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Resource Constraint Estimation using Performance Metric with respect to LEACH Protocol in WSN

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ABSTRACT: With the advancement in Wireless Communication and Micro Electro-Mechanical Systems which is followed by Nano-electromechanical System(NEMS) has lead the development of Wireless Sensor Network(WSN).Wireless sensor network whose acronym is "WSN" is a network that consists of nodes cable of sensing the environment and then send the sense data to the Base station (Sink Node).
The sensing nodes has resource constraints like low power as it runs on button cell(3Volt), so when they send the sense data then the routing protocol should be energy efficient and should have low/minimal latency as well. In this paper we have simulated the Low Energy Adaptive Clustering Hierarchy (LEACH) Protocol in MatLab and then evaluated the performance metric and have come out with conclusions which are left for the scope of future study and research.

KEYWORDS: Wireless Sensor Network, Latency, Clustering Hierarchy based routing.

I. INTRODUCTION

Rapid progress in Wireless Sensor Network in the beginning was motivated by Military and Defence applications. But due to the advancement in MEMS[1] technology the range of Applications is no longer constrained to Defence and Military instead it's now a days used in Vivid application like health care, monitoring and tracking, surveillance, etc, so WSN has achieved the tremendous prospects in Application.The Wireless Sensor Network can be broadly classified into Homogeneous Wireless Sensor Network and Heterogeneous Wireless Sensor Network and to enhance the lifetime of the network now a days the later kind is used. The Homogeneous Wireless Sensor Network consist of similar motes(nodes) having equivalent resources whereas the Heterogeneous Wireless Sensor Network consists of motes with varied resources.WSN contain heavy sense data and when the motes send the sense data to the cluster head then the CH send the sense data by aggregating the data thereby removing the unreliable and overlapped data. For example applying the beam forming technique several signals are aggregated into single signal which contain the information related to all the signal.Till now the research in wireless sensor network is done mainly in Network Layer and Medium Access Control(MAC) Layer protocols focusing on optimization of Energy, synchronization of Clock and localization of node; So research in routing protocol has increased tremendously.

In order to evaluate the LEACH[2] protocol we have used the following performance metrics:

a) *Energy Consumption:* The mote's energy is dissipated due to sending the sense data to the sink node and to come up with an energy optimized protocol it's important to evaluate this metric.
b) *Network Lifetime:* Since in heterogeneous WSN motes with different resourced are used so advanced node should be selected to form the cluster head(CH) , so we will check the type of selection of Cluster Head.
c) *Latency:* The latency of the network should be low or minimized overall, so we check this metric also.
d) *Ease of Deployment:* Since the WSN is self-organized, so the deployment of motes should be easy, so that anyone can deploy the motes in the field.

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II. BACKGROUND

The progress in MEMS technology has led to the development in WSN and the motes are power and resource constrained so to optimize the energy at various levels we need to have light knowledge on the energy depletion by the radio signal. The research in the low energy powered radio integrated circuit is on-going and this filed is highly motivated by the applications in mobile and embedded system. So to optimize the energy we must give a restriction to the duty cycle, which is actually the percentage of the duration for which the radio signal is active. For example European Countries need to maintain the duty cycle smaller than 10% for 434 Mhz band and less than 1% for 868 Mhz band.
The first order radio model[3] is used for the estimation of energy consumption by the radio signal for the Wireless Sensor Network.

A.THE FIRST ORDER RADIO MODEL

When the mote need to send the sense data to the Cluster Head then the mote's energy is depleted by the Transmitter to transmit the package of 'n' bits:

$$E_{Tx}(n, r) = E_{tc}(n) + E_{amp}(n,r) \quad \text{---------- (1)}$$

Where 'E_{Tx}' is the transmitter energy, 'r' is the distance between the sender and receiver, 'E_{tc}' is the energy that radio circuit needs to spend in order to process 'n' bits, 'E_{amp}' is the amplification energy.
The equation (1) can be further elaborated as follows:

$$E_{Tx}(n, r) = E_{tc}(n) + E_{amp}(n,r) = n.E_{trans} + n.\epsilon_{amp}.r^{\gamma} \quad \text{----------(2)}$$

Where 'E_{trans}' is the transmission energy for single bit &ϵ_{amp} is the transceiver energy dissipation & 'γ' is the Path loss component.

