Performance Evaluation of Efficient Energy protocols for clustering in WSNs

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Abstract— Wireless Sensor Networks (WSNs) is a group of sensor nodes with lightweight, inexpensive, low battery nodes distributed in interesting field to sense the environment and send collected data to Base Station (BS) for further processing. Communication distance between sensor node and BS affects the battery of sensor node, as distance between sensor node and BS increased, the energy consumed in data sending increased. There are many different routing algorithm designed for efficient data route from sensor node to BS, Cluster based routing is one of famous technique recently used in data transmission . Cluster Head (CH) node elected to gather data from other nodes in the cluster and this in turn reduce distance from sensor node to BS and perform data aggregation before sending to BS, This paper discuss the impact of network size and BS location in different Efficient-Energy protocols for WSN clustering on the network Performance. Simulation Results show Network life time, total energy consumption and data packets sent to BS for different protocols in order to analysis their performance.

Index Terms— WSN Clustering, Energy Efficient, Multi-Hop Network, Life time, stability, Fuzzy Logic.

1 INTRODUCTION

Wireless Sensor Network consist of small , inexpensive and low energy sensor nodes , distributed in planned or random manner in specific field to measure and react to events or phenomena in that area [9]. This area may be Physical location, to monitor conditions such as fire, pressure, temperature, and many more or Biological location, for healthcare application such as remotely blood pressure measurement, heart rate monitoring and many more.
Wireless Sensor Networks are deployed in several Applications which require remote monitoring and controlling such as military, medical, home and business Application [10, 9]. In WSN , sensor nodes perform three main tasks sensing ,processing and communicating , the communication task consume more energy when compared to other tasks [11] , so it's necessary to design proper energy efficient protocol to balance energy consumption in the network. Many routing protocols have been designed for WSN [12, 13], Clustering is one of the most known routing approaches which is a way of dividing the whole network into groups called Cluster and select one node from each Cluster called Cluster Head CH to act as a root to collect and aggregate data before sending to Base Station.

1.1 Energy-Efficient Clustering protocols in WSNs

In this section, an overview of the algorithms to be evaluated will be discussed which include well known LEACH protocol [1], EEM-LEACH [4], LEACH-H [6], I-LEACH [7] , DB-CH [5] and FZ-LEACH [8]. Each algorithm includes different factors for CH selection, Cluster formation. CHs send collected data in Single Hop or Multi-Hop approaches.

LEACH

First dynamic clustering protocol proposed by Heinzelman et al.2002 [1] and called Low-Energy Adaptive Clustering Hierarchy . The algorithm is divided into Rounds. Each round begin with Setup phase followed by steady state phase .

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CH selection done in Setup phase based on Threshold equation in (1), sensor node become CH if the random number selected between 0 and 1 less than T (n).

$$T(n) = \begin{cases} \frac{p}{1-p(r \bmod (\frac{1}{p}))}, & n \in G \\ 0 & , \text{ others} \end{cases} \quad (1)$$

CHs send advertisement packets to announce their states, sensor nodes join CH with max RSSI, and Steady state phase begins for data transmission.

EEM-LEACH

Energy Efficient Multi-Hop based LEACH is an algorithm proposed in [4] for clustering and routing in WSN that has the following characteristics:

- CH selection based residual Energy and average Energy Consumption as in (2)

$$T(n) = \begin{cases} \frac{p}{1-p(r \bmod (\frac{1}{p}))} \times P(RE) & n \in G \\ 0 & , \text{ others} \end{cases} \quad (2)$$

$$P(RE) = \begin{cases} \frac{E_{resi} - E_{avg}}{E_{resid}} & , E_{resi} > E_{avg} \\ 1 - E_{avg} & , \text{ otherwise} \end{cases}$$

- Inter-Communication between CHs based on minimum distance to BS , Direct Communication from nodes near to BS

LEACH-H

The proposed algorithm used three factor that include residual energy, closeness to BS and number of neighbours for each sensor node to elect CHs. In LEACH-H [6], Genetic Algorithm GA used to determine value of weights

$$T_{new}(n) = [w_1 . T_1(n) + w_2 . T_2(n) + w_3 . T_3(n)] * p \quad (3)$$

Where :

P percentage of CHs in the network

$$T_1(n) = \begin{cases} \frac{E_{res}}{E_{avg}} & , \quad E_{res} > E_{avg} \\ 0 & , \quad E_{res} < E_{avg} \end{cases} \quad (4)$$

$$T_2(n) = \begin{cases} \frac{D_{(n,BS)}}{D_{avg}} & , \quad D_{(n,BS)} < D_{avg} \\ 0 & , \quad D_{(n,BS)} > D_{avg} \end{cases} \quad (5)$$

$$T_3(n) = \begin{cases} \frac{Node_{neig}}{N_{avg}} & , \quad Node_{neig} > N_{avg} \\ 0 & , \quad Node_{neig} < N_{avg} \end{cases} \quad (6)$$

The average value for each weight factor determined in [6] and showed that the main factor in CH selection is Residual Energy then closeness to BS followed by number of neighbours for each node .

