Centered Sink LEACH Protocol for Enhanced Performance of Wireless Sensor Network

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***Abstract*— In this article, an improved protocol based on LEACH for WSN is developed. Performance of the modified LEACH protocol is evaluated for different network parameters. In WSN, lifetime is an important performance metric. The performance of the proposed protocol and LEACH are compared in terms of energy efficiency, delay in packet delivery and network lifetime.**

Keywords—WSN, LEACH, Cluster, Cluster Head, Sink Node, Delay

I. INTRODUCTION

A WSN comprises of a huge number of sensor nodes and at least one base station. The sensors can interface with the environment by taking in the physical parameters. Battery power consumption and range of communication are the main constraints of a sensor. The sensors interact and accumulate information from its surrounding and transmit through the wireless medium to the nearest base station.

Network lifetime, routing strategies and energy consumption of sensor nodes are significant research challenges in the field wireless sensor networks. Routing strategies are defined by the routing protocols used which can be hierarchical, data-centric, or location based. In this current article, we developed a modified LEACH protocol. LEACH is a hierarchical protocol which involves hierarchy in their networks by clustering the sensor nodes and selecting cluster head of each cluster. Hierarchical protocols are considered very energy efficient as clustering helps to sustain the energy consumption of each sensor node as well as the data aggregation helps to reduce the amount of data transmitted to the sink [1]. In this paper, we studied and analyzed the modified LEACH protocol by changing various parameters. The main focus is on the improvement of the lifetime of the network by increasing the time when the first node in the network under consideration runs out of energy. Further, it tries to maintain a significant number of alive nodes for a longer time.

II. RELATED WORKS

Many practices have been developed and used for the effective routing of wireless sensor networks. The protocols are application specific as they depend on the requirement of the application. Energy efficiency and long network lifetime are the basic needs of almost all WSNs. Hierarchical protocols, the protocols which involve clustering are very energy efficient. One of the most well-known hierarchical protocol is LEACH. The main steps that take place in LEACH are the election of cluster heads (CH), the formation of clusters and data transmission from cluster members to the CH and ultimately from CH to the base station.

In [1], a new variant of LEACH namely PEGASIS is proposed. Here chains are formed among the sensor nodes. Each node can transmit and receive from a neighbor and only one node from that chain is selected to transmit to the base station [1]. The data is accumulated and amalgamated in each node and finally sent to the base station.

Another hierarchical based protocol presented in [2], TEEN involves organizing the sensor nodes into various levels of hierarchy. Here the data is transmitted from sensor nodes to the cluster heads which gather, amalgamate and then transmit these data to a superior level cluster head till the base station is reached. The cluster heads are changed from time to time inside the cluster [2]. APTEEN has the same architecture as that of TEEN. The sensor nodes send their sensed data periodically to their cluster head. They then turn back to the cluster head when any change in the sensed data occurs [1].

The nodes send their sensed information regularly to their respective CHs. They also communicate to the CH when there is any instantaneous change in the value of the sensed attribute takes place.

III. PRELIMINARIES

A. Hierarchical Routing

The sensor nodes split themselves into clusters within the network and select the cluster head. Now the elected cluster-head acquires the data from the nodes within its cluster and then it sends the received data to the BS [1].

In places where nodes fail to transfer data directly to a considerable distance, cluster-based routing with hierarchical segregation becomes a reasonable solution [3]. The formation of the cluster is based on the amount of energy left in the sensor nodes and its propinquity to its cluster head.

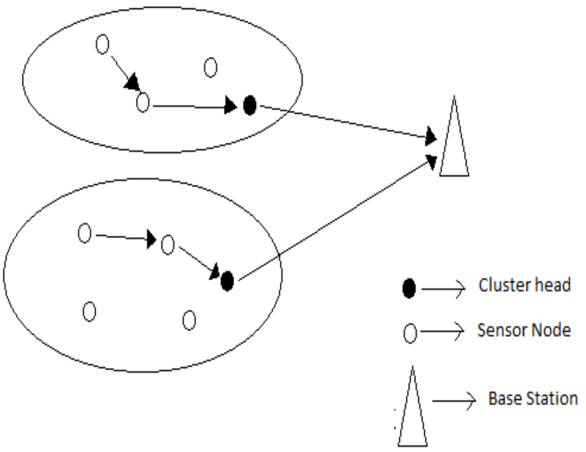

Fig. 1. Hierarchical Routing model

B. LEACH Protocolfor WSN

Wendi B. Heinzelman et al. proposed LEACH. It relies solely on the formation of cluster heads for WSN and which segregates the nodes into clusters and in each cluster a node with prerogative power called Cluster Head (CH) is elected [4]. The CHs act as an organizer. The role of cluster head is distributed randomly among nodes, and every node becomes a cluster head at some point of time [3].

