Spanning Tree Based Reliable Data Transmission in LEACH

Neeranjan Chitare[1], Rashmi M[1], Shalini R. Urs[1], and Srinivas Sampalli[2]

[1] International School of Information Management, India
[2] Faculty of Computer Science Dalhousie University, Canada
{neeranjan,rashmi}@isim.net.in, shalini@isim.ac.in,
srini@cs.dal.ca

Abstract. Wireless Sensor Networks are currently finding applications in various upcoming fields such as health care monitoring, environment monitoring, vehicular ad-hoc networks, and many more, even though they have limited power, computational and communication capabilities. Clustering protocols are crucial in wireless sensor networks as they optimize energy consumption. LEACH is a clustering protocol used for minimal consumption of energy. In this paper, we have proposed a scheme to enhance reliability in LEACH by making use of spanning trees generated at base station to achieve multipath and multi-hop data transmission. The assigned paths make use of only cluster heads. This scheme was validated through simulation exercises which highlight the effect of employing spanning trees on the average end to end delay in data transmission and total energy consumed by cluster heads.

Keywords: Wireless sensor networks, clustering protocol, reliability, spanning trees, base station, energy consumed.

1 Introduction

A wireless sensor network (WSN) consists of network of sensors which are used to sense any parameters of interest in the natural or artificial environment. These parameters may be sound, vibration, pollution, moisture, and many more. Accordingly, there are various applications of wireless sensors such as in battle fields, health care systems, and environmental monitoring systems [1].

A plethora of protocols have been proposed and designed for the effective performance of WSNs with respect to time, energy, security, privacy and reliability [2, 3]. Among these, clustering protocols are of great importance in wireless sensor networks as they conserve energy by reducing the amount of energy for message transfer [4].

Low-Energy Adaptive Clustering Hierarchy (LEACH) [5] is a clustering protocol that optimizes energy consumption in wireless sensor networks. LEACH focuses on random selection of cluster heads (CHs) for every round. In every round, data is aggregated at the CH, following which CH sends this data to base station. This data transmission from CH to base station (BS) has to be accomplished in one hop. This is

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a limitation since the one hop communication would determine the energy threshold required by the sensor nodes.

In this paper, we propose a novel scheme to enhance the reliability in LEACH. In order to ensure reliability; multiple spanning trees are generated at the base station. The base station is provided with cluster heads and its members for that particular round. These paths involve only cluster heads for multipath and multi-hop data transmission. By incorporating this technique, we overcome the limitation of one hop communication between the cluster head and the base station in the LEACH protocol. We provide simulation results, which shows the effect of incorporating spanning tree in terms of average end to end delay for data transmission and total energy consumed by all cluster heads involved in that particular round.

The rest of the paper is organized as follows. Section 2 surveys the literature in this area. Section 3 describes the proposed scheme. Section 4 provides a brief analysis of the scheme while experimental results are detailed in Section 5. Section concludes the paper.

2 Related Work

Erciyes *et al* [4] provide an excellent overview of different existing clustering algorithms. HEED (Hybrid, Energy Efficient Distributed), a Distributed Clustering protocol in Ad-hoc Sensor Networks proposes a distributed clustering algorithm for sensor networks. The approach used in HEED for electing cluster head is based on the residual energy of a node depending upon neighbors that particular node has. HEED assumes that the network is homogenous in nature, further it assumes the network has information about the node and its neighbors. PEAS (Probing Environment and Adaptive Sleeping) have peculiar feature that if node detects a routing node in its transmission range, the node goes to sleep, that is, node turns off its radio. In GAF (Geographic Adaptive Fidelity), the sensor network is divided into fixed square grid and each grid contains routing node. Routing nodes are responsible for data aggregation at sink. This scheme provides mechanism that ordinary nodes can go to sleep when they have no transmission.

