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An Augmented Clustering Hierarchy for LEACH – Energy Efficient WSN Protocol

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Abstract
With technological revolution in the field of MEMs and Embedded Systems, Wireless Sensors Networks has emerged as one of the prime research field in the recent years. In past few years many researchers have continuously worked on implementation of their novel ideas for the betterment of human life using this type of small tiny sensors and networks implemented using them. This well-organized innovation has multiple advantages to scrutinize and analyze the data where the humans can't reach or sustain. Here we have proposed Energy Efficient Routing Protocol for WSN which provide better life span of the network and augmented throughput. In this we have developed an Augmented LEACH protocol and Novel approach for the Cluster Head Selection Procedure. Now for augmented leach protocol achieved by implementing a Novel Clustering Algorithm based on the even area distribution criteria. This approach improves the system life time by an order of 1.5 times. Mainly these protocol improves the Network Life Span, Data Throughput while decreases the overall Energy Consumption by the network

Keywords: *Wireless Sensor Networks, Energy Efficient Routing Protocols, LEACH, Even Area Distribution Criteria.*

1. Introduction

We can say by the current scenario of technology that there is a wide future in Remote Sensing and which expands human abilities to communicate remotely with the physical world. Recent evolution in energy efficient micro-electro-mechanical systems (MEMS) technology, digital electronics, embedded systems & wireless communication have enabled the development of low-cost, low-power, multifunctional tiny sensor nodes which can communicate untethered in short distances.

When we use WSN in huge remote places like forests or deserts at that time many restrictions with the sensors come into the consideration like battery life, limited computing abilities with less memory and power consumption are the main life-threatening parameter for sensor. Therefor to transmit data we need multi sectional architecture. For this type of special application the energy consumption in sensors should be controlled by some self-organized architecture.

For the sensing purpose if many sensors are deployed in remote areas, and If each and every sensor starts to communicate and engage in data transmission in the network, great network congestion and data collisions will be experienced. This will result to drain limited energy from the network. Node clustering will address these issues. In cluster networks, sensors are partitioned into smaller clusters and cluster head (CH) for each cluster is elected. Sensor nodes in each cluster transmit their data to the respective CH and CH aggregates data and forward them to a central base station. Clustering through creating a hierarchical WSN facilitates efficient utilization of limited energy of sensor nodes and hence extends network lifetime. Low-Energy Adaptive Clustering Hierarchy (LEACH) is the most popular cluster-based routing protocols in Wireless Sensor Networks but main drawback of LEACH that we have observed during analysis part is its random Cluster Head Selection algorithm. The Cluster Head Selection is depending on the selection of random number from 0 to 1. If the threshold value for the Node is more than the random number then and only then the node can become a CH. In the [1], the authors of LEACH have mentioned that the best functioning of LEACH is depending on the maximum number of CHs. We have observed that the above mentioned random algorithm selects different number of CHs per round. This gives comparatively short life span of the network.

2. Literature Review

Zhiyong PENG, Xiao juan LI [2] have presented Variable Round LEACH algorithm to improve the network life time. VR-LEACH generates variable round time is calculated which is dependent on number of CHs and Energy of nodes etc. In VR-LEACH, First, at set-up phase sort out the nodes whose energy is less than the average energy; other nodes participate in selecting clusters.

Linlin Wang, Jie Liu and Wei Wang [3] have proposed new algorithm to balance energy consumption and to increase the network life cycle called Based Energy Clustering (BEC) algorithm. In the proposed scheme No. of clusters are calculated according to grid based partition method. BEC-LEACH divides the monitoring region into grids equably according to the grids theory; the nodes in each grid form a cluster and proposed the numerical computing methods of the number of cluster-head. The Threshold value is also set different compare to simple leach.

Wei Wang; Qianping Wang; Wei Luo; Mengmeng Sheng; Wanrong Wu and Li Hao [4] have presented Hybrid LEACH to reduce the energy consumption and increase life time of the network. In the first round of Leach-H, the base-station selects a cluster head set through adopting Simulated Annealing Algorithm; in the followed rounds, the cluster heads will select new cluster heads in their own cluster. This will not only solve the problem that the cluster heads are unevenly distributed in LEACH, but also maintain the characteristics of distribution. In the Initialization phase, simulated annealing algorithm is used. The algorithm for LEACH-H is shown in figure 2.1

Mu Tong and Minghao Tang [5] have implemented LEACH-B algorithm for wireless sensor networks. The goal of algorithm is to make protocol which has balanced the system energy consumption and has better performance of prolonging the network lifetime than LEACH protocol. In B-LEACH, the node is made cluster head according to the time interval generated which is ultimately depends on the Energy of that node. The disadvantage is still the algorithm is distributed; the nodes make autonomous decisions without any centralized control.

