY ADAPTIVE CLUSTERING FOR ENERGY OPTIMIZATION IN WIRELESS SENSOR NETWORK

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ABSTRACT

In Wireless Sensor Network the (WSN) main constraint against the enhanced lifetime of a network is the consumption of energy by the sensor nodes which are basically driven by battery. Extending the effective operating duration of wireless sensor networks remains in the center of attention while talking about wireless sensor network issues. As lifetime is directly related with the energy supplies of the nodes, a robust approach to contribute towards overall network lifetime is to optimize the energy consumption the nodes. At the same time an energy efficient routing protocol is the major concern in field of wireless sensor network. In this paper we present comparison of five energy efficient hierarchal routing protocols, developed from conventional LEACH protocol. We are concentrating in our research how these extended routing protocols work in order to enhance the longevity of the wireless sensor network. Simulation results shows that newly developed fuzzy based LEACH or LEACH-F is able to enhance the lifetime of the network better than any other version of existing LEACH protocol.

Keywords-*Wireless Sensor Network, LEACH, LEACH-F*

1. INTRODUCTION

A Wireless Sensor Network or WSN is supposed to be made up of a large number of sensors and at least one base station. The sensors are self-governing small devices with several constraints like the battery power, computational capacity, range of communication and memory. They also are equipped with transceivers to collect information from its environment and pass it on up to a certain base station, where the measured parameters can be queued and available for further analysis to the end user. Nowadya, WSNs have been heavily researched by several organizations and by the military where we can find some of the applications in battle field surveillance and other security issues. With the recent issues on climate change, WSNs can be utilized to track changes that affect the climate using a network of sensors to gather environmental variables such as temperature, humidity and pressure. One of the numerous advantages of these sensors is their ability to operate unattended which is ideal for in accessible areas. However, while WSNs are increasingly equipped to handle some of these complex functions, in-network processing such as data accumulation, fusion of information, computation and transmission activities requires these sensors to use their energy efficiently in order to extend effective longevity of network. Sensor nodes are very much susceptible to energy drainage and failure, and their battery source might be irreplaceable, instead new sensors are deployed. Thus, the constant re-energizing of wireless sensor network as old sensor nodes die out and/or the uneven terrain of the region being sensed can lead to energy imbalances or heterogeneity among the sensor nodes. This can negatively impact the stability and performance of the network system if the extra energy is not properly utilized and leveraged. Several clustering schemes and algorithm have been proposed with varying objectives such as load balancing, fault- tolerance, increased

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connectivity with reduced delay and network longevity. A balance of the above objectives can yield a more robust protocol. LEACH protocol and the likes assume a near to perfect system. But more recent protocols developed which is more applicable to real life scenario for WSN. Thus, energy heterogeneity should therefore be one of the key factors to be considered when designing a protocol that is robust for WSN. A good protocol design should be able to scale well both in energy heterogeneous and homogeneous settings, meet the demands of different application scenarios and guarantee reliability. Conventional protocol designs do not address these situations. This research explores existing work done in this area. The goal is to present a modified protocol design that is more robust and can ensure longer network life-time while taking other performance measures into consideration.

2. RELATED WORK

A. LEACH Protocol

Efficient management of energy leads to the involvement of clustering method in WSNs. Low Energy Adaptive Clustering Hierarchy(LEACH)protocol is the first clustering technique developed in 2000[1] for wireless sensor network which partitions the nodes into clusters, where a dedicated node with extra functionalities called Cluster Head (CH), is responsible for creating and manipulating a TDMA(Time division multiple access) schedule and sending aggregated data from nodes to the base station(BS) where these data is needed using CDMA (Code division multiple access). Except CH, all other nodes are normal cluster members.