I-LEACH

The Improved Routing algorithm based LEACH algorithm proposed in [7] to address limitation of LEACH protocol .Initially CHs selected based on improved threshold shown in (7):

$$T(n) = \begin{cases} \frac{p}{1-p(rmod(\frac{1}{p}))} \times \frac{E_{cur}}{E_{avg}}, & n \in G \\ 0 & , \text{ others} \end{cases} \quad (7)$$

The new threshold introduce the residual energy of each sensor node in CH selection process , after that each node join CH based on formula (8) :

$$f(i, CH_j) = w\left(\frac{E_{CHj}}{E_{ini}} \frac{1}{d(i,CH_j)}\right) + (1-w)\left(\frac{E_{CHj}}{E_{ini}} \frac{1}{d(CH_j,BS)}\right) \quad (8)$$

Where w is the weighting factor, E_{CHj} is the residual energy for CHj , d(i,CHj) is the distance from sensor node to CHj and d(CHj , sink) is the distance from CHj to BS , Each sensor nodes compute fitness function in (8) ,and join CH with Maximum value . After that CHs are communicate with each other to select one root CH that can communicate directly with BS [6].

$$P_H = w_1 \frac{E_{CHi}}{E_{ini}} + w_2 \frac{d(CHi,sink)}{dis_{max}} + w_3 \frac{(N-N_{CHi})}{N} \quad (9)$$

Where NCHi is the number of nodes in CHi , N total number of nodes , dismax is the Maximum distance between the monitoring area and BS , CH become root node if the probability computed in (9) is the Maximum.

FL-LEACH

In [8]; authors propose a new clustering technique called Energy Efficient Fuzzy Logic Cluster Head (FL-LEACH) using three fuzzy parameters , Residual Energy which is difference between initial energy and consumed energy , Closeness to base station and number of neighbour for each node.

In the proposed algorithm each node calculates its chance value based on the three fuzzy parameters, and if the maximum chance less than threshold T (n) that mentioned in (1), the sensor node will be CH for the current round. After CHs have been elected, the steady state phase begin as same in LEACH protocol.

DB-CH

The Energy Efficient Distance Based CH selection is an algorithm proposed In [5] to address the limitation in CH threshold calculation for each node, The proposed algorithm modify takes into account the residual energy of each node, and distance from sensor node to BS when calculating the threshold value. The new threshold function showed in (10)

$$T(n) = \begin{cases} \frac{p}{1-p(rmod(\frac{1}{p}))} + (1-p)\frac{D_{max}-D_{itoBS}}{D_{max}-D_{min}}\left(\frac{Ei}{Eo}\right), & n \in G \\ 0 & , \text{ others} \end{cases} \quad (10)$$

Where Ei is the residual energy for node i,Eo is the initial energy ,Dmax and Dmin is the maximum and minimum distance from sensor node to BS respectively . With new modification sensor nodes with more residual energy and with nearer to BS will have higher chance to be CH.

2 Performance Model

2.1 WSN Model

The sensors deployed randomly in area of M (100m x100m) field ,and BS located distance away from sensor field to show the effect of Multi-Hop instead of Single-Hop .The optimal number of CHs determined by [1,2] that shows the desired percentage of CH equals 5% of network nodes N. Table 1 shows the parameter used in experiments .

2.2 Energy Consumption Model

The radio model used in [2] is adopted in this paper,

$$E_{TX}(m,d) = \begin{cases} m.E_{elec} + m.\varepsilon_{fs}.d^2 & d \le d_0 \\ m.E_{elec} + m.\varepsilon_{mp}.d^4 & d > d_0 \end{cases} \quad (11)$$

Energy consumption in receiving process as:

$$E_{RX}(m) = \begin{cases} m.E_{elec} & , \text{ node not intermediate} \\ m.E_{elec} + m.E_{DA}, & \text{node is intermediate node} \end{cases} \quad (12)$$

Where ETX and ERX ,the Energy dissipated per bit at transmitter and receiver respectively ,Eelec Energy consumed in running electronic circuit in TX and RX , εfs, εmp is free space and multipath coefficient factor , respectively ,m data packet size ,d0 threshold distance and d is the distance between TX and RX .

