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Threshold Based Energy Efficient Adaptive Cluster Head Selection Protocol for WSN.

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Abstract - **As the sensor nodes have limited energy resources, the protocol designed for the wireless sensor networks should be energy efficient and provide low latency. We propose a Threshold based Energy Efficient Adaptive Cluster Head (TEACH) selection protocol for WSN architecture where nodes make autonomous decision without any central intervention. The proposed TEACH selection protocol enables selection of best suited node as the cluster head by taking in to account the mean distance between nodes and the power remaining with the nodes, to maintain uniform energy among all the nodes in the network. The simulation results show that the protocol can improves network lifetime and is energy efficient compared to V-LEACH .**

Keywords — Sensor nodes, Base station, Cluster head, Threshold, Network Lifetime.

I. INTRODUCTION

In the design of wireless system, there are two key resources namely communication bandwidth and energy. In wireless micro-sensor networks [1, 2], the data being sensed by the nodes in the network must be transmitted to a control center or the base station through cluster head where the end user can access the data. Since all nodes can transmit/receive data, the node's energy decreases. The main constraint of the sensor node is their low finite energy. Therefore, energy efficient protocols [3, 4] for sensor networks are of paramount importance. Our protocol is based on the clustering technique and follows considerations of maximizing the lifetime of the network - the lifetime is taken to be the time at which the first node or the last node dies out of energy (application specific). Instead of enforcing transmission energy constraints on every individual node, the cluster head (leader) node collects data from all its neighbor nodes, then aggregate and send those data to the base station (BS).

The LEACH protocol [5, 6] and its variants [7, 8] emphasize the election of the leaders randomly and through a fixed probability (it means all the sensor nodes have an equal probability to become a leader). In these protocols there is no effective mechanism for locating the leader in the network. Therefore, one of the major problems with these protocols is that there is a possibility that sensor node with lower energy than other sensor nodes may be elected as leader and lose its energy more rapidly than other sensors nodes and die out ultimately. In LELE protocol [9] the probability of the leader's election is in accordance with the remainder nodes' energy. This protocol uses two probabilities in electing the good and average leader. In LELE protocol each node compares the amount of energy and distance with its neighboring nodes to be elected as a leader. In order to maintain uniform energy among nodes, we propose a clustering algorithm that considers both energy and distance to increase the network lifetime, in the proposed algorithm the most energy effective node is selected as the cluster head and will remain as the cluster head in the subsequent round till its energy remains above the set threshold. Vice cluster-LEACH(V-LEACH) [11], based on the residual energy in each sensor node, assigns the vice cluster. When the cluster head dies, the vice cluster will quickly take control. The vice cluster head has a favorable effect on the network's lifespan. According to the simulation results, the vice cluster head extends the network lifetime by roughly 12.5 percent. In addition, the V-LEACH routing protocol uses less energy in a given number of rounds than the LEACH protocol. To elect the Cluster Head and Vice Cluster Head, the proposed algorithm uses numerous dynamic decision criteria such as residual energy, distance, and neighborhood degree. By reducing energy usage and routing overhead, this adaptive selection ensures a longer network lifetime. Party CH is compared to LEACH, and the results are presented and analyzed[10].

II. NETWORK MODEL AND PHYSICAL MODEL

A. The Network Model.

The WSN consists of group of sensor nodes that are capable of sensing the physical parameters such as temperature, smoke, pressure and so on. Depending upon the application, they may send highly correlated sensed information either periodically or triggered by some event (sporadically) to the cluster head. The aggregated data is

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sent to the base station from the cluster heads. In this paper, we assume a sensor network model with the following properties:

i) A fixed base station is located far away from the sensor nodes.

ii) The sensor nodes are energy constrained with a uniform initial energy allocation (say, 2 joules).

iii) The nodes are equipped with power control capabilities to vary their transmitted power.

iv) Each node senses the environment continuously and always has data to send to the base station through the leader.

v) All sensor nodes are immobile.

B. Physical Model

The physical model [5] used in our approach is shown in fig 1, in which the transmitter and receiver is separated by a distance **d.** The transmitter has the ability to change its transmit power to take care of free space loss (d^2) and multipath fading (d^4). Each sensor node has a transceiver to transmit k-bit of data to the leader on TDMA frame , and **d**is the distance between the sensor nodes.