The execution of the LEACH consists of several rounds with each round being divided into two parts namely, Set-up phase and Steady-state phase. The primary motive of the Setup phase is to form clusters of the complete network and choose the cluster head for each cluster by selecting the nodes with the highest amount of energy. Steady Phase mainly deals with the agglomeration of useful information at the cluster heads and transference of agglomerated information to the Base station, and it is longer in duration compared to the set-up phase [5].

C. Working of LEACH Protocol

The first phase or Setup Phase starts with the selection of the cluster heads of the network. This is completed according to a limen value C(n).

The limen value is based upon the chosen fraction to become a cluster-head (g), the present round (r), and the nodes that have not become the CH in the last 1/g rounds is expressed by G [5]. The formulae are as follows:

$$C(n) = \begin{cases} \dfrac{g}{1-g*\left(r \bmod \left(\frac{1}{g}\right)\right)} & \text{if} \quad n\in G \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Every node that needs to be the cluster-head picks a random number $\xi \in (0,1)$. The node becomes the cluster-head for that particular round if $\xi < C(n)$. After that, the advertisement messages are broadcasted by each elected CHs to the neighboring nodes in the network. The nodes which are not part of the cluster then decide to join the clusters based on the strength of the advertisement signal received by it. The non-CH nodes send an acknowledgment message to inform their respective cluster heads. After the acknowledgment message is received, the cluster-heads create a TDMA schedule for its cluster members. The TDMA schedule is created depending upon the number of member nodes under the CH. Each node can transmit data in the desired time slot only. The TDMA schedule is then announced among all the cluster members. The cluster-head which is once chosen for the present round cannot again become the CH until all the other cluster members become CH for once. The CH node then aggregates the received data from all the sensor nodes and forwards it to the base station.

IV. PROPOSED WORK

A. Placement of Sink Node

It is found that the number of dead nodes is smaller when the number of rounds is small. However, as the number of round increases, the number of dead nodes rises. Effectively, the number of existing nodes decreases which in turn dwindles the system lifetime and finally diminishing the efficiency of the system.

Generally, it is seen that the cluster heads spend more energy than the member nodes and the energy consumption is more when the sink is at a long distance. The paper proposes some methods to overcome such problem and also to ameliorate the network lifetime. We imply some modifications in the existing protocol to improve the lifetime of the network (i.e., increase the number of alive nodes or decrease the number of dead nodes) which in turn increases the efficiency of the network. The placement of the sink node plays a crucial role in WSNs. The gathered information from all the nodes is transmitted to the CH in the LEACH protocol then the CH forwards the data to the sink node. As a result, the location of the sink node is very important on the energy consumption and efficiency of the network. We consider a homogenous network with random node placements. The geometry of the network can be rectangular or circular depending on the requirements. Our primary focus here is on single static node placement [6]. Now the optimum position of the sink node can be calculated mathematically and then the results are simulated based on that position.

Consider N as the total number of nodes and node i (i=1, 2, 3……..N) is established exclusive of each other at (Pi, Qi) in the concerned region R. [7]

Now our work here is to choose the optimized-position for the sink node so that the network lifetime increases.

Here, E_{TX} and E_{RX} are the Energy of the transmitting and receiving side respectively.

Now consider the function

$$F(x,y) = E\left[\sum_{i=1}^{N} E_{TX}(D_i)\right] \qquad (2)$$

Where D_i is Distance between sink (x, y) and node (P_i, Q_i)

$$D_i = \sqrt{(x-P_i)^2 + (y-Q_i)^2} \qquad (3)$$

$$F(x,y) = E\left[\sum_{i=1}^{N} E_{TX}\left(\sqrt{(x-P_i)^2+(y-Q_i)^2}\right)\right] \quad (4)$$

$$= N\int\int_{p,q\in \mathrm{R}}^{\mathrm{i}} E_{tx}\left(\sqrt{(x-p)^2+(y-q)^2}\right).f(p,q)dpdq$$

(5)

Now for minimizing the function F(x, y) we differentiate it with respect to x and y and then we intent the result to 0.

$$\frac{df}{dx} = 0, \quad (6)$$

$$\frac{df}{dy} = 0 \quad (7)$$

Now finally equation is solved and the final result is

$$x = \iint p.f(p,q)dpdq \quad (8)$$

$$y = \iint q.f(p,q)dpdq \quad (9)$$

This shows that the center of the region under consideration is the optimal position for the sink node. Hence, in our proposed version of the LEACH protocol, we have changed the position of the sink node in the middle and compared it with the general condition i.e. where the sink is at the end. Moreover, we see that the outcome is more efficient than the former case.

We have computed the number of dead nodes in different cases and then compared it with the original model.