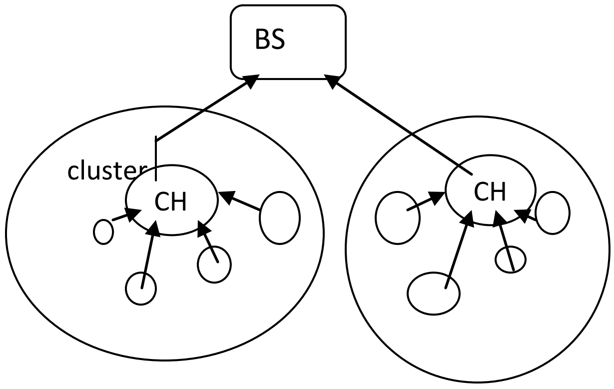

Fig 1.LEACH Protocol

In LEACH two phases gives rise to a complete round.They are-

- Set-up Phase

(1) Advertisement Phase

(2) Cluster Set-up Phase

- Steady Phase

(1) Schedule Creation

(2) Data Transmission

A.1 Setup Phase

Each node decides if it will become a Cluster Head(CH) or not.A node which is not selected as CH previously has more probability to become head of the cluster.In the advertisement phase, analyzing advertisement packet, a normal nodes comes to know that which node became cluster head in its cluster. After that,.by analyzing join packets which contains the identity of a node,CH understands that which nodes are within its cluster area..Now the CH knows the number of member nodes and their identity. Based on all messages received within the cluster, TDMA schedule is constructed by cluster head node and TDMA table is sent to the cluster members to indicate their turn for sending data.

A.2 Steady-state phase

Now data transmission begins at steady state phase.CH receives data from the nodes at their allocated TDMA schdule. This transmission uses a minimam amount of energy (chosen based on the received strength of the CH advertisement). The radio of each normal member nodes can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes.When all the data has been received, the CH accumulates these data and send it to the BS. LEACH is able to perform aggregation of data locally in each cluster to reduce the amount of data that transmitted to the base station. Although LEACH protocol first gave the idea of energy optimization but certainly it suffers from few incompleteness, like-

- CH selection is randomly, that does not take into account energy consumption.
- Due to single hop routing within cluster it is not able to cover large area.
- LEACH protocol offers no guarantee on the placement of cluster head nodes. CHs are

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not uniformly distributed; where CHs can be located at the edges of the cluster.

- Fixed percentage of cluster heads (5%).

B. LEACH-C Protocol

LEACH cannot ensure guarantee about the placement and/or number of cluster heads. So enhancement over the LEACH protocol was done, called LEACH-C or Centralized LEACH, described in [2],uses a centralized clustering algorithm and the same steady-state phase as LEACH. Certainly this protocol can produce better performance by dispersing the cluster heads throughout the network. During the set-up phase of LEACH-C, information about its current location is being sent by the node itself (possibly using GPS) and residual energy level to the sink .Now the residual energy level plays an important role in deciding the clusters. Depending upon the residual energy clusterfication is done for even distribution of the load across the whole network. Once the cluster heads and associated clusters and cluster member nodes are found, the sink broadcasts a message that contains the cluster head identity for each node. If a cluster head identity matches its own identity, the node is a cluster head; otherwise the node determines its TDMA slot for data transmission and starts waiting for its turn to transmit data. When it comes to the steady state phase,there is no difference between LEACH and celtralized LEAH or LEACH-C.

C. LEACH-M Protocol

In LEACH, Each CH directly communicates with BS irrespective of the distance between CH and BS. It will consume more energy if the distance is far. But, multiple hop-LEACH or LEACH-M,described in[7],determines a optimal path between CH and the BS through other CHs and use other CHs as a relay station to transmit data to the BS.Initially, multi-hop communication is adopted among CHs. Then, according to the determined shortest path, these CHs transmit data to the corresponding CH which is nearest to BS. Finally, this CH sends data to BS.LEACH-M protocol is almost the same as LEACH protocol, only changes communication mode from single hop to multi-hop between CHs and BS and due to this multihop communication it is able to cover larger area than LEACH.

D. Energy LEACH Protocol

This is an advanced energy balanced multiple-hop routing protocol named Energy LEACH or LEACH-L,described in [7], can be characterized as follows:

- when the cluster-heads are close to base station, they directly communicate with Base Station(BS);
- when they are far awar from BS, they telecommunicate by multiple-hop way, and the shortest transmission distance is limited. Different frequencies are being used by sensor nodes in different areas for communication.

In order to explain the concept, let us define some parameters as follows.