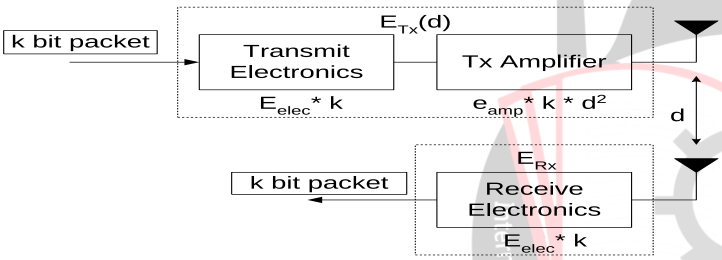

Fig.1. Physical model

According to the physical model (Fig.1.) of energy consumption introduced above, to reach an acceptable rate of Signal-to-Noise (SNR), the allocated energy to send the k-bit message to the distance of 'd' is calculated through the relation (1):

$$\begin{cases} k.E_{elec} + k.\in_{fs}.d^2 & if\ d \le d_0 \\ k.E_{elec} + k.\in_{mp}.d^4 & if\ d > d_0 \end{cases} \quad \text{-- (1)}$$

Where E_{elec} is the consumed energy for each bit in the transmitter circuit or receiver circuit; $\epsilon_{fs}d^2$ and $\epsilon_{mp}d^4$ are the amplifier energies for free space and multipath respectively. ϵ_{fs} and ϵ_{mp} depend on the model boosting the transmitter circuit and d is the distance between the transmitter and receiver which in case of $d=do$ we have $do=\sqrt{(\epsilon_{fs}/\ \epsilon_{mp})}$;

The energy required by the node to send k bit of data to a cluster head at a distance 'd_{toCH}' is given in the relation 2:

$$E_{nonCH} = E_{elec} \times k + \in_{amp} \times k \times d^2{}_{toCH} \quad \text{-- (2)}$$

Similarly, to receive the k- bit message the energy consumed by the cluster head is equal to

$$E_{Rx}=k.E_{elec} \quad \text{-- (3)}$$

The energy consumed by the cluster head node during each frame is computed through the relation 4:

$$E_{CH} = E_{elec} \times k \times (n-1) + n \times k \times E_{DA} + E_{elec} \times k + \in_{fs} \times k \times d^2{}_{toBS} \quad -(4)$$

E_{DA} is the cost of processing (aggregate the data) of each bit to be reported to base station; and the d_{toBS} is the mean distance between the leader and base station.

III. SIMULATION MODEL

In the simulation of our protocol, we made use of Matlab. The reference network of our simulation has 100 nodes distributed randomly across an area of 100x100 meters. The base station is located far away from the network (50,175). Each node is assumed to transmit a data of 500bytes in its scheduled slot. The physical parameters used in our simulation are given in Table 1

Operation	Energy dissipated
Transmitter/Receiver Electronics	E_{elec}=50nJ/bit
Data aggregation.	E_{DA}=5Nj/bit/report
Transmit Amplifier $d_{toBS}<=d_0$	ϵ_{fs}=10pJ/bit/m²
Transmit Amplifier $D_{toBS}>d_0$	ϵ_{mp}=0.0013pJ/bit/m⁴

TABLE 1.

Physical parameters.

In this work, clustering is done based on the density of nodes in a particular region in the network. Five clusters are made in the network using k-means algorithm. Nodes lying in the particular cluster are assumed to be in that cluster throughout the network operation. Once the cluster is formed sensor nodes of a particular cluster do not change. In our approach, at the beginning of the network the node which is having highest value of parameter Y in each cluster is elected as cluster head for that cluster. Parameter **Y** is defined as the "Ratio of remaining energy of a node to the square of its mean distance to all other nodes and the base station in the particular cluster" as mentioned in equation 5. All the nodes maintain position information of all other nodes in their cluster and each node is given particular slot to transmit the sensed data to the cluster head as shown in Table 2. After completion of a round the cluster head calculates a parameter **Y** for all other nodes, then cluster head calculates the average of the parameter **Y** called threshold. The node which is having highest value of **Y** above the threshold is elected as cluster head as mentioned in equation 6. If the cluster head meets the above requirement then it will continue as cluster head, otherwise new cluster head is elected for a cluster

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Node	1	2	3	4	.	.	Clustm	Mean D	P_i	$Y=P_i/D$
1	D_{11}	D_{12}	D_{13}	D_{14}	.	.	Clustm	$D_{1\,Mean}$	P_1	Y_1
2	D_{21}	D_{22}	D_{23}	D_{24}	.	.	Clustm	$D_{2\,Mean}$	P_2	Y_2
3	D_{31}	D_{32}	D_{33}	D_{34}	.	.	Clustm	$D_{3\,Mean}$	P_3	Y_3
4	D_{41}	D_{42}	D_{43}	D_{44}	.	.	Clustm	$D_{4\,Mean}$	P_4	Y_4
. . .	.	.	.	.	.	.	.	.	.	.

