Enhanced Clusterhead Selection Algorithm Using LEACH Protocol for Wireless Sensor Networks

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Abstract
WSN is now a days a vast field for research. Its growth increases day-by-day. Routing protocol with energy efficiency has been a challenging issue in the design of wireless sensor networks. Efficiency and security are two topics in the design of routing protocol for WSNs. Heinzelman, ET. Al. introduced a hierarchical clustering algorithm for sensor networks; called Low Energy Adaptive Clustering Hierarchy (LEACH).The new proposed scheme describes two new ways to select Cluster head. Analysis shows that the improved or enhanced LEACH protocol balances the energy expense, saves the node energy and hence prolongs the lifetime of the sensor network.

Key Words: Clusterhead, , Energy conservation, Energy level, Optimum distance.

Introduction

LEACH is a cluster-based protocol. LEACH is one of the first hierarchical routing approaches for sensors networks. LEACH randomly selects a few sensor nodes as clusterheads (CHs) and rotate this role to evenly distribute the energy load among the sensors in the network. In LEACH, the clusterhead (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station(negotiation). WSN is considered to be a dynamic clustering method.

Operation :

It has 2 phases :

1. Set up State Phase
2. Steady State Phase

- In the setup phase, the clusters are organized and CHs are selected.
- In the steady state phase, the actual data transfer to the base station takes place.
- The duration of the steady state phase is longer than the duration of the setup phase.
- During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs.
- A sensor node chooses a random number, r, between 0 and 1. Let a threshold value be T(n). If this random number is less than a threshold value, T(n), the node becomes a cluster-head for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, denoted by G.
  It is given by [2]:

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \quad if\ n \in G$$

where G is the set of nodes that are involved in the CH election.

Each elected CH broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster-heads. All the non-cluster head nodes, after receiving this advertisement, decide on the cluster to which they want to belong to. This decision is based on the signal strength of the advertisement. The non cluster-head nodes inform the appropriate cluster-heads that they will be a member of the cluster. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster.
During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster-heads. The cluster-head node, after receiving all the data, aggregates it before sending it to the base-station. After a certain time, the network goes back into the setup phase again and enters another round of selecting new CH.

Related Works

The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols, although some protocols have been independently developed [1]. Taxonomy of the different architectural attributes of sensor networks is developed [3]. Further improvements on LEACH protocol for wireless sensor networks has been developed where both security & efficiency features have been dealt with[4]. Here the sensing area has been divided into a number of equilateral areas, called as clusters. Each cluster consists of six equilateral triangles called cells. The protocol consists of a number of rounds but after forming the clusters they do not change in each round. Both each equilateral triangle & each equilateral hexagon has same number of nodes. In each cell one cell head is selected & one CH is selected is chosen from six cell heads. The data are sent to the base station by using the multi-hop manner through a secure path consisting of cluster heads. The analysis shows that the improved protocol saves nodes energy, prolongs WSN lifetime, balances energy expenses and enhances security for WSNs.

To allow a single-tier network to cope with additional load & to be able to cover a large area of interest without degrading the service, networking clustering has been pursued in some routing approaches [7]. The hierarchical routing protocols involve nodes in multi-hop communication within a particular cluster to efficiently maintain the energy consumption of sensor nodes as well as perform data aggregation fusion to decrease the number of transmitted messages in the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head [5][6]. LEACH is one of the first hierarchical routing approaches for sensors networks [1].

The aim of LEACH protocol is to minimize energy consumption or in other words, to maximize the network lifetime. To make this happen several ideas are proposed for CH selection but they were based on mainly the node's (to be selected as CH) energy level. The node having greater energy level will be selected as CH most of the times. But here in the new proposed scheme not only the node's energy level is considered but also it's location or position both within the CH & from outside the cluster(neighbour clusters) are considered.