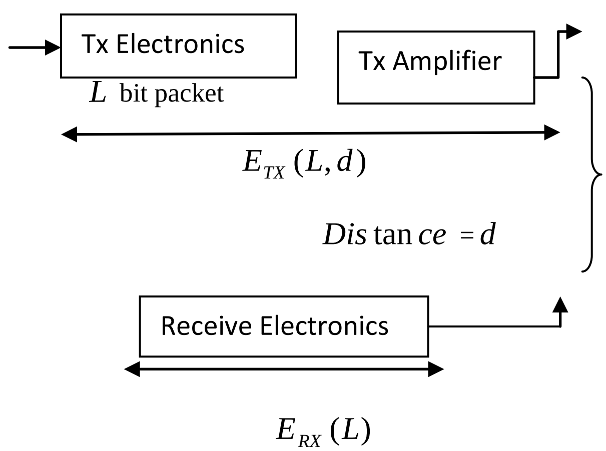

Fig 2.Radio Energy Dissipation Model

Considered Parameters are: E_{elect} Consumed energy per bit, $\in_{fs}$ Energy consumed by free space amplifier, $\in_{mp}$ Energy consumed by multipath amplifier, d is the distance between transmitter and receiver, L is the length of the message in bits. Both the free space (d^2 power loss) and the multi-path fading (d^4 power loss) channel models are used in the model, depending on the distance between transmitter and receiver .Now the transmission cost E_{TX} and receiving cost E_{RX} is calculated as $E_{TX}(L,d) = L.E_{elect} + L \in_{fs} d^2$, when $d \le do$; $do = \sqrt{\in_{fs}} / \sqrt{\in_{mp}}$ and $E_{TX}(L,d) = L.E_{elect} + L \in_{fs} d^4$, when $d \ge do$ and $E_{RX}(L) = E_{elect} L$ .A sensor node also consumes some amount of energy for data aggregation. We assumed that the sensed information is highly correlated, thus the cluster-

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head can always aggregate the data gathered from its members into a single length-fixed packet.

E. Fuzzy-C-Means LEACH Protocol

The method of gathering the similar type of data elements into a particular confined area, known as cluster, is called data clustering. This clustering can be of two types- hard clustering and soft clustering. In hard clustering, a data element can be a member of exactly one cluster. In soft clustering (also referred as fuzzy clustering), data elements can be a member of more than one cluster, and associated with each element is a set of membership levels. One of the most widely used fuzzy clustering algorithms is the Fuzzy C Means (FCM) Algorithm, introduced by Bezdek in 1981. The FCM algorithm tries to partition a finite set of n elements $X = \{x1, x2, ...xn\}$ into a collection of c fuzzy clusters with respect to some given parameter. Considering a finite set of data, the algorithm returns a list of c cluster centers $C = \{c1, c2, ...cc\}$ and a partition matrix $W = w_{i,j} \in [0,1], i = 1,2,..n, j = 1,2,..c,$ where each element Wij tells the degree to which element xi belongs to cluster cj. FCM aims to minimize an objective function. The standard function is:

$$w_k(x) = \frac{1}{\sum_j \left(\frac{d(center_k, x)}{d(center_j, x)}\right)^{2/(m-1)}}$$

which differs from the k-means objective function by the addition of the membership values and the fuzzifier m. The fuzzifier m determines the level of fuzziness of a cluster. A large m results in smaller memberships w_{ij} and hence, fuzzier clusters. In the limit $m = 1$, the memberships w_{ij} converge to 0 or 1, which implies a brusque partitioning. In the absence of domain knowledge, m is generally set to 2. Any point x has a set of coefficients giving the degree of being in the *k*th cluster $w_k(x)$. With fuzzy *c*- means, the centroid of a cluster is the mean of all points, weighted by their degree of belonging to the cluster: $C_k = \sum_x w_k(x)x / \sum_x w_k(x)$.The degree of belonging, $w_k(x)$, is related inversely to the distance from x to the cluster center as calculated on the previous pass. It also depends on a parameter m that controls how much weight is given to the closest center.

3. PROBLEM FORMULATION

While forming clusters, initially the nodes should be organized into different clusters and then cluster head-node should be selected. Here we use the Fuzzy-clustering technique, using fuzzy-c-means algorithm(FCM) that can effectively select and rotate cluster heads in the network clusters. Fuzzy c-means is a method of clustering which allows one piece of sensor node to belong to two or more clusters. The degree of being in a certain cluster is related to the inverse of the distance to the cluster. By iteratively updating the cluster centers, the membership grades for each sensor node is updated. Within a set of nodes, cluster centers iteratively moved to the proper location by using FCM algorithm.