Hu Junping and Jin Yuhui [6] have presented a Time-based Cluster- Head Selection Algorithm for LEACH for improving network lifetime. In TB-LEACH the CHs are decided on the depending upon the time interval rather the randomly generated numbers as in simple LEACH. But the limitation is that the timer is again generated randomly. TB-LEACH constructs the cluster by using an algorithm based random-timer, which doesn't need any global information.

Hu Yu; Li Wei and Kang Zhenhua [7] have proposed Energy Efficient Clustering Hierarchy algorithm for LEACH. It uses the threshold value for selection of CH based on current and average energy. Moreover Communication between CH and SINK is done in three steps. Multi hop routing, CH broadcast WEIGHT message and CH chooses another CH whose weight is greater than its own. And transmit CHILD information.

In wireless sensor network energy collecting is essential in some applications, especially when sensor nodes are placed in non-reachable areas like battle area [8]. Some of applications solar-ware LEACH (sLEACH) has been projected by authors [8] in which lifespan of the wireless sensor network has been improved through solar power. Some nodes are facilitated by solar power and these nodes will act as cluster-heads mainly depending upon their solar status in sLEACH. In sLEACH both of LEACH and LEACH -C are extended.

LEACH conceives all nodes are homogeneous with respect to energy which is not realistic approach. In particular round uneven nodes are attached to multiple CH, in this case CH with large number of member ode will drain its energy as compare to cluster-head with smaller number of associated member nodes. Furthermore mobility support is another issue with LEACH routing protocol, to mitigate these issues, M-LEACH is proposed in [9]. M-LEACH allows mobility of non-cluster-head nodes and cluster-head during the setup and steady state phase. MLEACH also considers remaining energy of the node in selection of cluster-head.

3. Performance Analysis & Implementation of LEACH Protocol

3.1 LEACH

Low-Energy Adaptive Clustering Hierarchy, application-specific protocol architecture. LEACH is a clustering based protocol that includes the following features…

- randomized, adaptive, self-configuring cluster formation,
- localized control for data transfers,
- low -energy media access, and
- Application, specific data processing, such as data aggregation

In LEACH, the nodes organize themselves into local clusters, with one node acting as the cluster-head. All non-cluster head nodes must transmit their data to the cluster head, while the cluster head node must receive data from all the cluster members, perform signal processing functions on the data e.g., data aggregation, and transmit data to the remote base station. Therefore, being a cluster-head node is much more energy intensive than being a non-cluster-head node. In the scenario where all nodes are energy limited, if the cluster heads were chosen a priori and fixed throughout the system lifetime, as in a static clustering algorithm, the cluster head sensor nodes would quickly use up their limited energy. Once the cluster head runs out of energy, it is no longer operational.

Thus, when a cluster head node dies (e.g., uses up all its battery energy), all the nodes that belong to the cluster lose communication ability. Thus LEACH incorporates randomized rotation of the high-energy cluster-head position such that it rotates among the sensors in order to avoid draining the battery of any one sensor in the network. In this way, the energy load associated with being a cluster-head is evenly distributed among the nodes.

The operation of LEACH is divided into rounds. Each round begins with a setup phase when the clusters are organized, followed by a steady-state phase. Setup phase includes three section in it.

Section A: Determining Cluster-Head Nodes

In that we want to design the algorithm such that there are a certain number of clusters, k, during each round. Second, we want to try to evenly distribute the energy dissipation among all the nodes in the network so that there are no overly utilized nodes that will run out of energy before the others. This will perform signal processing functions on the data, and transmit the data to an end user who may be far away; evenly distributing the energy load among all the nodes in the network requires that each node take its turn as cluster-head. Therefore, the cluster formation algorithm should be designed such that nodes are cluster heads approximately the same amount of time, assuming all the nodes start with the same amount of energy. The CH selection threshold is designed to ensure that a predetermined fraction of nodes, P is elected CHs at each round. Further, the threshold ensures that nodes which served as CH in the last 1/P rounds are not selected in the current round. To meet these requirements, the threshold T(n) of a competing node n is expressed as,