Yeuyang *et al* [7] proposed PEGASIS, an algorithm based on the data chain, where each node aggregates data from downstream node and sends it to upstream node along the chain. PEGASIS has some advantages compared with LEACH; it eliminates the overhead in dynamic formation of cluster. Another problem which PEGASIS addresses is that it provides much shorter distance from nodes to cluster head as compared to LEACH. Consequently, it saves lot of energy. This algorithm constructs chain which result in long distance between a pair of sensors resulting in greater energy consumption. PEGASIS endangers reliability by focusing on aggregation of data at any one node and electing it as a cluster head. Consequently, if this particular node is affected, this may affect entire network.

Chakrabarty and Sengupta [7] in their protocol have suggested an energy efficient scheme which combines and thus enhances the performance of LEACH and PEGASIS (Power-Efficient Gathering in Sensor Information Systems). The protocol provides an optimized solution which is based on minimum cost spanning tree using greedy algorithm to gather the data. This optimized solution is enhanced taking into account the distances between the nodes and the energy dissipation by each node. The protocol increases the system performance as development time is much shorter than using traditional approaches and it is relatively insensitive toward noise.

Wu *et al* [8] in their protocol 'SS-LEACH' provide a modified way of cluster head election. The SS-LEACH algorithm makes use of nodes self-localization technology and keys pre-distribution strategy. It is an extension of LEACH with the pre-distribution of keys and self localization technique. It improves the method of electing cluster heads and forms dynamic stochastic multi-paths cluster-heads chains. SS-LEACH algorithm increases the lifetime of wireless sensor networks effectively. In addition, this protocol also has a mechanism of multi-paths for ensuring reliability. Thus, it also enhances routing security. It is successful in checking for compromised nodes in the network. Although it provides secrecy of packets, it fails to mitigate Sybil and selective forwarding attacks.

3 Proposed Scheme

In this section, we explain how incorporating spanning trees enhances reliable communication in LEACH thereby removing the constraint of one hop communication between CH and BS. Cluster heads will form 5-8% of the total nodes whereas each cluster contains 7-10% nodes as its member [9].

Assumptions:

- Sensor nodes are homogenous.
- Sensor nodes are stationary.
- Data is aggregated at respective CH of that group.
- Base Station has location information of all the nodes prior to computing the spanning tree.
- Base Station has list of all the CH for that particular round.
- CH and nodes are authenticated.
- Packet size is the same for all nodes.

Overview of Steps:

(i) With the available information, BS computes the multiple Spanning trees for that particular round 'n' for time't'.
(ii) As per the spanning tree, the BS computes the parent and the child nodes for each CH.
(iii) BS also computes TD (Time Division) schedule for a CH and unicast it to respective CH.
(iv) Every CH sends the data to respective parent node as per the schedule provided.

(v) As the BS receives the data, it also receives the node information from which it is send. Base station will cross check it against the available CH information. After certain time‘t’, BS validates the source of data and incase data from a CH is missing BS selects the next spanning tree and repeats from step (i).

Let us consider an example.

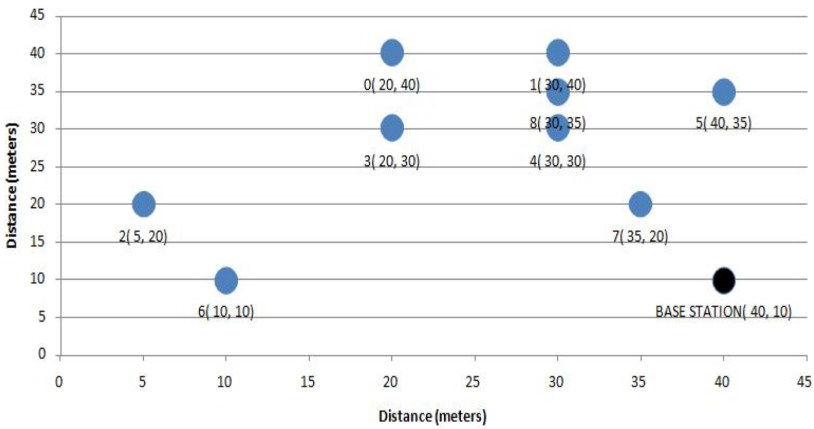

Fig. 1. Deployed sensor nodes along with the base station

As in Fig. 1, each node is a cluster head which is involved in data transmission. BS has the location information of each node and member nodes of cluster head. Based on the location information, BS generates number of spanning trees. For instance, for the nodes in above Fig. 1, we have mentioned four spanning trees possible in TABLE I. Actually, many spanning tree may exist for the given graph, but for explanation we are considering only four spanning trees.

