E-LEACH: An enhanced LEACH protocol for minimal data loss

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Abstract— Wireless Sensor Networks (WSN) are usually deployed in hostile environments with adverse conditions. They are highly resource constrained in nature. Increasing the energy efficiency is one of the important aspects in the design of WSN. LEACH (Low Energy Adaptive Cluster Hierarchy) is one of the most popular adaptive cluster based routing algorithms which has been widely used in WSN. To distribute the energy load evenly, LEACH suggests probabilistic cluster head(CH) selection and rotation of the cluster head position amongst different nodes. In this paper we present an improved cluster head selection criteria for existing LEACH. This new algorithm is named as Enhanced-LEACH (E-LEACH). In E-LEACH, cluster head selection is based on probability as well as a node's residual energy. Depth analysis on network parameters of E-LEACH such as energy efficiency, network life time, packet delivery ratio, is carried out. Simulation results exhibit a significant improvement in performance metrics in terms of increased total network remaining energy, prolonged network lifetime and improved packet delivery ratio.

Index Terms— Base Station (BS), Cluster Head (CH), Enhanced Low Energy Adaptive Cluster Head (E-LEACH), Packet Delivery Ratio (PDR), Wireless Sensor Network (WSN).

1 INTRODUCTION

A **Wireless Sensor Network** (WSN) consists of spatially distributed autonomous devices using smart sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations. A WSN node comprises of sensing, computing, communication and battery as energy source. It stimulates and reacts to events occurred in specified environment.

The WSN has wide range of applications in agricultural, industries, research, securities such as Civil Structural Health Monitoring[1], Industrial Process Monitoring[2], Habitat Monitoring[3],Perimeter Security and Surveillance[4], Monitoring Greenhouse[5], Rapid Emergency Response[6] etc.

A WSN consists of numerous autonomous sensor nodes. They may have a fixed location or may be randomly deployed in the area under surveillance. These autonomous nodes transfer data from source to destination. Base station (BS) is the destination. Communication between sensor nodes utilizes transmission bandwidth and network energy. Energy to each sensor node in the network is provided by the batteries. when large number of sensor nodes are deployed in WSN, battery energy requirement increases. Intermediate relay nodes are needed to route the data to the base station. So, for the effective utilization of transmission bandwidth and the network energy utilization various routing protocols are introduced.

Based on network structure, protocols are classified as follows:

- Flat based routing
- Hierarchical based routing
- Location based routing

Hierarchical based routing protocol primarily aims to improve the network energy consumption.

Low Energy Adaptive Clustering Hierarchy [LEACH] is used to lower the energy consumption and to increase network lifetime. Central process in LEACH is cluster formation and cluster head selection. This process is carried out by using a probability criterion. Each node has individual probability of becoming a cluster head in each round.

This paper is organized as follows: Section 2 explains the LEACH protocol and related work. Section 3 explains the proposed E-LEACH protocol. Section 4 discusses and analyses the observations. Section 5 concludes the paper.

2 BACKGROUND AND RELATED WORK

LEACH protocol [7] is a self-organizing, adaptive clustering routing protocol. Operation of LEACH is explained in rounds. Each round consists of set up phase and steady state phase. At the time of creation of cluster, each node has to make the decision of whether to be cluster head or not for this round. The decision is based on node n selecting a random number between 0 to 1. If this number is less than threshold T(n) then the node becomes cluster head for current round.

The threshold is given as.

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(rmod\left(\frac{1}{p}\right)\right)} & if\ \ n \in G \\ 0 & otherwise \end{cases}$$

Where P is the percentage of nodes that can be cluster head, r is the current round and G is the set of nodes that have not been cluster head in last 1/P rounds. Using this threshold each node will become cluster head at some point within 1/P rounds. Nodes that are cluster head in round r = 0 are not allowed to be cluster head for next 1/P rounds.

Nitin Mittal et al.[8] presented an algorithm in which cluster contains CH and sub-CH(the node that will become cluster

head in case existing cluster head die). This technique extends the network lifetime and minimizes the power consumption. In TEEN [9], energy consumption is reduced by allowing sensor nodes to sleep during inactive period. PEGASIS [10] (Power-Efficient GAthering in Sensor Information Systems) is a near optimal chain based protocol which exhibits an improvement over LEACH. In PEGASIS node communicates only with the neighboring close node and take turns in transmitting to base station which reduces the amount of energy spent per round. Clustering techniques including fuzzy logic [11] have been proposed. Fuzzy logic based algorithm are designed to simplify the next step of operation which is data or decision fusion operation.