Proposed Scheme

We know that there may a number of nodes in a cluster & there is always a CH. Suppose for example, if the CH lies at a distant position from the majority of nodes. So to communicate between CH & sensor nodes, since the distance between them is high, energy consumption for the communication is also high. That means, the higher the distance between CH & sensor nodes the greater the energy consumption.

Here a new idea to select the CH is given below :

1. Select the CH in the dense node zone.
   To illustrate this say for example, you are announcing something. If the persons, for whom your announcement is, are very far from you, you have to shout more to make them listen to it but if those persons are near to you, you won't have to shout that much.
   That means, if nodes are near to the CH, energy consumption is less.

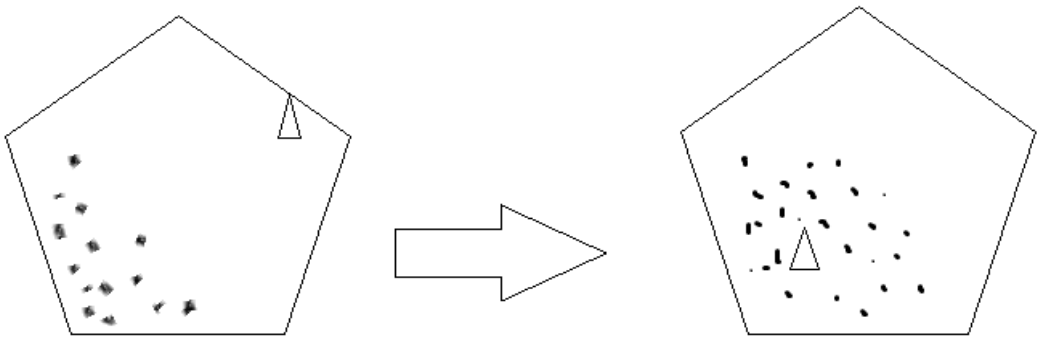


Fig. 1

2. Suppose a cluster is surrounded by 6 clusters. So 6 CH can communicate with the central CH. This central CH should be at an optimum distance from those CH. That means the distance between them should be balanced or on average.
   Say, C0,C1,C2,C3,C4,C5,C6 are the CH of cluster 0(central cluster),cluster 1, cluster 2, cluster 3, cluster 4, cluster 5, cluster 6 respectively. There should not be a huge difference among distances between C0-C1,C0-C2,C0-C3,C0-C4,C0-C5,C0-C6.
   Hence, energy consumption will be in control.

- New Proposed Mathematical formula:

$$\frac{P}{1 - P \times (r \bmod P^{-1})} \frac{E_{n\_current}}{E_{n\_max}} \frac{D_{avg}}{\sum D_{inter\_node}} \frac{D_{ch\_avg}}{D_{centre\_avg}}$$

Where:

$E_{n\_current}$ is the current amount of energy
E_{n_max} is the initial amount of energy
D_{avg} is the average distance from all other nodes in the cluster
E_{inter_node} is the distance between any two nodes in the cluster
D_{ch_avg} is the average distance from the node to the neighbouring cluster heads
D_{centre_avg} is the average distance of the neighbouring cluster heads from the centre of the cluster

Illustration:
Here with the original formula 2 factors are multiplied.

I. [Average distance from other nodes in same cluster/∑ inter-node distance]

This factor checks whether the node, to be selected as CH, belongs to a density popular area as well as the distance from the node to the other nodes within the cluster is on average.