4. RESULTS

In this paper MATLAB is used as experiment platform and simulates two different scenarios. The simulation parameters which are taken into account are listed below in the table.

Table 1. Simulation parameters.

	Scene1	Scene 2
Scope (meters)	(200,200) and(400,400)	(200,200)and(400, 400)
Numbers of sensors	300	1000
Location of BS	(100,100)and (200,200)	(100,100) and (200,200)
Initial eneygy	0.5J	0.5J
E	1 J	1J
Packet Length	4000bits	4000bits
E_{TX}	5×10^{-8}	5×10^{-8}
E_{RX}	5×10^{-8}	5×10^{-8}
$\in_{mp}$	1.3×10^{-15}	1.3×10^{-15}
$\in_{fs}$	10^{-11}	10^{-11}
E_{DA}	5×10^{-9}	5×10^{-9}

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In the figure 3 and figure 4 network lifetime is shown by plotting number of alive nodes over number of rounds taking 300 sensor nodes into account and the area considered is 200X200m and 400X400m respectively.

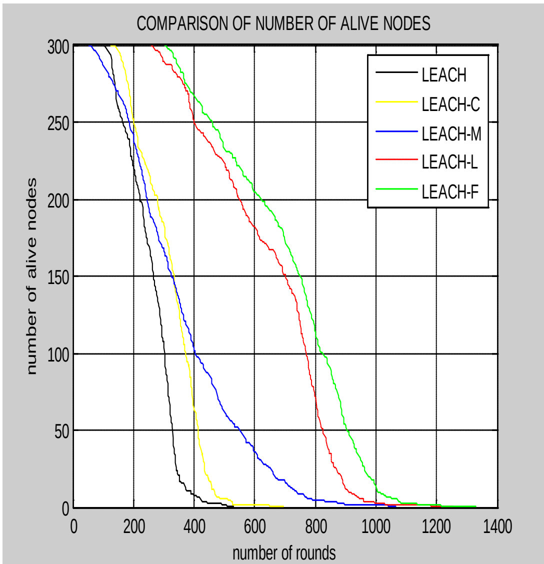

Fig 3.Alive nodes over rounds for 200X200m area

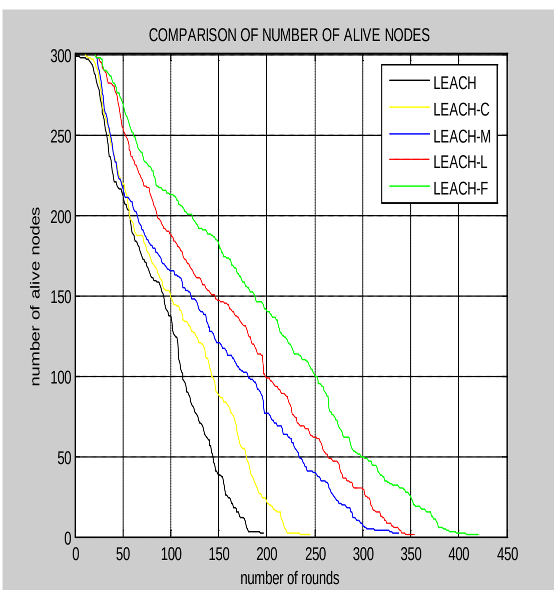

Fig 4.Alive nodes over rounds for 400X400m area

From the figure it is clearly visible that, the new fuzzy logic based LEACH-F is able to operate more number of rounds than mult-ihop LEACH(LEACH-M)and energy LEACH(LEACH-L) which are basically modified version of basic LEACH protocol, because of the new fuzzy logic based cluster head selection technique is applied in LEACH-F. All the Nodes of Energy LEACH (LEACH-L) is died around 1100 round but Fuzzy LEACH(LEACH-F)is able to operate upto almost 1350 round in figure 3 and in case of the larger scenario also LEACH-F is performing better which is depicted in figure 4.In figure 5 and figure 6 we have considered 1000 sensor nodes in two different scenarios of 200X200m and 400X400m respectively. The result we got in figure 3 and figure 4, is verified in later