Table 1 Parameter Setting

Parameter	*Value*
M	100m * 100m
N	50
Sink Node	(50 ,200)
P	0.05
E_0	0.1J
ϵ_{fs}	10pJ/bit/m^2
ϵ_{mp}	0.0013pJ/bit/m^4
E_{da}	5nJ/bit/signal
E_{elec}	50nJ/bits
m	4000 bits

3. Simulation Results and Discussions

A. Simulation Results for small network size

Table 2 shows average results for the rounds until FND for 5 simulation run , its clearly shown that I-LEACH provide more stable region than other LEACH extensions and this is because I-LEACH target the important factors in the clustering process .

Table 2 stable region comparison

Protocol	FND	HND	PND	% Stable region enhancement
LEACH	105	164	235	-----
DB-LEACH	122	275	1000	16%
EEM-LEACH	142	209	247	35.2%
LEACH-H	182	232	256	73.33%
FL-LEACH	220	500	1200	109.52%
I-LEACH	227	257	285	116%

Figures 1 ,2 shows the improvements for network life time for different protocols as a comparative to LEACH, [3] stated that protocols try to minimize unstable region and increase stable region for better reliability so there is tradeoff between reliability and network life time ,better reliability means shorter network life time. Some protocols provide long interval for last alive node which still give feedback about sensing area as in DB-CH and FL-LEACH in Figure 2, but this could be unreliable , where in other hand as shown in Figure 1 protocols provide enhancement in Stable region and increase reliability of the Network .

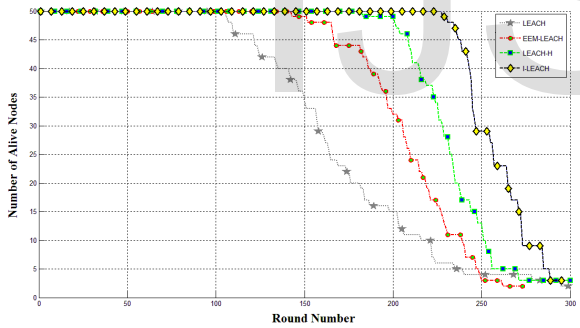

Fig1, NLT for EEM-LEACH, I-LEACH , LEACH-H and LEACH

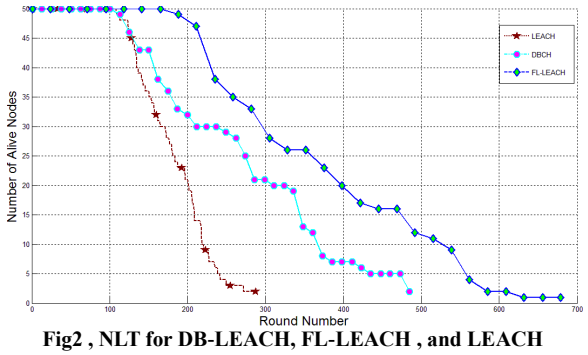

Fig2 , NLT for DB-LEACH, FL-LEACH , and LEACH

Figures 3, 4 shows Network energy consumption evaluated protocols , and as shown for reliable protocols I-LEACH recorded lower energy consumption than others , where for unreliable protocols FL-LEACH proved better performance than DB-CH as its way in electing CH considered more important factors .