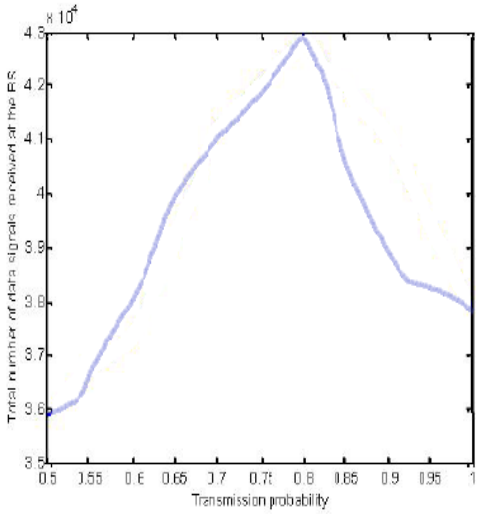
II. [Average distance from neighbouring clusterheads / average distance from the centre of the cluster to the neighbouring clusterheads]

This factor measures the distance from the node, to be selected as CH, to its neighbouring CHs as well as the distance from the centre point of the cluster to the neighbouring CHs.

If we follow the new proposed formula, then the clusterhead will be selected in such a way that will be very energy efficient. That means if we select the clusterhead by following the new proposed formula instead of the original formula of LEACH then the fact energy consumption to select the clusterhead will be emphasised this is a very important factor.

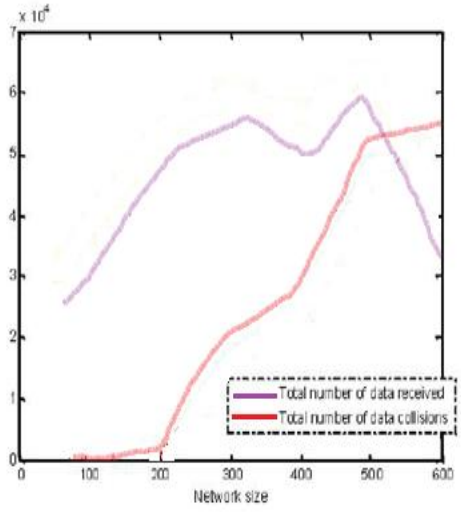
Results :

Fig. 2



Total amount of data received at the BS at the end of the network lifetime over transmission probability of nodes' sending data. Network size is 100 nodes.

Fig. 3



Total number of data signals received at the BS and the total number of data collisions over network size.

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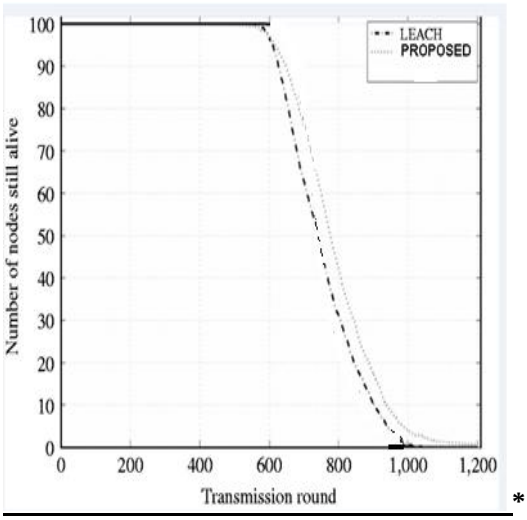

Fig. 4

Comparative Study:
According to **Stochastic Threshold Algorithm :**

- Cluster-heads can be chosen *stochastically* (randomly based) on this algorithm:

$$T(n) = \frac{P}{1 - P \times (r \bmod P^{-1})} \quad \forall n \in G$$

$$T(n) = 0 \quad \forall n \in G$$

Where n is a random number between 0 and 1
P is the cluster-head probability and
G is the set of nodes that weren't cluster-heads the previous rounds

- If n < T(n), then that node becomes a cluster-head
- The algorithm is designed so that each node becomes a cluster-head at least once

According to **Deterministic Threshold Algorithm**:

- A modified version of this protocol is known as LEACH-C (or LEACH Centralized)
- This version has a *deterministic* threshold algorithm, which takes into account the amount of energy in the node…

$$T(n)_{new} = \frac{P}{1 - P \times (r \bmod P^{-1})} \frac{E_{n\_current}}{E_{n\_max}}$$

Where $E_{n\_current}$ is the current amount of energy and
E_{n_max} is the initial amount of energy

- …and/or whether or not the node was recently a cluster-head

$$T(n)_{new} = \frac{P}{1 - P \times (r \bmod P^{-1})} \left[\frac{E_{n\_current}}{E_{n\_max}} + (r_s \operatorname{div} P^{-1}) \left(1 - \frac{E_{n\_current}}{E_{n\_max}} \right) \right]$$

Since the goal is to maximize the lifetime of the network or to minimize the energy consumption, according to the new proposed formula the lifetime of the network will be greater than the above mentioned formulae.