Kanwalnainpreet Kaur et al. presented a technique [12] for enhancing the network lifetime. The aim of this algorithm is to reduce the transmission between cluster heads and BS node. Instead of transmission between every cluster head and BS node the technique follows the election of master cluster head for transmission of data from different cluster heads to base station. Chong Wang et al. [13] exhibited an improvement over LEACH by proposing a more reasonable set up phase. The proposed algorithm focuses on saving the energy cost induced due to redundant nodes and balancing the energy consumption by splitting large clusters into smaller ones. This algorithm reduces energy consumption and results in prolonged WSN lifetime as compared to LEACH. Fuzhe Zhao et al. presented a technique[14] for even distribution of energy load amongst the node. This is achieved by modifying the traditional equation of CH selection. The concept of Vice Cluster Head (VCH) has been proposed in this algorithm. VCH is selected by taking into consideration the node's residual energy. VCH will diminish the energy consumption spent on re-clustering, if the existing CH died. However, if a CH dies before the completion of the round, there exists no CH for the remaining round leading to data loss. Thus although residual energy is considered in selection of CH, data loss is exacerbating.

In this survey it has been observed that there is shortcoming of ignorance of node's residual energy for selection of CH. We propose Enhanced LEACH (E-LEACH). In E-LEACH cluster head selection criteria has been modified .A node will be allowed to become CH only if it satisfies two threshold conditions. Analysis of this modified approach has proved that E-LEACH optimizes performance in terms of energy efficiency, Packet Delivery Ratio(PDR) and network lifetime.

3 THE ENHANCED-LEACH (E-LEACH) PROTOCOL

In LEACH, the cluster head selection criteria is based on only probability of that node being cluster head and ignores the remaining energy of that node. Hence there is possibility that nodes with less remaining energy are selected as CH. Energy consumption of a node increases while serving as CH. As CH consumes more energy, CH will drain out its energy resources and die, this reduces network lifetime.

Considering this demerit of LEACH, We have proposed a new strategy for selection of cluster head in set up phase. It takes into consideration an additional parameter for selection of CH. Considered extra parameter is that node will be allowed to become cluster head only if its remaining energy is greater than threshold energy(Eth). Along with the Eth probabilistic threshold is also considered as CH selection criteria. The modified cluster head selection criteria results in optimal performance of LEACH in terms energy efficiency, Packet Delivery Ratio (PDR) and network lifetime.

The modified selection criterion is expressed mathematically as given below:

$$T(n) = \begin{cases} \dfrac{P}{1 - P * \left(rmod\left(\frac{1}{p}\right)\right)} & \&\& \ (E_0 > E_{th}) \quad if \ \ n \in G \\ 0 & otherwise \end{cases}$$

E-LEACH algorithm is as shown in Fig.1.