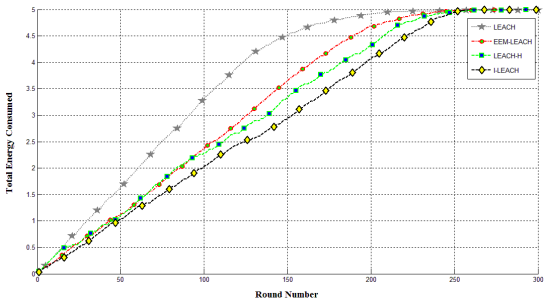

Fig.3 , NEC for EEM-LEACH, I-LEACH , LEACH-H and LEACH

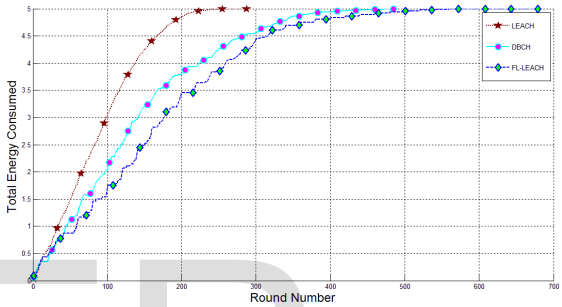

Fig.4 , NEC DB-LEACH, FL-LEACH , and LEACH

B. Simulation Results for different Network N Size

This section provide the simulation results and discussion when running different protocols in different network size to show the effect of nodes density , the parameters used are the same in Table 1 and varying network size to 100 , 300 and 500 sensor nodes . Table 3 shows mean of average consumed energy for nodes (in jouls) with their Standard Deviations (SD) for different number sensors for 5 different runs , it is clearly shown that I-LEACH proves better performance than other protocols because all these scenarios runs with BS distance away from sensing area that makes Multi-Hop important factors to be considered to reduce energy consumption.

Table 3 Mean and SD for average Consumed Energy for different N size

Protocol	50 Sensor Nodes		100 Sensor Nodes		300 Sensor Nodes		500 Sensor Nodes	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LEACH	3.632	1.561	7.0993	3.1818	21.0445	9.5844	35.23	15.93
LEACH-H	2.457	1,55	6.9755	3.2143	20.338	9.7631	33.52	16.23
EEM.LEACH	2.800	1.58	6.2883	3.2556	18.3379	9.6651	32.58	16.36
I-LEACH	3.013	1.666	5.5628	3.1258	16.1157	9.1773	29.32	16.03
DB-LEACH	2.647	1.183	5.4741	2.8251	16.085	8.1825	28.33	14.33
FL-LEACH	2.022	1.121	4.8951	2.5831	15.814	7.888	26.10	12.85

Figure 5 shows the stable region performance for different protocols in different network size , its clearly shown that LEACH protocol record worst stable region performance for their limitations , I-LEACH protocol cover important factors

to balance energy consumption as mentioned before and working as well as network size increased . Figure 8 shown the performance of each protocol in terms of HND , and for reliable protocols ILEACH considered more efficient as long as network size increased ,LEACH-H proved better performance than EEM-LEACH in small network size ,while EEM-LEACH in dense network become more efficient than LEACH-H

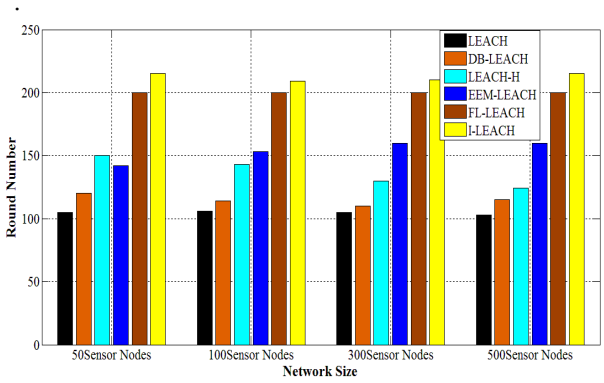

Fig.5, Comparative Result in terms of FND

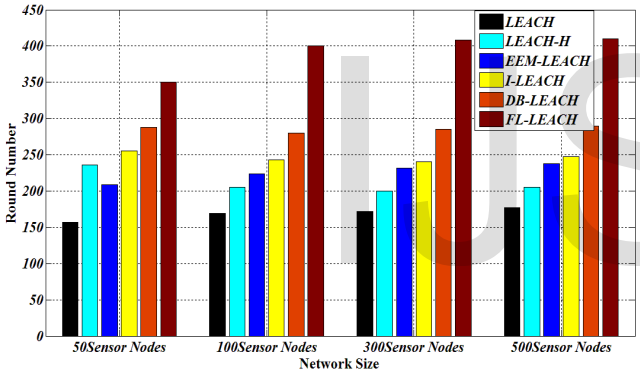

Fig.6, Comparative Result in terms of HND

Fig. 7 shows data packets sent to BS and as clearly shown in small network size LEACH-H and I-LEACH recorded better data packets received at BS and in large network size as EEM-LEACH and ILEACH record better performance than LEACH-H and LEACH, DB-CH and FL-LEACH increase Network life which increase number of data packets send to BS.