B. Residue Energy

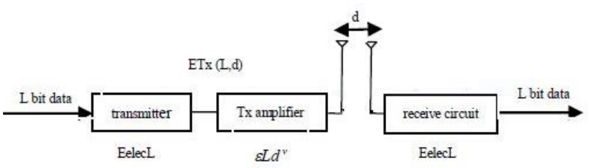

Fig. 2. Transmitter Receiver Model

The energy consumed in a round for the above model is given by

$$E(L,d) = \begin{cases} AE + A\in_{as} d^2, & d < d_0 \\ AE + A\in_{as} d^4, & d > d_0 \end{cases} \quad (10)$$

E=Energy consumed in transmission of 1 bit

A=amount of bit sent by the transmitter.

d=distance between CH and sink node.

$\in_{fs}$ =Represent the amplification in free space

$\in_{mp}$ =Represent the multipath fading co-efficient.

So the residue energy can be calculated as,

$$S(i).E = \begin{cases} S(i).E - \left(AE + A\in_{as} d^2\right), & d < d_0 \\ S(i).E - \left(AE + A\in_{as} d^4\right), & d > d_0 \end{cases} \quad (11)$$

Where $d_0 = \sqrt{\frac{\in_{fs}}{\in_{mp}}}$

C. End to End Delay or one-way delay (OWD)

Another critical parameter to evaluate is the delay in data transmission. After formation of cluster and cluster-heads, the data transmission can take place. The data transmission takes place using TDMA or CDMA multiple access technologies. In this phase, assuming all nodes have data to send, in TDMA the nodes send data to CH in a given time slot and in CDMA the nodes sends the data in a given orthogonal code. The data received by the CH nodes then forwarded to the sink using TDMA or CDMA. The data sent by the CH to sink can take from few microseconds to few milliseconds and hence there is an OWD. This OWD can be reduced by installing the nodes in a sophisticated manner. One of the most efficient solution to reduce the delay can be installing two sinks. CHs will send the data to the intermediate sink using TDMA or CDMA (here, CDMA is used for further reduction of delay in data transmission) and the intermediate sink will send the data to the primary sink. The intermediate sink node is kept in the middle of this proposed protocol. The total energy consumption in this central position is decidedly less in comparison with LEACH protocol.

D. Delay Calculation for a Round

In every round after the formations of clusters and cluster head the data transmission take place. Data are transmitted using TDMA or CDMA multiple access. It takes some time to reach the sink and hence a certain amount of delay occurs.

Let us consider coordinates of any cluster heads are (x_i ,y_i) and the coordinate of sink node is (X ,Y). Let N is the number of CHs in a round. The total distance can be calculated as

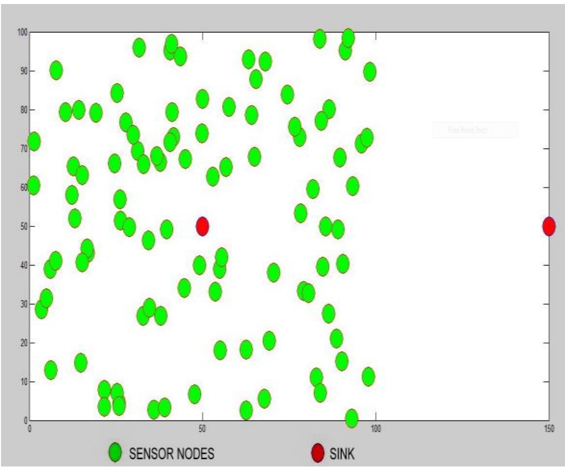

Fig. 3. Installed Sensor Node and Sink Node

$$D = \sum_{i=1}^{N} \sqrt{\left(x_i - X\right)^2 + \left(y_i - Y\right)^2} \qquad (12)$$

The average distance can be calculated as

$$D_{avg} = \frac{D}{N} \qquad (13)$$

Thus the average delay can be calculated for a round

$$\text{Delay}(t) = \frac{D_{avg}}{EM_{val}} \qquad (14)$$

Where EM_{val} is the velocity of the electromagnetic wave in the medium where the sensor node is installed.

V. Simulation and Results

The network parameters employed in the analysis are described in Table 1. The comparison between the actual protocol and the proposed version is demonstrated for a different number of rounds.