$$Pt(t) - \frac{k}{N-k*\left(r \bmod \frac{k}{p}\right)} : Ct(t) - 1$$

Or (1)

$$Pt(t) = 0 : Ct(t) = 0$$

Where If Ci (t) is the indicator function determining whether or not node has been a cluster head in the most recent ($r \bmod \frac{N}{k}$) rounds (i.e., Ci (t) = 0 if node has been a cluster head and one otherwise), then each node should choose to become a cluster head at round with probability Pi(t). This can be achieved by setting the probability of becoming a Cluster-head as a function of a nodes energy level relative to the aggregate energy remaining in the network, rather than purely as a function of the number of times the node has been cluster-head:

$$Pi(t) = \frac{Ei(t)}{Etotal(t)} * k \quad (2)$$

Where Ei is the current energy of node i, and Etotal is total energy given by.

Section B: Set-up Phase.

Once the nodes have elected themselves to be cluster heads using the probabilities in Equation (1) or (2) the cluster head nodes must let all the other nodes in the network know that they have chosen this role for the current round. To do this each cluster head node broadcasts an advertisement message (ADV) using a non-persistent carrier sense multiple access CSMA

MAC protocol. In short all NCH listening to advertising message will select one node whose signal strength is maximum as its CH and send its ID, CH ID and a request message to join its cluster. Below figure1 shows the flow graph of the distributed cluster Formation algorithm for LEACH [1]. Starts after CHs receive all requests from NCHs. Now the CHs broadcast their ID, confirmation messages to their cluster members and the TDMA schedule to be used during the steady state phase which commences next.

Section C: Steady-state Phase.

The Steady State phase consists of two steps. In Section A NCHs use the TDMA schedule to send their sensor data with their ID and CH ID to respective CH. The schedule prevents collisions among data messages and allows NCH to turn off their radio components until its allocated time slots. In Section B upon receiving data packets from its cluster nodes, the CH aggregates the data and sends them to the BS along with its CH ID and BS ID. The communication between a CH and a BS is achieved using fixed spreading code and CSMA. Figure 2 shows the flow graph of the steady state operation for LEACH [1].

3.2 LEACH-C (centralized) :

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. Since the clusters are adaptive, obtaining a poor clustering set-up during a given round will not greatly affect overall performance. 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 in-formation about its current location (possibly determined using a GPS receiver) 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. Using the remaining nodes as possible cluster heads, the BS finds clusters using the simulated annealing algorithm [10] to solve the NP-hard problem of finding optimal clusters [11]. This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster head, by minimizing the total sum of squared distances between all the non-cluster head nodes and the closest cluster head.

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.

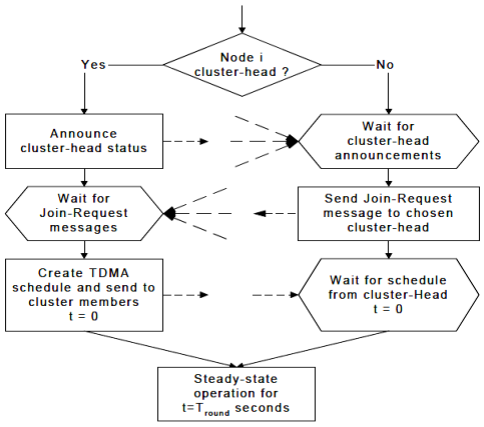

Fig. 1 Flow graph of the distributed cluster Formation algorithm for LEACH

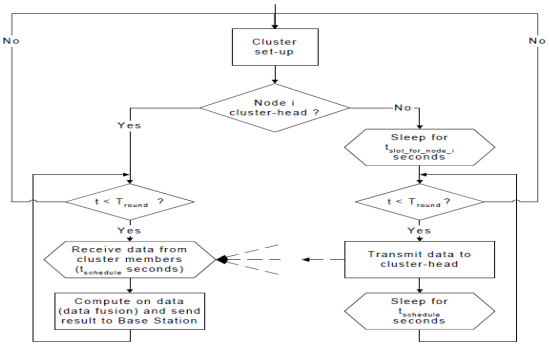

Fig. 2 Flow graph of the steady state operation for LEACH

3.3 Simulation Environment:

We have done the simulation for following conditions and energy model given below.