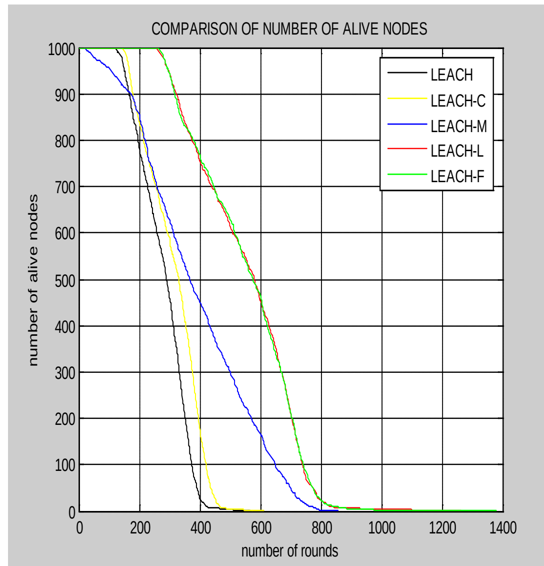

Fig 5.Alive nodes over rounds for 200X200m area

two figures where also LEACH-F is proved efficient for 1000 sensor nodes in both scenarios.

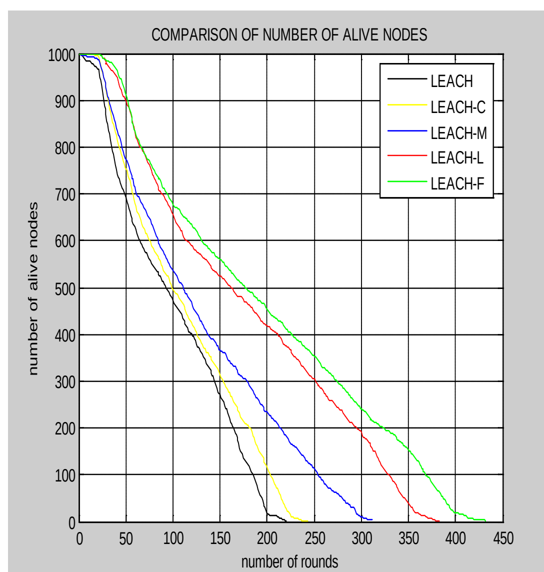

Fig 6.Alive nodes over rounds for 400X400m area

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Now summary of residual energies are presented for various scenarios. In the following figures, comparison of residual energies of different algorithms is shown in different rounds. All the energy values are calculated in joules and 0 in the table indicates all the nodes has been died in the corresponding algorithm. The values which we obtained from MATLAB simulations, used to prepare the following graphs.