Comparison Between SPIN, LEACH, Directed Diffusion and the Enhanced LEACH :

	SPIN	LEACH	Directed Diffusion	Enhanced LEACH
Optimal Route	No	No	Yes	No
Network Lifetime	Good	Very Good	Good	Better than LEACH
Resource Awareness	Yes	Yes	Yes	Yes
Use of Meta-data	Yes	No	Yes	No

Advantages

- Optimises the distance between head nodes and other nodes reducing energy consumption and chances of loss of signal strength.
- Optimises the distance between the inter cluster head nodes, thus optimising the communication between head nodes and central server.
- The new approach selects the optimised node as head node which has the minimal cost in terms of energy while communicating with other nodes, thus increasing the lifetime of the network

Conclusion

The LEACH routing protocol was designed to increase network lifetime. Since nodes are active until energy becomes finished in nodes battery. LEACH protocol takes in concern only the current energy level and calculates how much possibility a node has, to be selected as clusterhead.The Enhanced clusterhead selection algorithm using LEACH not only concerns about the current energy level but also takes into account the position or location of that node to be selected as clusterhead. If the node, to be selected as CH is near rest nodes within or outside (neighbour clusters) a clustrer, then it will consume less energy for communication. So the new proposed scheme calculates the distance of the node from other nodes within the cluster as well as the distance of the node from the neighbour clusterheads and the distance from the centre position of the cluster to the neighbour clusterheads.These factors are there in the new proposed scheme. Hence the proposed one is improved compared to the previous LEACH algorithm in terms of energy conservation.

If we analyse the new mathematical formula for increasing network lifetime, we will find enhanced results with the new.The new proposed scheme obviously has future scope for betterment of increasing network lifetime. There will be more advancement in placing CH over the cluster to minimize energy conservation. The two new factors need further studies and practical implementation to understand their exact importance and efficiency. After further study and research they can be raised to the power n and m respectively where n and m can be any rational number.

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References

1) W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Mi- crosensor Networks," Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00), January 2000.
2) Jamal N. Al-Karaki Ahmed E. Kamal – "Routing Techniques in Wireless Sensor Networks: A Survey" Dept. of Electrical and Computer Engineering Iowa State University, Ames, Iowa 50011.
3) S. Tilak et al., "A Taxonomy of Wireless Microsensor Network Models," in *ACM Mobile Computing and Communications Review (MC2R)*, June 2002.
4) ZHANG Yu-quan, WEI Lei – "IMPROVING THE LEACH PROTOCOL FOR WIRELESS SENSOR NETWORKS"; School of Information and Electronics, Beijing Institute of Technology, Beijing 100081.
5) A. Buczak and V. Jamalabad, "Self-organization of a Heterogeneous Sensor Network by Genetic Algorithms," *Intelligent Engineering Systems Through Artificial Neural Networks*, C.H. Dagli, et.(eds.), Vol. 8, pp. 259-264, ASME Press, New York, 1998.
6) C.R. Lin and M. Gerla, "Adaptive Clustering for Mobile Wireless Networks," *IEEE Journal on Selected areas in Communications*, Vol. 15, No. 7, September 1997.
7) Kemal Akkaya and Mohamed Younis – "A Survey on Routing Protocols for Wireless Sensor Networks"; Department of Computer Science and Electrical Engineering University of Maryland, Baltimore County, Baltimore, MD 21250.