Table 1. Spanning Trees for the network of figure 1

ST1		ST2		ST3		ST4	
S	*D*	*S*	*D*	*S*	*D*	*S*	*D*
8	7	2	0	2	0	6	2
7	6	1	0	3	0	2	0
2	6	0	3	0	1	0	3
6	3	6	7	1	5	7	3
3	0	7	8	5	4	3	4
4	1	3	4	4	7	1	4
0	1	4	8	6	7	4	8
1	5	5	8	8	7	8	5
5	9	8	9	7	9	5	9

Out of the above spanning trees, BS selects one spanning tree randomly and assigns respective parent node and child node for all cluster heads. These parent and child nodes are allotted taking the location of BS into consideration. When the base station generates a spanning tree, it also keeps record of nodes and the number of hops from the node to the BS. Each node is assigned as parent node and the nodes available within one hop distance are assigned as child node for that particular parent node.

The node with greatest number of hops *n* from base station is allotted first time slot for data transmission to its parent node. Second time slot is allotted to nodes with *n-1* hops from base station. if at a particular hop than one nodes are available, the node sequence to transmit data to parent node is random in nature.

This assists in proper aggregation of data at the cluster head. For the spanning trees mentioned in Table 1, the parent and child nodes for all the nodes are mentioned in Table 2.

Table 2. Parent (P) and Child (C) nodes

Node	ST1		ST2		ST3		ST4	
	P	C	P	C	P	C	P	C
0	1	3	3	2,1	1	2,3	3	2
1	5	0,4	0		5	0	4	
2	6		0		0		0	6
3	0	6	4	0	0		4	0,7
4	1		8	3	7	5	8	1,3
5	9	1	8		4	1	9	8
6	3	2,7	7		7		2	
7	6	8	8	6	9	4,6,8	3	
8	7		9	4,5,7	7		5	4
9		5		8		7	0	5

Along with the parent and child node information, it should also allot the time schedule for data transmission for each node. The BS computes the time schedule for each round and accordingly assigns each node with its time slot for communication. Thus each node gets the data from its child node and forwards it to the parent node within the time provided by time schedule.

4 Analysis of Our Approach

In LEACH, if the node fails to communicate with the base station because of any reason the entire process has to be repeated starting from cluster head election, group formation and communication with base station. Our scheme provides more than one spanning tree. Consequently, when cluster heads send data to base station, base station verifies the source. If in case data from any mentioned source is missing, then base station incorporates another spanning tree with same cluster heads. Thus, the scheme provides different paths with each spanning tree and avoids the iteration of entire process.

In our scheme, base station performs number of tasks which involves generation of spanning trees, assigning parent and child nodes to each cluster head, preparing time division schedule for cluster heads involved in that particular round and maintaining record of data received. As base station has more computational and communication capabilities than other nodes, this reduces the workload from other nodes.

The base station has location information of all authenticated nodes, this resists and minimizes the possibility of addition of fake nodes and paths in network. Consequently, the scheme has the potential to mitigate sybil attack and wormhole attack.

5 Performance Evaluations

In this section, we analyzed the effect of incorporating different spanning trees for a given graph with simulation studies. We placed 30 nodes randomly in a terrain of 150 meters x 150 meters. Further we manually generated 10 spanning trees for the given nodes. The layout of the nodes is illustrated in Fig. 2.