A. Conditions:
- Base station at (50, 175)
- Each node starting with 2 Joules of energy.

B. Energy Model:
- RXThresh = 6e-9
- CSThresh = 1e-9
- Rb = 1e6
- Excvr = 50e-9
- Efriss_amp = 9.6741659015025702e-12
- Etwo_ray_amp = 1.3037037037037037e-15
- Ebf = 5e-9
- Pidle = 0
- Psleep = 0

C. Thresholds have chosen using original probs.
- Desired number of clusters = 5
- Spreading factor = 8
- Changing clusters every 20 seconds

D. Output Files
- LEACH.OUT

LEACH.out contains all the information regarding nodes like node position, threshold value for each round, cluster head for the given round, distance from cluster head, and the spreading code. It also contains information about data received by base station from which nodes. As well as it has information of network at every 10 seconds like total energy, total data, total alive nodes.
- LEACH.ALIVE

Leach.alive contains information that the given node is alive or not. First column is the time in seconds, second column indicates node number and third column indicates the status of node, if it is 1 then node is alive otherwise it is dead.
- LEACH.DATA

Leach.data contains information about data sent by any node in bytes. First column indicates time, second indicates node number and third column contains data sent.
- LEACH.ERROR

This file give the error message occur when simulation run.
INITIALIZE THE LIST xListHead
channel.cc:sendUp - Calc highestAntennaZ_ and distCST_
highestAntennaZ_ = 1.5, distCST_ = 222.8
SORTING LISTS ...DONE!
- LEACH.ENERGY

Leach.energy logs information about energy of each node at every 10 seconds. First column shows time, second column shows node number and third column shows energy of corresponding node.
- STARTUP ENERGY

Startup energy contains information about energy of nodes at startup of each round. First column shows time, second column shows node number and third column shows energy of node at startup of round. Every round is 20 seconds.

3.4 Simulation Results & Analysis For LEACH & LEACH-C

A. Number of alive nodes/Round

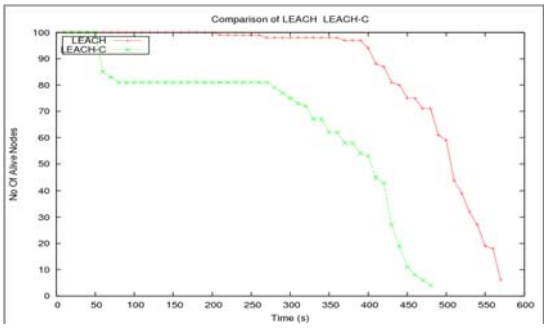

Fig. 3 Comparison of LEACH & LEACH-C for Number of Alive Nodes/Round

B. Amount of Data Received at BS VS Alive Nodes

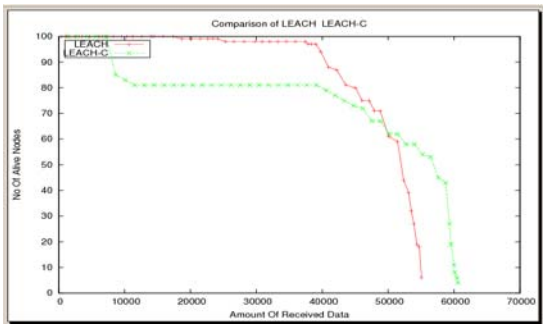

Fig. 4 Comparison of LEACH & LEACH-C for Amount of Data Received at BS VS Alive Nodes