Path loss component (γ) is linked to medium of propagation and the value range from '2' to '4' where former value is used for free space propagation and later value is used for multi path propagation where there are some obstacles.

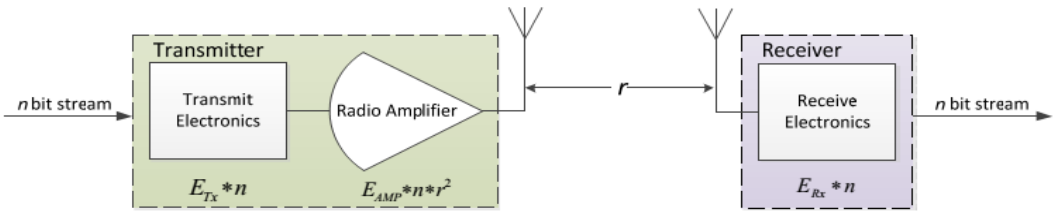

Fig. 1. Radio model for the transmission of n bits of information [4]

After transmitting the packet the receiver that is the Cluster Head needs to receive the packet and to receive the package of 'n' bits the following energy is spent:

$$E_{Rx}(n) = R_{rc}(n) = n \cdot E_{recv} \quad \text{----------(3)}$$

Where E_{Rx} is the energy spent on receiving the signal, E_{recv} is the energy depletion for receiving the single bit.

III. LEACH PROTOCOL[5]

The Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol organized themselves in the form of clusters. Two types of clusters are formed:

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- *Intra Cluster*: This cluster is formed by association of mote with a Cluster Head (CH).
- *Inter Cluster:* This cluster is formed by the association of CH with the Base Station (Sink Node).

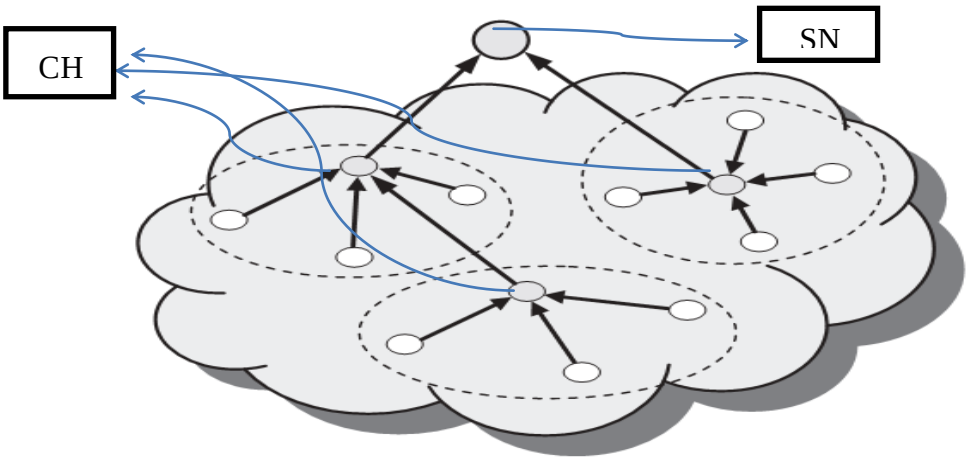

Diagram:WSN N/W with motes, CH & SN.

All motes in the WSN other than the CH & SN senses the environment and send the sense data to the CH and on receiving the sense data the CH performs the data fusion technique to aggregate the data. The aggregated data is then send to the Base Station by the Cluster Head so as to reduce the network bandwidth & Energy dissipation in the nodes.

The LEACH is self-organized& Self Adaptive protocol where the operation is based on the rounds and each round begins with the following stages:

a) **Advertisement Phase:** In this phase the node contend in the election process by choosing a random number in between **0** to **1** and then compare this value with the Threshold value (T_n). If the generated random number is less than T_n then that node is chosen as the Cluster Head(CH).

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Where 'P' is the desire % of Cluster Head for the Network, 'r' is round number,'G' is the set of nodes that has not formed CH yet in the current epoch that is (r mod 1/P).

b) **Cluster Set Up Phase:** After the former phase the non CH decides to form cluster with the selected CH based on the minimum distance of the node (n_i) to the CH using the *Euclidean Distance Equation:*

$$\sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

c) **Steady State Phase:** After forming the cluster the respective CH creates a schedule based on the number of nodes using TDMA. The non CH nodes turn off the radio signal until their turns came for data transfer to CH.