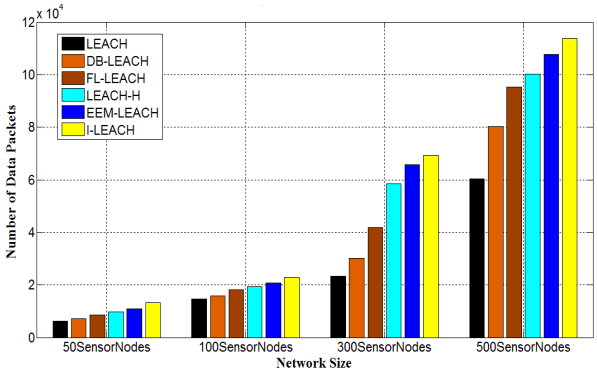

Fig.7, Comparative Result in terms of Data Packets Sent to BS

C. Simulation Results when BS at Corner

This section provides the simulation results and discussion when running different protocols in different network size when BS located at Corner of sensing field. Table 4 shows mean of average consumed Energy for nodes (in joules) with their Standard Deviations (SD) for different number sensors for 5 different runs , which indicates that in small area LEACH-H perform better than LEACH ,EEM-LEACH and I-LEACH ,but as network increase in density ,EEM-LEACH and I-LEACH record better results .

Table 4 Mean and SD for average Consumed Energy for different N size

Protocols	50 Sensor Nodes		100 Sensor Nodes		300 Sensor Nodes		500 Sensor Nodes	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LEACH	3.217	1.613	6.7442	3.2612	18.493	9.8179	30.505	16.106
LEACH-H	2.859	1.516	6.4600	3.3023	18.115	9.6251	30.734	16.203
EEMLEACH	2.607	1.568	6.2280	3.2445	17.515	9.6256	30.073	16.018
I-LEACH	2.786	1.552	5.6321	3.1111	16.815	9.3078	30.059	16.160
DB-LEACH	2.499	1.362	5.7038	2.865	16.149	8.6291	29.389	15.249
FL-LEACH	2.043	1.137	5.0161	2.0125	14.16	6.0122	26.844	10.675

The Performance of different protocols in terms of first node dead showed in Figure 8 and indicates that when BS at Corner of sensing field , EEM-LEACH proves better performance against LEACH-H , DB-LEACH and LEACH protocols in small network size.

Figure,13 shows that I-LEACH in reliable protocols category has more than data packets sent to BS than LEACH-H ,EEM-LEACH and LEACH ,while FL-LEACH record better data packets sent to BS in poor reliable category.

