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Reduction of Energy Consumption using Self-Organizing Tree for Wireless Sensor Networks.

R Rathna[1]*, MP Vaiyshnavi[2], and V Maria Anu[1].

[1]Department of Information Technology, Sathyabama University,Chennai. India.
[2]Department of Computer Science and Engineering, University College of Engineering, Anna University, Panruti. India

ABSTRACT

The Wireless Sensor Network (WSN) composed of several nodes are used for different types of monitoring applications. The objective of deploying WSN is to observe a particular site for monitoring physical parameters like temperature, light, pressure, humidity or the occurrence of a phenomenon. The Sleep/Wake up scheduling for Wireless Sensor Networks has become an essential part of its working. In this work, the details of Low Energy Adaptive Clustering Hierarchy (LEACH) which introduced the concept of clustering in sensor networks, Energy-Efficient Clustering routing algorithm based on Distance and Residual Energy for Wireless Sensor Networks (DECSA) which describes about scheduling based on distance and energy and the Energy efficient clustering algorithm for data aggregation (EECA) were discussed. The LECSA (Load and Energy Consumption based Scheduling Algorithm) has also been discussed. Based on that, in this proposed work, the cluster head finds the nearest active node in the neighbor cluster and then it forwards its data to it. From all the cluster heads the data reaches the sink not directly, but by using a self-organized efficient routing algorithm.

Keywords: Architecture, Base Stations, Clustering Methods, Scheduling Algorithm, Wireless Sensor Networks.

Corresponding author

INTRODUCTION

Wireless Sensor nodes have to be densely deployed for environmental monitoring applications. There are different types of sensors available in market for different types of functions. The bio sensors are used to monitor the body health and micro or nano-sensors [1] used in human body invasive diagnostic procedures. But the size of these sensors is far smaller and much different than those used for structural and behavioral monitoring. The sensors used in outdoor hazardous conditions [2] are more prone to damage. So they should be more in number and have to withstand for a long period of time. For many nodes in a network, if all the nodes try to communicate with the sink, there will be lot of traffic and thereby it increases the overall energy consumption of the WSN rapidly and drastically. This will soon deplete the residual energy of all the nodes. The nodes will be dying one by one. Thereby the hot data sensed by a node at a particular spot will be lost and the main objective of deploying the WSN to sense the occurrence of an event becomes meaningless.

For an environmental monitoring application, the nodes are generally placed by simply throwing them in the required area from an aerial vehicle (Military and defense purpose). In some cases like monitoring the pressure or temperature in an area, monitoring the moisture content or water content of the soil [3], sensing the presence of oil in water [4], finding the presence of smoke from overcooked oil , monitoring the strength of the old bridges and buildings [5], and detecting the presence of harmful radiations in the air the nodes, the sensors will be placed in already planned locations. Since they are openly placed in environments, any catastrophe or any form of small changes in the climate may completely damage them. So in the initial network set up phase itself, some nodes get damaged. Hence in the working phase of the network, the functionality of the active nodes is very crucial and plays a vital role for not reducing the lifetime of the WSN.

RELATED WORKS

Sleep/wake-up scheduling protocols schedule the transceiver of the sensor node for three states namely active state, sleep state and idle state. During its active state data is transferred to sink node. If the transceiver is in idle state it forwards the data to sleep mode to save the lifetime of wireless sensor network. The energy of transceiver must be saved so that it has to shift to active mode at the required time. Remaining time it should be in sleep mode.

In Distance Energy Cluster Structure Algorithm (DECSA) it examines both the distance and residual energy information of the nodes. DECSA protocol can be divided into initialization stage and working stage [6]. In the initialization stage the Cluster Head (CH) is elected and it coordinates with its cluster members. After the election of cluster head, the election of the Base Station Cluster Head (BCH) takes place based on the threshold level. In the working stage CH collects the data from the cluster member and transmits the data to their nearest CH. Then, the CH collects the data and sends to the base station (BS) to balance the energy consumption and completes the data transmission of the network.