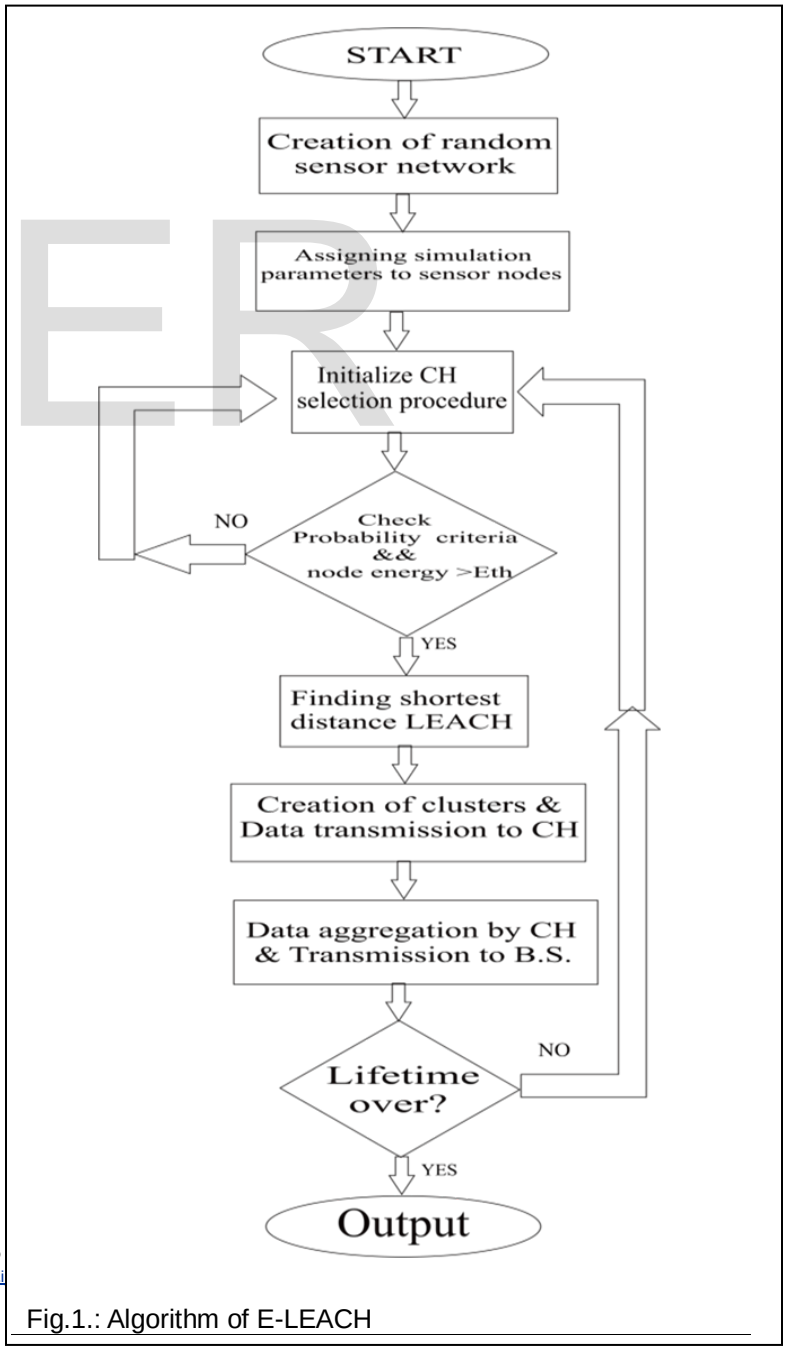

Fig.1.: Algorithm of E-LEACH

4 PERFORMANCE ANALYSIS

4.1 Simulation Parameters

Simulation is performed using Matlab R2009b.

We have made the following assumptions:

1. Base station position is fixed and data transmission from nodes to cluster heads is lossless.
2. Data transmission from cluster head to base station is lossless.
3. All sensor nodes have zero mobility.
4. Energy loss during idle and sleep state is assumed to be zero.
5. Processing energy consumption is assumed to be zero.

All results are obtained after averaging the results of 50 repeated simulations. Simulation parameters are mentioned in Table 1.

DESCRIPTION	VALUE
Simulation Area	1000 X 1000 m^2
No. of sensor nodes	Varied from 50 to 100 in steps of 10
Simulation time	1000 sec.
Initial energy of node(E_0)	10 J
Threshold energy level(E_{th})	2.5 J
Control Message size	64 bits
Packet size	8000 bits

Table 1. Simulation parameters

4.2 Simulation Results and Analysis

The performance of E-LEACH protocol is compared with the LEACH. Total network remaining energy after completion of simulation for fixed time, number of dead nodes per round and packets delivered to base station per round are the performance metrics used to compare the performance of E-LEACH and LEACH. Network life time is estimated on the basis of number of dead nodes per round of simulation.

A] Energy Efficiency Analysis

As observed from figure 2 total network remaining energy in case of E-LEACH is more as compared to that of LEACH protocol. This is the indication of the fact that energy consumption in case of E-LEACH is more evenly distributed than LEACH. Because of the introduction of threshold energy level monitoring concept, E-LEACH does not allow the nodes having energy less than E_{th} to be a CH. Thereby our modification increases the remaining network energy and hence the lifetime of the network.

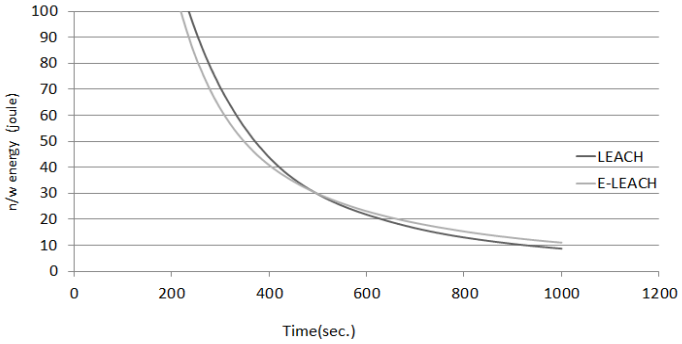

Fig.2. Remaining network energy with respect to time of simulation

B] Network Life Time Analysis

As observed from figure 3, number of dead nodes per round in case of E-LEACH is less than that of original LEACH. Newly added energy condition for CH selection prevents nodes with less remaining energy to become CH. Therefore, these nodes are less likely to die. Thus our modified
E-LEACH increases the network lifetime as more number of nodes remains alive at the end of the simulation.