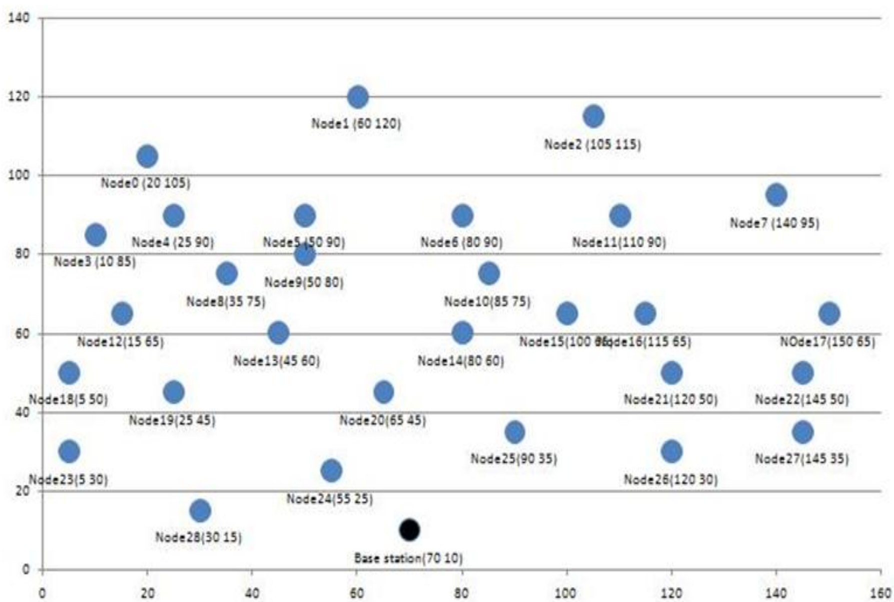

Fig. 2. A sample setup for simulation

For each spanning tree we observed:

- Total energy consumption = Sum of energy consumed at all the nodes
- Average end to end delay = (sum of average end to end delay between pair of nodes)/pair of nodes

We also calculated the same parameters for LEACH and plotted it with the spanning trees.

The simulator used is Glomosim [10], which is an open source simulator and works with PARSEC (Parallel Simulation Environment for Complex Systems). GloMoSim simulates networks consisting of nodes linked by a heterogeneous communications capability that includes multicast, asymmetric communications using direct satellite broadcasts, multi-hop wireless communications using ad-hoc networking, and traditional Internet protocols.

We used constant bit rate [11] for generating time schedule for data communication between nodes. For each spanning tree, we assigned respective parent and child node for all nodes. We simulated the networks for total time of one second. The following parameters were kept constant throughout the simulation:

- Number of items to send: 5
- Size of each item : 100 bit
- Time interval between two transmission of two items: 1 microsecond
- Duration of communication between two nodes: 10 millisecond