Energy Efficient Clustering Algorithm (EECA) is used to fasten the process of data aggregation. EECA algorithm separates the sensor network into Clusters (Figure 1) with CH and its members. In EECA, phases can be divided into set-up phase and steady state phase [7]. In set-up phase cluster head allocates (TDMA) time slots to cluster members.

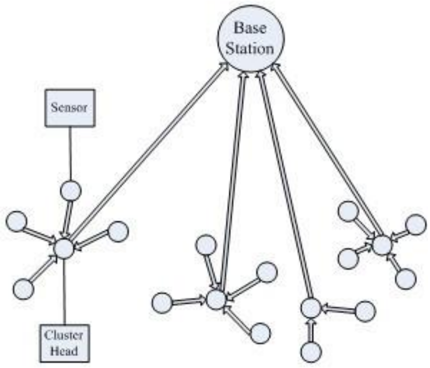

Figure 1: Cluster Architecture of EECA

In steady state phase cluster members send the data to the CH within its time slot. Then, the CH transmits aggregated data to sink nodes through intermediate Cluster Heads (CHs).

In LECSA (Load and Energy Consumption Based Scheduling) protocol, there are two phases namely distance based hierarchical clustering and scheduling and Load and energy balanced scheduling. Initially cluster head is selected based on the highest alpha value. The node transmits the data to a node in the increasing order of alpha value and it finally reaches the sink node. The scheduling is performed by using (TDMA) based protocol [8]. The data from any node transfers to the CH, then the CH sends the data to sink node. So the cluster head should have higher reserved energy. In each round the CH can dynamically changes. So the energy consumption of the network will be uniformly distributed.

TREE STRUCTURE ANALYSIS FOR ROUTING

Clustering is the concept introduced by Wendi Rabiner Heinzelman et al in LEACH [9]. Deploying cluster of nodes greatly reduces the energy consumption by reduced traffic. The routing of data from the source through the nodes to the sink needs a route [10]. The route can be planned only if the nodes are arranged in a tree. For that a proper tree structure is needed. There are several tree structures available. Several research papers and works are done and some still going on in the topic of best tree structure for the WSN. The node which actually senses the data simply handover it to next immediate active node in the tree structure and if there are cluster of nodes in the tree, the node will be transmitting it to the Cluster Head (CH). The CH is responsible for transmitting the data to the active node in the neighbor cluster in the tree hierarchy. The cluster head should aggregate the data from all other nodes in the cluster [11]. The CH is a normal node. In some applications it has some extra features like GPRS facility with extra storage units and will be the permanent CH for that cluster in the WSN throughout its lifetime. But for the environmental monitoring applications considered here for this work, the CH is also a normal node. All the nodes in a cluster get the chance of becoming a CH based on certain conditions.

Initially the nodes are randomly placed. But all the nodes are considered to be in a tree structure. As initially given, the tree structure helps in routing the packets form the hot spot where it originated to the sink node. The tree can be are constructed in many ways. The aim of tree construction is to reduce the time taken for data transmission to the sink node. This will automatically reduce the overall energy consumption of the WSN. There are several tree topologies available for routing in WSN. Some of them are

Shortest Paths Tree (SPT) – The basic tree structure for routing in any type of network. Here the shortest distance between the source and the destination (Sink node) is calculated.

Minimum Spanning Tree (MST) – This is also meant to calculate the shortest route but by using a different algorithm.

Steiner Trees – This is a variant of Minimum Spanning Tree. In addition to the already existing Minimum Spanning Tree for a WSN, some more new vertices are added. The goal of Steiner tree is to reduce the overall spanning length of the tree [12].

Center at Nearest Source (CNS) – This tree structure is basically used for data aggregation in WSN. In this type the node nearest to the sink node will act as aggregating node. All the other nodes in the network directly send the data to this node. This node will aggregate the data and send it to the sink [13].