Table 2 :Table maintained by each node in cluster.

$$Y_i = P_{i\,Rem} / D^2_{i\,Mean} \quad \text{......................(5)}$$

$$Y_{Threshold} = \frac{\sum_{i=1}^{clustm} Y_i}{clustm} \quad \text{......(6)}$$

IV.RESULTS & DISCUSSION

Fig.2. shows the random deployment of nodes in the sensor field, nodes of different cluster are represented differently. It can be seen from fig.3. that the first node death occurs at 1640 seconds (each round is of 20 seconds duration), which is better than V-LEACH where the first node death occurs at about 400 seconds assuming same initial conditions as illustrated in [11]. Also, compared to V-LEACH we obtain considerably prolonged network lifetime for half nodes death and last node death in the network. This is mainly because of the rotation of leader based on the threshold, which takes into account- various parameters such as energy remaining in each node, mean distance to all other nodes and also the distance to the base station. As a result of this we have an effective distribution of energy among the nodes.

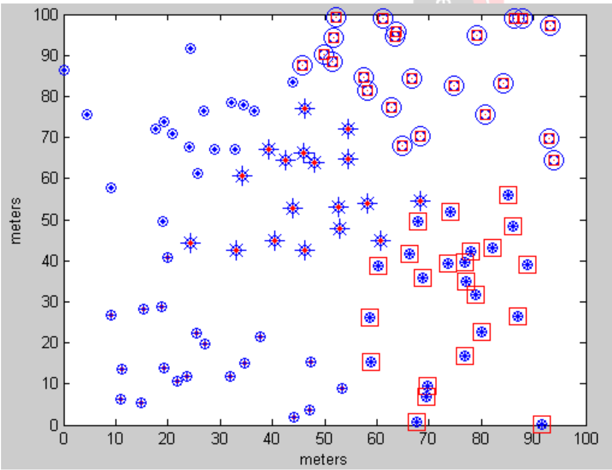

Fig.2. Deployment of nodes in sensor field showing five different types of cluster.

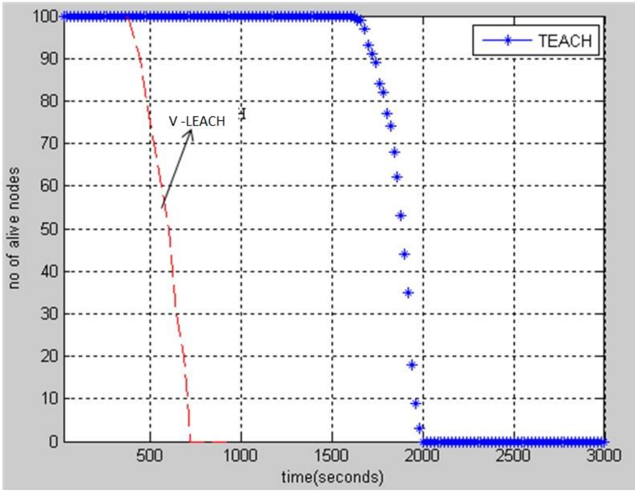

Fig.3. Network lifetime.

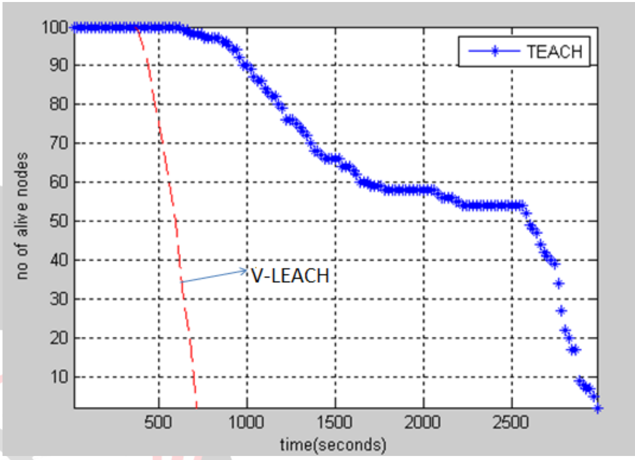

Fig.4 Network lifetime for varying frames.

The change in network lifetime with variation in number of frames transmitted per round is plotted in Fig.4. The number of frames is varied according to the average energy in the cluster as shown in Fig 5. The first node death occurs at 640 seconds whereas it occurs at 380 seconds in V-LEACH protocol also last node death occurs at 2980 seconds and in V-LEACH it occurs at 720 seconds. This improvement is tabulated in Table 2.