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The LEACH Protocol process[6] is shown below:

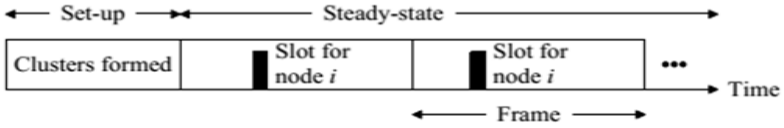

Diagram LEACH Protocol process.

The cluster head loses its energy rapidly compared to non-cluster head due to the following reasons:

- In **intra cluster** operations the CH energy depleted due to 'E_{Rx}' as shown in equation (3).
- In **inter cluster** activity the CH node energy depleted due to 'E_{da}' that is the Aggregation energy for aggregating the sense data before transmitting it to the SN. In addition to E_{da} energy the CH expend the energy in 'E_{Tx}' as shown in equation (2).

As discussed earlier the 'E_{Tx}' energy is also dependent on the path loss component and due to which we compute the Threshold distance '$d_0 = \sqrt{(E_{fs}/ E_{mp})}$ ' where 'E_{fs}' is the amplification co-efficient of free space and 'E_{mp}' is the amplification co-efficient of multi path. If the distance between the CH to the BS that is 'd' is less than or equal to 'd_0' then the free space component is considered that is $\gamma=2$ else multi path component is considered that is $\gamma=4$.

IV.SIMULATION OF LEACH

To simulate the LEACH protocol we have used MatLab R2009a and in the simulation we have tried to figure out the demerits of LEACH protocol using the following input parameters. As discussed earlier to evaluate the performance of LEACH we have considered those performance metrics

A SIMULATION PARAMETER

The following parameters were considered for simulation:

a) The motes are randomly deployed so as to ease the deployment process and then to evaluate LEACH in that environment.

b) We have considered the Heterogeneous WSN where we have two kinds of nodes:
   - Normal nodes: These are the nodes having initial energy E_0 .
   - Advanced Node: These are the nodes having α times more energy than E_0.

c) We have placed the Sink Node or BS at the center of the area.
   The other specific parameters are listed in the Table 1.

Parameter	Parameter	Parameter	Parameter
EDA=5 nJ/Bit	Packet Size:4000 Bits	Area=100 * 100 m^2	E_{Tx}= 50 nJ/Bit.
Rmax= 1200.	m= 20 % of N.	SN= (50,50)at Center	E_{Rx}= 50 nJ/Bit.
α= 50 % of E_0.	m= 20 % of N.	E_0=0.25 J	E_{fs}= 10 pJ/Bit/m^2
N= 100.	E_{mp}= 0.0013 pJ/Bit/m^4	P= 10 % of N.	E_{mp}= 0.0013 pJ/Bit/m^4

Table 1: Simulation Parameters.

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B EVALUATION OF SIMULATION

The motes are deployed randomly and it can be analyzed from the fig 2. that the distribution is Uneven .