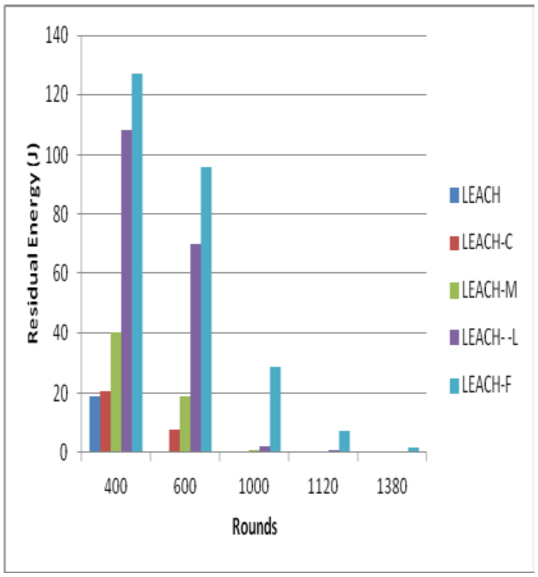

Fig 7. Comparison of residual energy for 300 nodes over 200m area

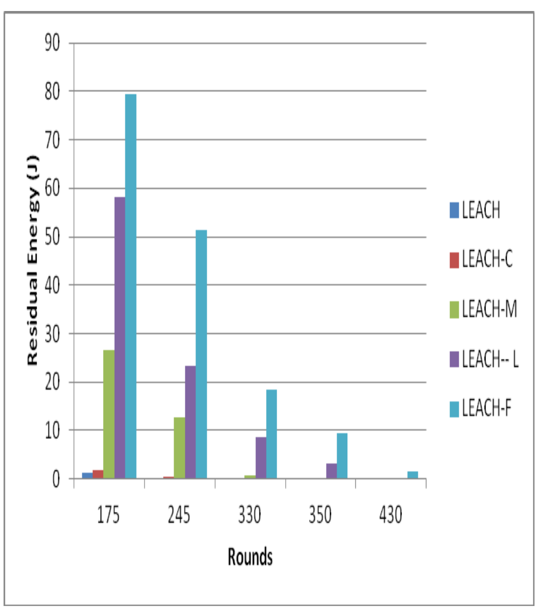

Fig 8. Comparison of residual energy for 300 nodes over 400m area

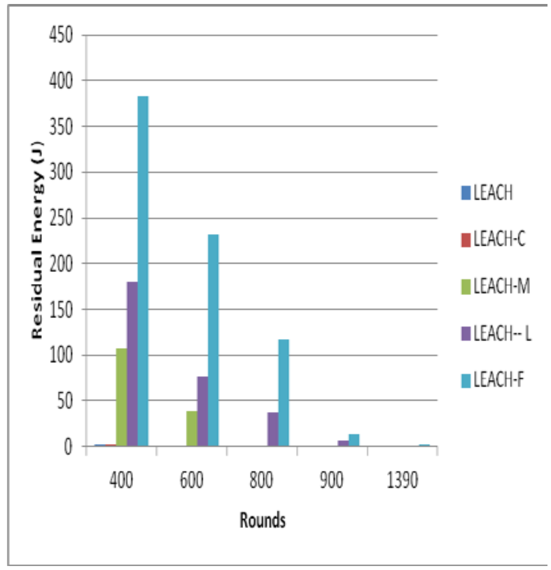

Fig 9. Comparison of residual energy for 1000 nodes over 200m area

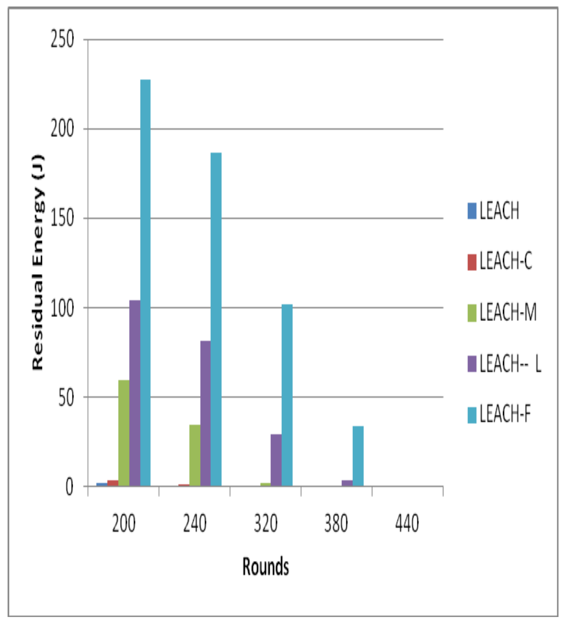

Fig 10. Comparison of residual energy for 1000 nodes over 400m area

From all the simulation results we can infer that the fuzzy logic based cluster head selection reduce the consumption of energy and for this reason LEACH-F is able to operate more number of rounds. Clearly, the new method of cluster head selection giving advantage to LEACH-F than any other existing protocol.

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5. CONCLUSIONS

In this paper we have presented performance comparison between existing versions of LEACH protocol and a new modified routing protocol based on fuzzy logic called LEACH-F. This protocol uses fuzzy c means (FCM)algorithm to select cluster head nodes assuming all the nodes are fixed in their position and they possess same initial energy. We particularly used fuzzy logic because this deals with reasoning that is approximate rather than fixed and exact as it is not possible to get uniform cluster shape in real time scenarios. It is clearly indicated by our results, this new approach is giving better result than any other existing version of LEACH protocol because efficient energy optimization is done during cluster head selection. We are planning to compare this result with the other hybrid (such as GA-ABC)algorithms as future scope of our work.

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