C. Time VS Amount of Data Received at BS

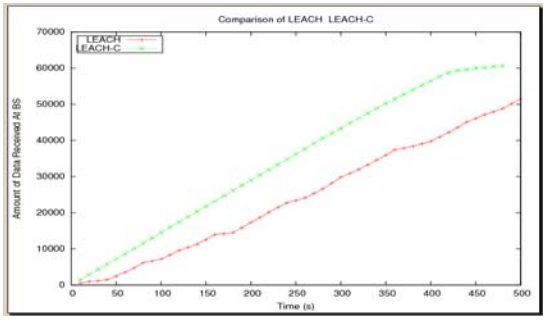

Fig. 5 Comparison of LEACH & LEACH-C for Time VS Amount of Data Received at BS

D. Energy VS Amount Of Data Received at BS

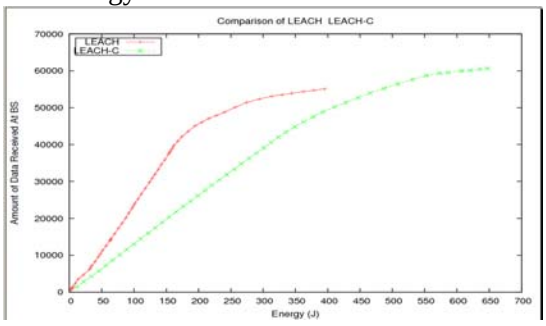

Fig. 6 Comparison of LEACH & LEACH-C for Energy VS Amount of Data Received at BS

4. Proposed Augmentation & Simulation Results

4.1 Drawback with the LEACH Protocol:

The main drawback of LEACH that we have observed during analysis part is its random Cluster Head Selection algorithm. Here we have mentioned few of our analyze cons of LEACH protocol.

1. The Cluster Head Selection is depending on the selection of random number from 0 to 1. If the threshold value for the Node is more than the random number then and only then the node can become a CH.
2. In the [1], the authors of LEACH have mentioned that the best functioning of LEACH is depending on the maximum number of CHs. We have observed that the above mentioned random algorithm selects different number of CHs per round. This gives comparatively short life span of the network.

4.2 Finite Number Of Cluster Heads Per Round Using Even Area Distribution Criteria

Improvement suggested in this paper is limiting the number of cluster heads per round or in other words dividing the area into the finite number of grids. By doing this we are controlling the energy distribution between the nodes & making it even.

As described in the above sections in LEACH the CH selection is random & cluster formation is also unpredictable. This randomness results in an uneven energy distribution between nodes. In the proposed method we have divided the whole area into the finite fix number of section. At beginning of every round the proposed improvement divides the whole area into finite sections and then decides the CH from each section. The division of area is a random process so by doing this we are equally distributing the energy load in between all the nodes equally. Also every node will get a chance to become a CH and this will result in a more even distribution of energy. The simulation analysis of this approach shows a significant improvement in the network life time & throughput of the network.

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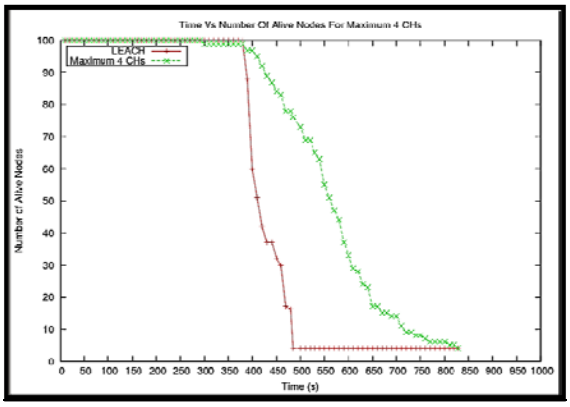

Fig. 7 Comparison of LEACH & 4 CHs/Round for Number of Alive Nodes/Round (Maximum 4 CHs)

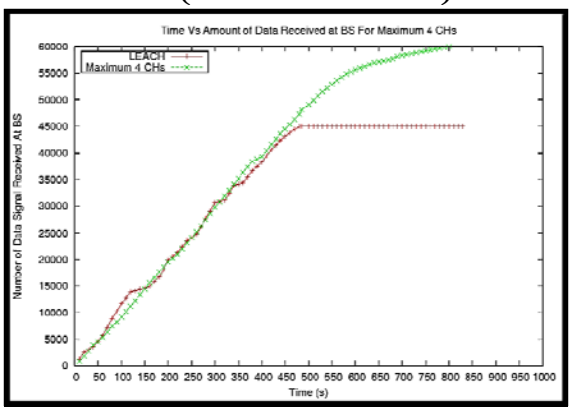

Fig. 8 Comparison of LEACH & 4 CHs/Round for Time VS Amount of Data Received at BS (Maximum 4 CHs)