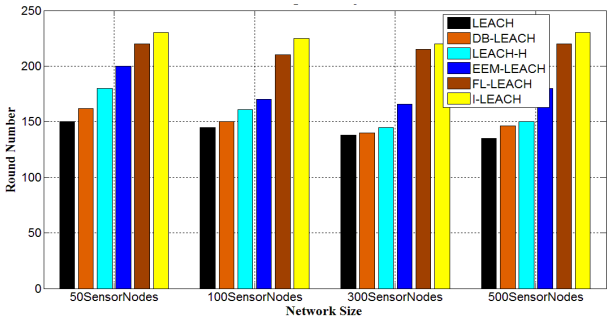

Fig.8.Comparative Result in terms of FND

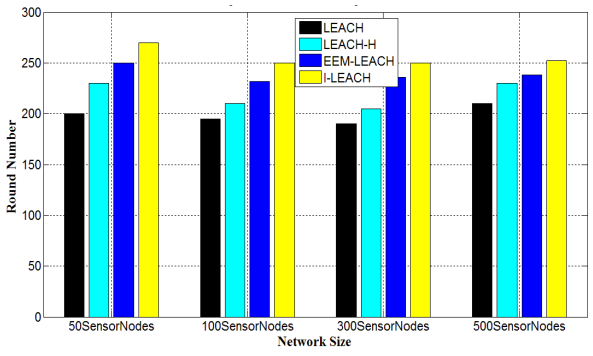

Fig.9. HND for EEM-LEACH, I-LEACH , LEACH-H and LEACH

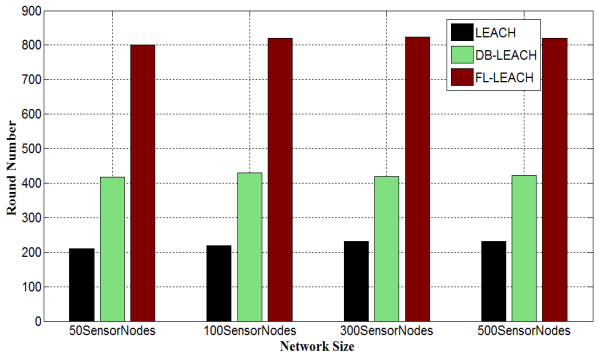

Fig.10. HND for DB-LEACH, FL-LEACH , and LEACH

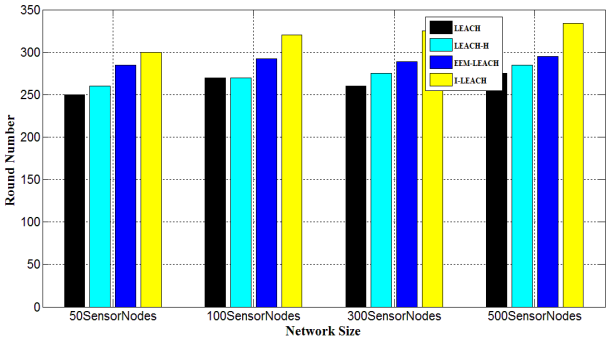

Fig.11. PND for EEM-LEACH, I-LEACH , LEACH-H and LEACH

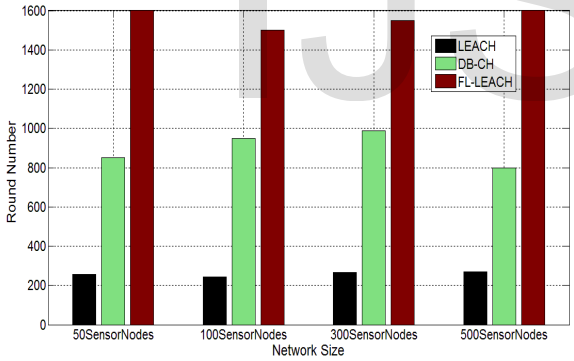

Fig.12. of PND for DB-LEACH, FL-LEACH , and LEACH

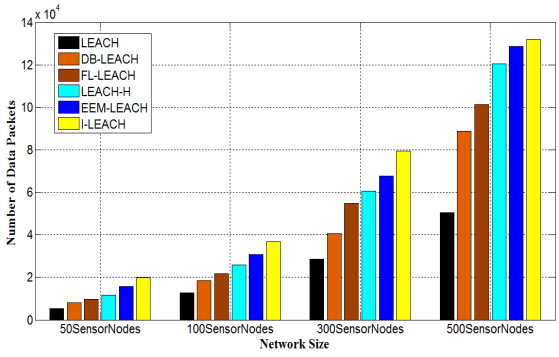

Fig13, Data Packets Received at BS for DB-LEACH, FL-LEACH and LEACH

4. CONCLUSION

In this paper various distributed clustering algorithms used in WSNs are presented. The main goal of the clustering algorithm presented in this paper is to balance energy consumption, increase stable region, and prolong network life time.

The way of electing CHs in the network play an important factor in reducing total network energy consumption. Various protocols mentioned use different criteria to elect CH from normal nodes , EEM-LEACH use residual energy as main factor in threshold function where LEACH-H enhance the criteria for CH selection to include distance and closeness to other normal nodes additive to residual energy to modify threshold function .

In other hand where I-LEACH protocol elect CHs based on residual energy for each node , but it modify the way that each sensor node join cluster , which is based on cost function that include each CH energy and its closeness to BS . DB-CH is another algorithm mentioned that elect CH based on distance to BS as main criteria.

For large scale area Multi-Hop approach become necessary for data transmission from CH to BS , this paper discuss two different protocols that construct a network between CHs for data transmission. In FL-LEACH the random number compared to threshold value is modified to be representative of each node residual Energy, its distance to BS and number of neighbouring nodes.

In first part of simulation ,Base station placed distance away from sensing field ,and record the result from different protocols with different number of sensor nodes from 50 sensor in 100x100 area to 500 sensor in same area ,and results showed that in small network size LEACH-H perform better than EEM-LEACH, but as network size increased multi-hop protocols become more preferable.

In second part of simulation ,Base station set at corner of sensing filed ,and varying number of sensors from 50 sensor in 100x100 area to 500 sensor in same area ,and the results showed that in new position for BS EEM-LEACH-H perform better than LEACH-H in small network size.

Future study should be done to elect CHs in a centralized way using Evolutionary Algorithm to elect optimal set of CHs that minimize energy consumption, balance energy consumption around the network and include multi-Hop routing for data transmission to BS.

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