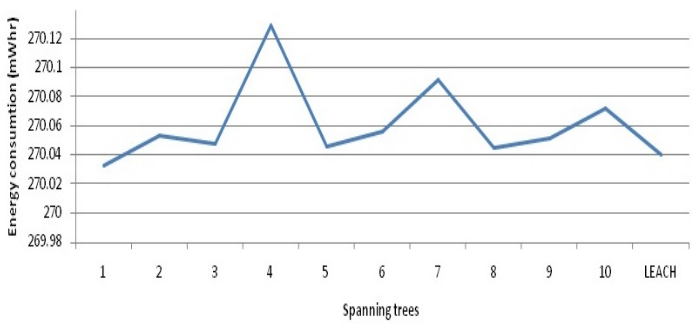

Fig. 3. Total energy consumed

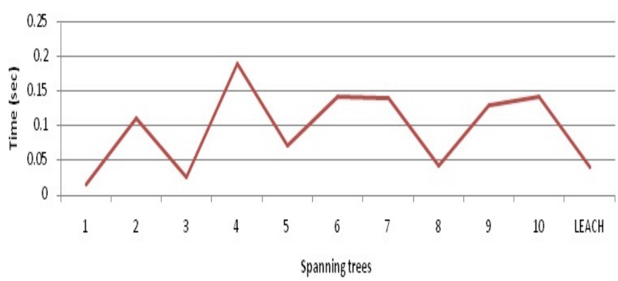

Fig. 4. Average end to end delay

As in the Fig. 3, we can observe that for the spanning tree 1 and spanning tree 4 have total energy consumption less than that of LEACH, whereas remaining spanning trees have comparatively greater energy consumption than LEACH. In terms of average end to end delay (Fig. 4), we observe that spanning tree 1, spanning tree 3 have less average end to end delay compared to LEACH. The rests of the spanning trees have greater average end to end delay.

6 Conclusion and Future Work

In this paper, we have proposed and designed a scheme for enhancing the reliability in the LEACH. The novelty of our approach is the generation of multiple spanning tree paths at the base station to improve the reliability. These paths involve only cluster heads for multipath and multi-hop data transmission. By doing this, we overcome the limitation of one hop communication between the cluster head and the base station as in LEACH protocol. Further, base station performs the task like generation of spanning tree and assigning parent and child nodes for a particular spanning tree for given round. This reduces the workload on the individual sensor nodes. Simulation results show the effect of incorporating spanning tree in LEACH for data aggregation. The proposed scheme adds reliability to the LEACH but the total energy consumption may be greater than or lower than required for LEACH. This also holds true for average end to end delay.

For future work, we intend to provide mechanism where in the base station cross checks the data received with the sender information. This may assist in validating the source of data and furthermore, if information from a particular source is missing then system will be able to detect it. For given layout of the sensor nodes, more than one spanning trees is available. In future, we intend to enhance the protocol to categorize and select the spanning tree based on energy consumed and total time require for unit data transmission.

References

1. Akyildiz, F., Su, W., Sankarasubramaniam, Y., Cayirci, E.: Wireless Sensor Networks: A Survey. Computer Networks, Elsevier Journal 38(4), 393–422 (2002)
2. Perillo, M., Heinzelman, W.: Wireless Sensor Network Protocols. Fundamental Algorithms and Protocols for Wireless and Mobile Networks, 1–35 (2005)
3. Sohrabi, K., Gao, J., Ailawadhi, V., Pottie, G.: Protocols for Self-organization of a Wireless Sensor network. In: 37th Allerton Conference on Communication, Computing and Control, pp. 1–24 (1999)s
4. Erciyes, K., Ozsoyeller, D., Dagdeviren, O.: Distributed Algorithms to Form Cluster based Spanning Trees in Wireless Sensor Networks, pp. 1–10
5. Heinzelman, W., Chandrakasan, A., Balkrishnan, H.: Enery-Efficient Communication Protocol for Wireless Sensor Networks. In: 33rd Hawaii International Conference on System Sciences, pp. 1–10 (2000)
6. Yueyang, L., Hong, J., Guangx, Y.: An Energy-Efficient PEGASIS- Based Enhanced Algorithm in Wireless Sensor Networks. DCN Lab, pp. 1–7. Beijing University of Posts and Telecommunications, Beijing (2006)
7. Chakrabarty, K., Sengupta, A.: An Energy Efficient Data Gathering Scheme in WSN Using Spannig Tree. In: IEMCON, pp. 1–6 (2011)

8. Wu, D., Hu, G., Ni, G.: Research and improve on secure routing protocols in wireless sensor networks. In: Proc. of the 4th IEEE International Conference on Circuits and Systems for Communications, pp. 853–856 (2008)
9. Sharma, S., Jena, S.: SCMRP: Secure Cluster Based Multipath Routing Protocol for Wireless Sensor Networks. Wireless Computing and Networking, 1–6 (2010)
10. GloMoSim, Wireless Sensor Network Simulator, http://pcl.cs.ucla.edu/projects/glomosim/
11. Nuevo, J.: A Comprehensible GloMoSim Tutorial, pp. 1–34 (2004)