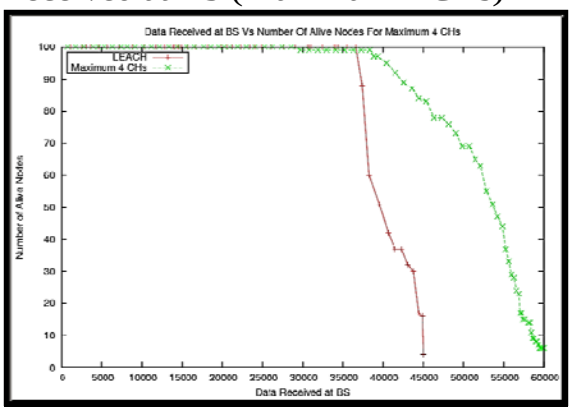

Fig. 9 Comparison of LEACH & 4CHs/Round for Amount of Data Received at BS VS Alive Nodes (Maximum 4 CHs)

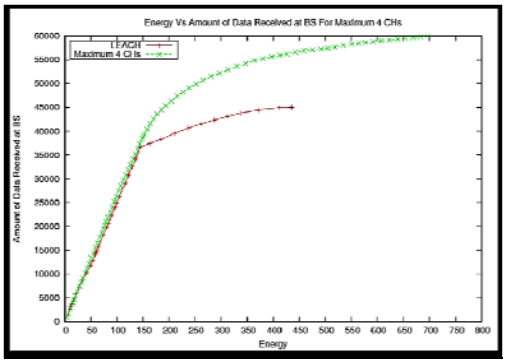

Fig. 10 Comparison of LEACH & 4 CHs/Round for Energy VS Amount of Data Received at BS (Maximum 4 CHs)

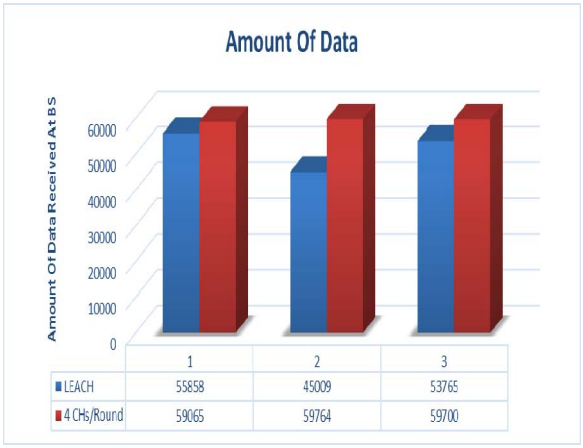

Fig. 11 Comparison of Total Amount Of Data Received At BS for LEACH & 4 CHs/Round - Number Of Simulation

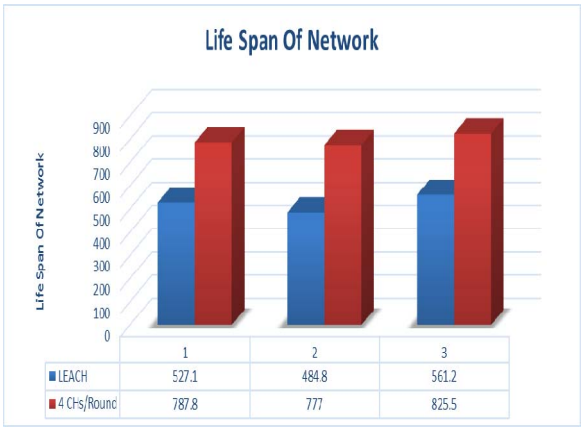

Fig. 12 Comparison of Life Span Of Network for LEACH & 4 CHs/Round - Number Of Simulation

As shown in Figure 6, 7, 8, 9, 10, 11 and 12 the proposed method improves the existing LEACH protocol in terms on Network Life Time & Amount Of Data. One of the most significant improvements can be noticed from the Figure 9. In Figure 9 the amount of data received at BS for a particular value of Energy consumption is very much high in improved LEACH compared to the conventional LEACH.

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5. Conclusions

The Paper includes overview of wireless sensor network and problems of re source constrains like energy, limited available bandwidth etc. Also it differs from the mobile ad-hoc network such as it has no fixed architecture. So to improve performance of WSN, LEACH protocol is used. But LEACH has also some limitations like cluster head is selected based on threshold value generated by considering random variable. From the analysis of the LEACH protocol, We have concluded the main drawback of LEACH protocol which is uneven distribution of cluster heads. We have tried to improve this con by implementing even area distribution criteria. By this we have improved the Life Span of network and throughput of network. The performance of LEACH has been improved in terms of Life Span of Network and data transferred from cluster nodes to cluster head and at the end to the BS.

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