Table 2.

	V-LEACH	TEACH
First node death (sec)	380	640
Last node death (sec)	720	2980

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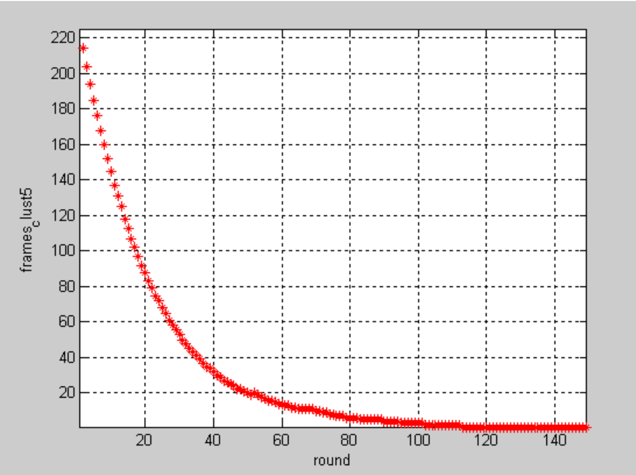

Fig.5 Frames varied

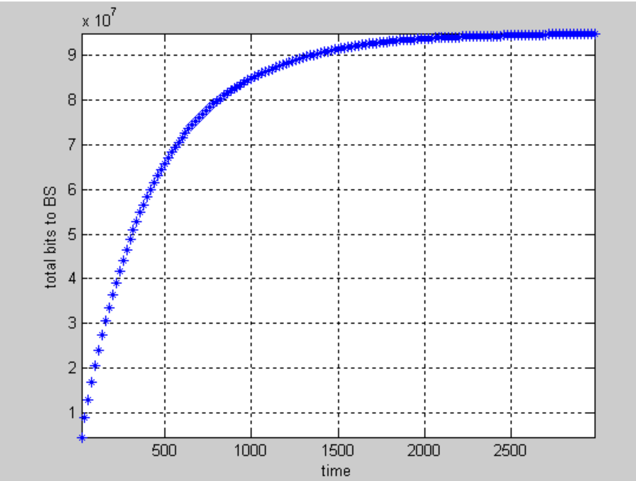

Fig.6 Total bits sent to base station

Fig.6 shows the total amount of information sent to the base station from the cluster heads when the number of frames are varied. Here, the data sent to the base station is much higher than V-LEACH as in[11]

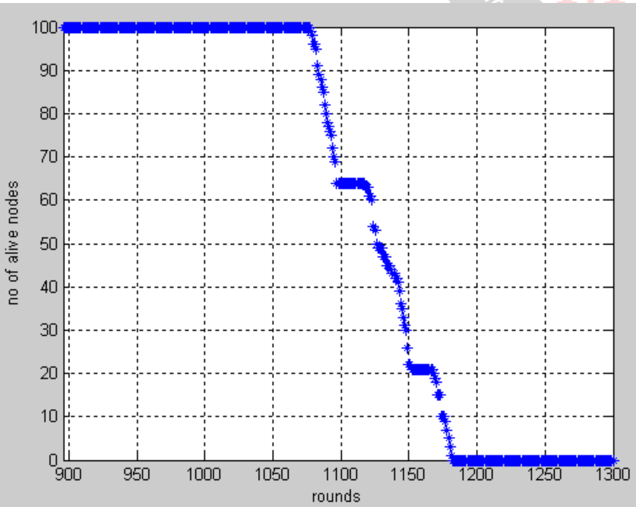

Fig.7. Network lifetime for single frame.

Simulation results for single frame and 0.5 joules of initial energy is shown in fig.7. We can see that the network lifetime increases considerably when the frames are reduced, but however the overhead on nodes due to frequent cluster head rotation is high. The first node death occurs at about 1078 rounds.

IV. Conclusion

In V-LEACH, low energy nodes may be selected as the cluster head which may lead to non-uniform distribution of energy. In the proposed TEACH selection protocol, the network lifetime is enhanced by rotating cluster head positions to evenly maintain the energy among all the nodes. In TEACH, as the clusters are static compared to dynamic clustering V-LEACH [11], the complexity of clustering is reduced. The clusters are formed based on density of nodes deployed in the network. The main idea of TEACH is to rotate cluster head based on average threshold set. The average threshold depends on both energy and distance; it elects the most optimized node to become a cluster head.

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