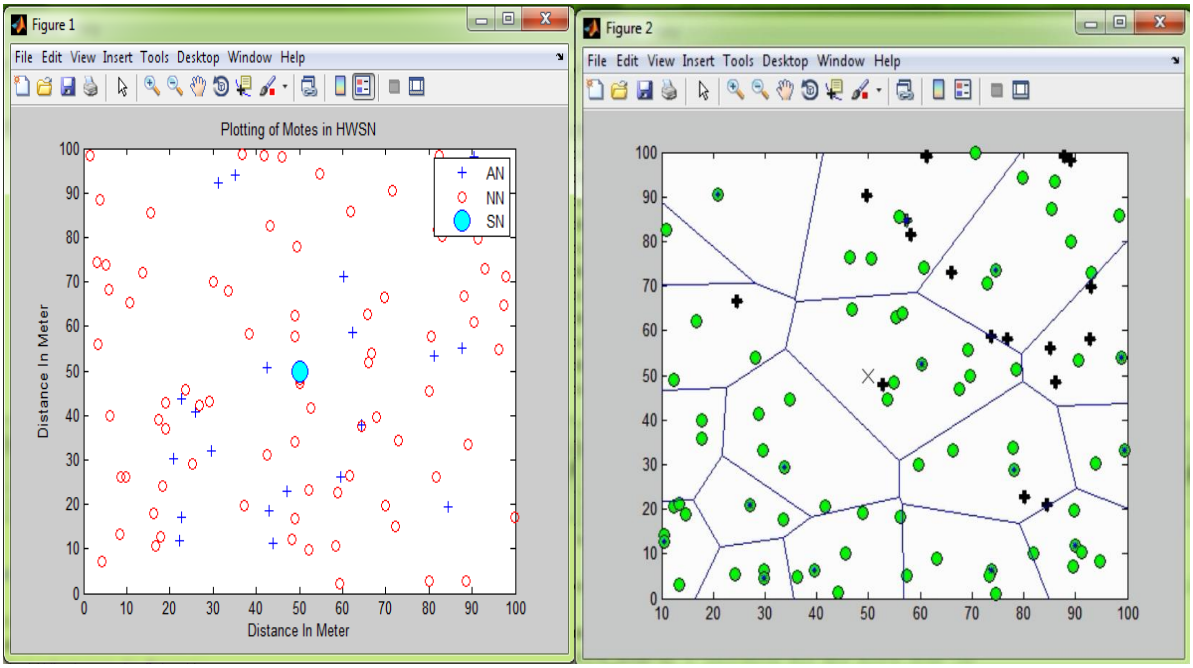

Fig 2.Random Node Deployment.Fig 3 Formation of CH with the associated clusters.

The above fig (3) shows the formation of Cluster Head which is shown in "* with green colored".
To evaluate the Network life time performance metric we have came out with following graph fig 4.

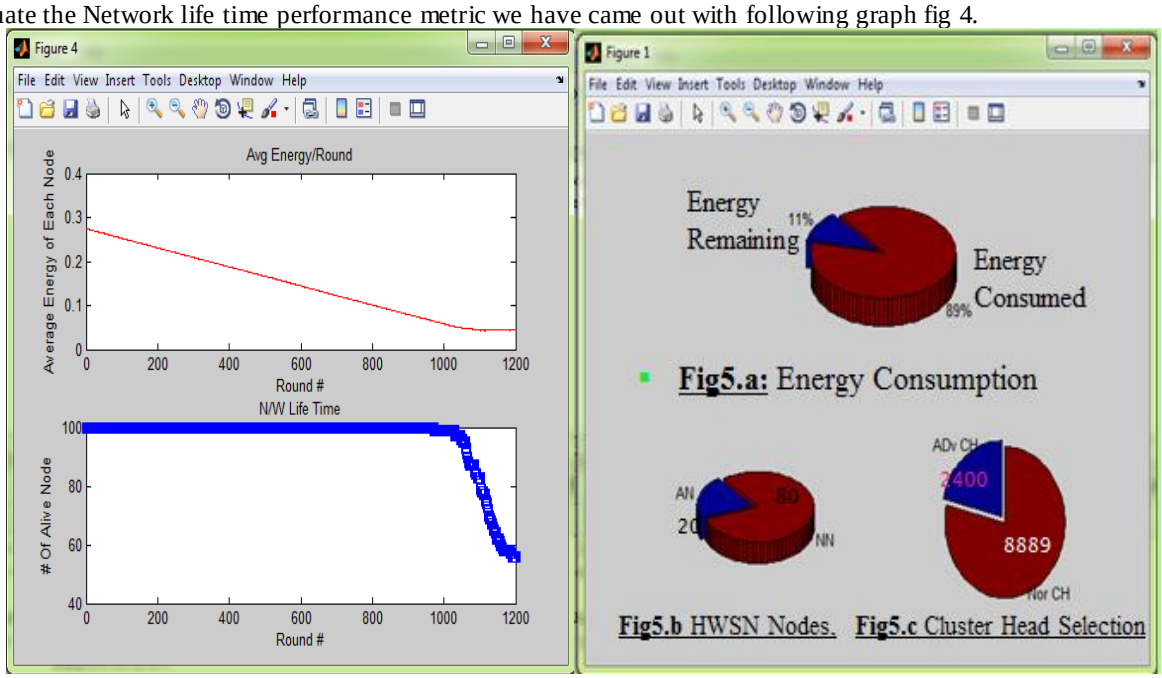

Fig. 4 Energy depletion & Life time of N/W

To evaluate the energy consumption after Rmax=1200 rounds we have come out with the abovefigure5.