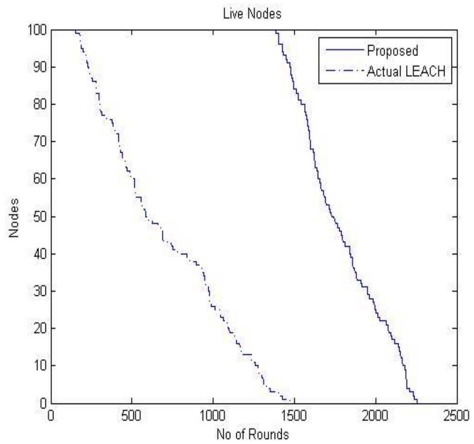

Fig. 4. Live nodes comparison plot

TABLE I. Network Parameters

Parameters	*Value*
Simulation Area (x,y)	100 x 100
No. of Nodes (n)	100
Probability Vector(p)	0.2
Initial Energy (Eo)	0.1J
Energy loss on transmission (E_{TX})	50 nJ
Energy loss on receiving (E_{RX})	50 nJ
Energy loss on forward (E_{fs})	10 nJ/bit/m^4
Energy loss on cluster (E_{mp})	0.013 pJ/bit/m^4
Energy loss on Delay (E_{DA})	5 nJ/bit
Coordinates of sink at middle	X=50, Y=50

TABLE II. Quantitative Analysis for (R_{MAX}=1000)

Parameter	*Normal Leach*	*Proposed Leach*
First Dead	178	0
Half Dead	640	0
All Dead	0	0

TABLE III. Quantitative Analysis for (R_{MAX}=2500)

Parameter	*Normal Leach*	*Proposed Leach*
First Dead	150	1211
Half Dead	614	1709
All Dead	1521	2246

Fig. 4 shows the plot of the alive nodes as a function of the number of the rounds. It is found that the protocol proposed by us offers superior performance concerning the number of alive nodes at any given time. In the proposed protocol, the first node dies at round 1211, whereas in case of LEACH protocol the first node dies at round 150. The other performance parameters are shown in Table. 3.

Fig. 5 presents the number of Dead nodes as a function of the number of rounds. It is found that in case of LEACH protocol all nodes become dead at round 1521 where using proposed protocol all node become dead at round 2246.

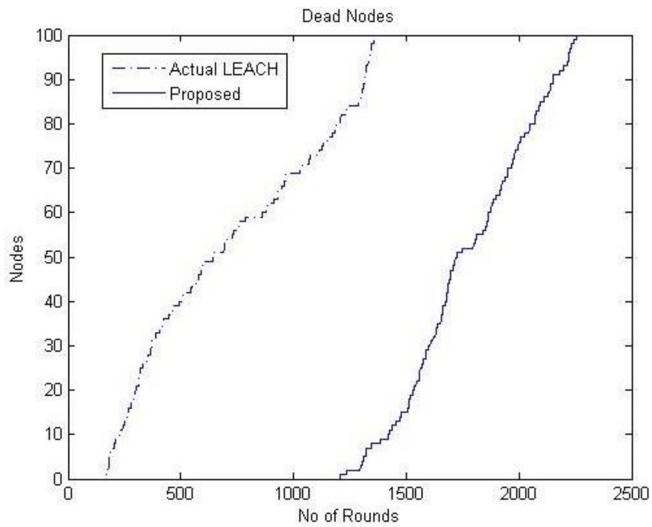

Fig. 5. Dead nodes comparison plot

Fig. 6 shows the average residue energy for 2500 number of rounds. It is found that the proposed protocol exhausts the energy very efficiently and enhances the network lifetime.

Fig. 7 shows the average delay (in microseconds) to communicate a packet to the sink for a different number of

CH nodes. In the proposed protocol the delay time has reduced up to 70% of that required in case of LEACH protocol.

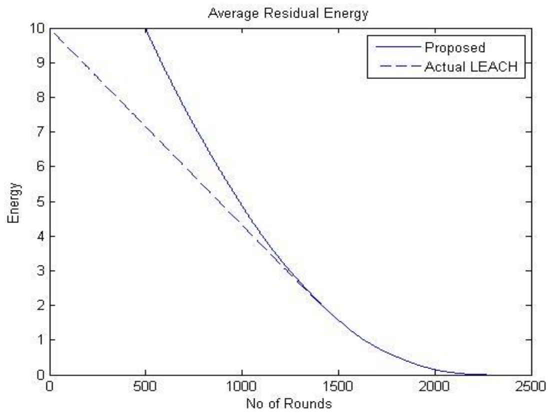

Fig. 6. Average Residual Energy plot

Fig. 6. Delay vs. cluster head node comparison

VI. Conclusion

Wireless Sensor Network plays a key role in different fields of work and it requires efficient protocols to function properly. The LEACH protocol works well when the sink is not very far from the nodes of the WSN. Generally when the sink is placed at a far distance, then the nodes lose their energy at a rapid rate and hence the network lifetime decreases. Hence in this article sink is placed at the middle of the network to increase the network lifetime. The results of the simulations show that the number of alive nodes is more than the actual LEACH protocol with an increasing number of rounds. Furthermore, delay to deliver a packet to the sink is much less in case of the proposed protocol. It is observed that the delay in the proposed protocol is reduced to 70% compared to the original LEACH protocol. The present work is simulated in MATLAB platform and the results of the same indicate that the efficiency and the lifetime of the network have improved manifold with respect to that of the original protocol.

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