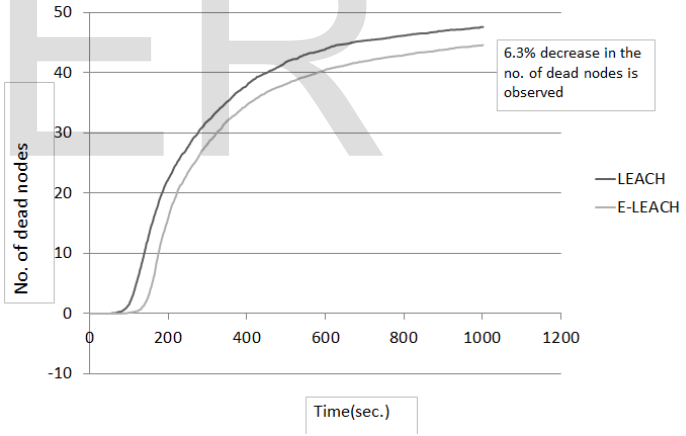

Fig.3. No. of dead nodes with respect to simulation time.

C] Packet Delivery Ratio(PDR) Analysis

Figure 4 shows that the number of packets delivered to the base station per unit time is more in E- LEACH as compared to LEACH . The network performance depends on the amount of data received by cluster heads and amount of data forwarded to the base station. This enhances PDR and therefore efficiency of the network increases. In original LEACH sometimes CH dies due to insufficient energy causing data loss. This problem is avoided in E-LEACH which reduces data loss. Reduced data loss is exhibited by packet delivery ratio.

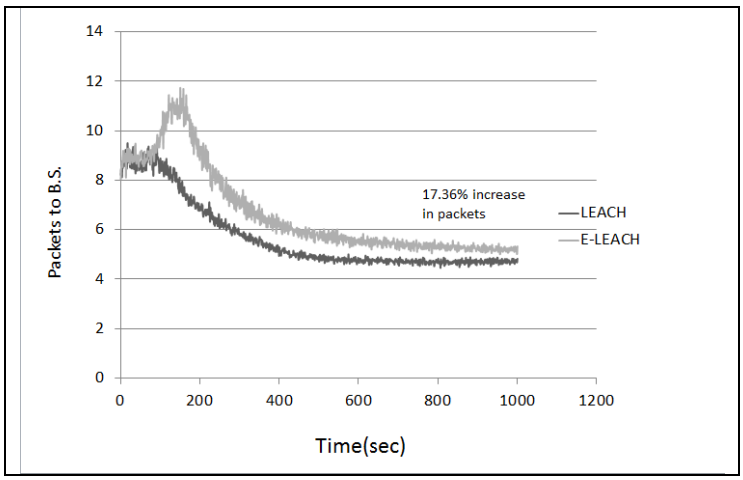

Fig.4. Packets delivered to base station with respect to simulation time.

The comparison of the performance metrics of the proposed E-LEACH protocol and the LEACH protocol is tabulated in table 2.

Parameter	LEACH	E-LEACH	% Change
Remaining network energy(J)	8.706228	11.02542	+26.64%
No. of dead nodes	48	45	-6.25%
Packets delivered to BS	5703	6694	+17.38%

Table 2. Comparison of LEACH and E-LEACH.

5 Conclusion

In this paper, we have focused on providing remedy for overcoming major shortcomings of LEACH associated with the ignorance of nodes residual energy while selection of cluster head for each round. A novel idea of considering both randomly assigned probability value as well as nodes residual energy as a criteria for selection of cluster head is presented. Matlab simulation results of this modified cluster head selection algorithm has supported the fact that performance of traditional leach protocol is improved appreciably by considering node energy constraints during cluster head selection procedure.

For fixed time of simulation comparison between total remaining energy of E-LEACH and LEACH we got 26.64% increase in the remaining network energy, 6.3% decrease in the number of dead nodes. The number of packets received to base station is increased by 17.36%. Performance improvement in terms of increased energy efficiency, improved packet delivery ratio and prolonged network lifetime is accomplished.

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