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After running the simulation with the given parameters at last we have the came out with the following graph fig 6.

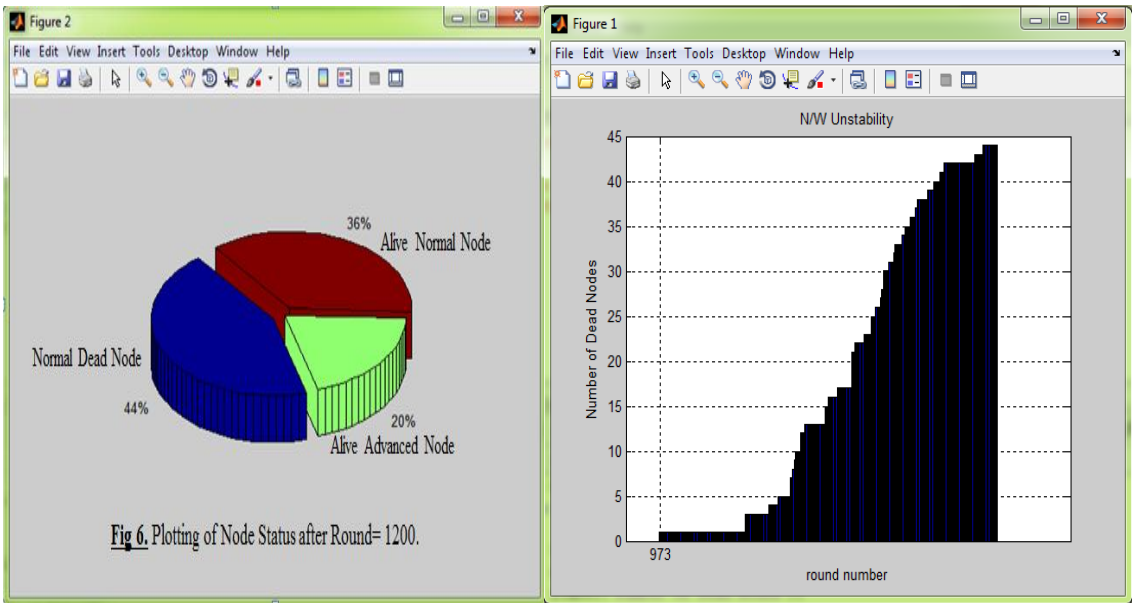

Fig. 7. Trend of forming dead Nodes after round=973.

When we run the simulation for the last round r=1200 then we have come out with the above graph figure 7.

V. CONCLUSION

On the basis of our simulations we have come out with the following conclusions which are listed below:

i) In fig 5.(c) we have seen that in r=1200, "11289" CH were selected i.e an average of 9.4075 CH are selected per round and out of which only *2400 Advanced nodes were selected against 8889 Normal nodes, so an average of 2 Advanced node per round only.*
So this is left for the scope of future study to make the election process better.

ii) While running the simulation it has been noticed that sometimes **no CH were selected** for *particular rounds that is round= '1196' & '1200';* as the selection is based on the generation of random number between (0-1) & then comparison with a threshold value (T_n). So it can be possible for some rounds no CH may be selected & so the latency increase abruptly as no form of communication exist.
So this is left for the scope of future study to lower the latency.

iii) LEACH protocol is **restricted to small area** as non CH to CH is single hop & CH to BS is also single hop, & using First order radio model, *node's dissipation energy is directly proportional to the Path Loss Component.*
So this is left for the scope of future study to make LEACH better.

iv) LEACH **does not consider the residual energy** while selecting the CH, so although LEACH is dynamic but rotating the CH causes this issue & due to which the *life-time of the node reduces.*
So this is left for the scope of future study.

v) It has been noticed via the bar graph of figure= 6 that after the round 973 to 1200 the **tendency of the dead nodes increase exponentially.**
So this is left for the scope of future study to reduce the rate of dead node

vi) When CH are selected then although nodes select the CH on the basis of it's minimum distance to CH, but that **does not** necessarily imply **that CH so selected is closest to the BS** in the inter-cluster operation.**So this is left for the scope of future study to make the selection process better.**

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BIOGRAPHY

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