Greedy Incremental tree (GIT) – This is also an aggregation tree. The node which is nearest to the sink will be calculated using the SPT. Then that is added to a set. From that node again the node which is nearest is calculated and it is added to that set. This will proceed till the source node is reached.

Connected Dominating Set Tree (CDS) – This is a graph based tree construction technique using set theory [14]. The sink node will be made black and its child nodes will be gray. In increasing order, all the nodes now will be either black or gray. If there are any white nodes, the one with smallest ID will be made black, and it goes on. The nodes which are black are now the dominating nodes. They will be the cluster heads for the white nodes surrounding them.

Shortest Path Tree and Minimum Spanning Tree

Among the above listed set of tree structures available the data transmission in a WSN is simulated using Shortest Path Tree (SPT) and the Minimum Spanning Tree (MST). Let us first see how the routing tree using SPT is constructed. All the nodes transfer beacon signals to know about their neighbors. Initially, the sink node will be placed in a set. The other nodes will be in another set. Then from the sink node, based on the intermediate distance, the nodes which are all directly reachable are calculated. They are then added to the set in which the sink node is present. This is actually based on the Dijkstra's algorithm. This simulation was carried out for 50 nodes.

Then the simulation was carried out using Minimum Spanning Tree (MST) for routing. In this algorithm, from the Sink node, the link to nodes in the entire WSN has to be constructed based on the smallest intermediate distance between the nodes. All the nodes have to be traversed starting from the sink node. This is actually based on the prims' algorithm. The tree construction takes more time than the SPT. But the time taken for data transfer using MST is lesser than using the SPT. The overall energy consumption of the WSN using both SPT and MST were compared and shown in Table I.

TABLE I. COMPARISON OF ENERGY CONSUMPTION USING SPT AND MST

Time in ms	Energy (SPT) (mj)	Energy(MST) (mj)
8	40.019	31.653
16	73.662	58.83
24	102.31	84.14
32	112.51	93

From the tabular values it can be observed that the energy consumption for the WSN using MST is slightly lesser than that of using SPT. This simulation study is for 100 nodes. This difference is not very significant. Then for a Connected Dominating Set Tree, the simulation was carried out.

Connected Dominating Set Tree

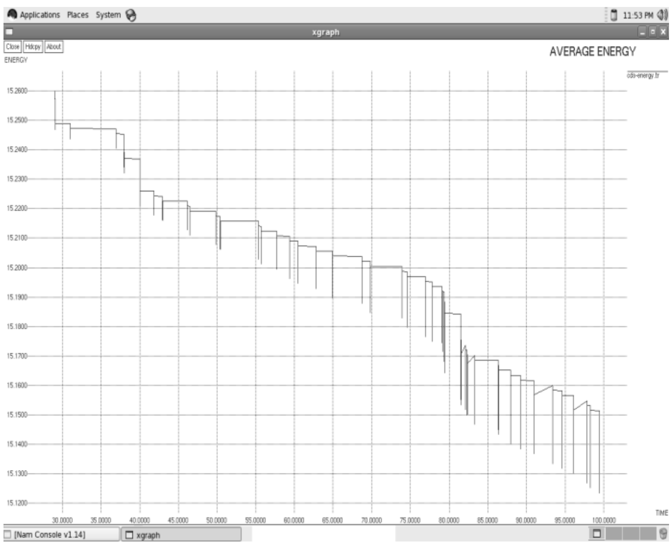

Figure 2: Energy consumption (mJ) graph while using Connected Dominating Set for tree construction

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Fig.2 shows the performance of WSN, if the routing takes place using CDS (distributed) tree. The Y-axis denotes energy consumption in mJ. The X-axis denotes the increase in time in milliseconds. This graph shows the reduction in energy consumption for a simulation which runs in 100 milliseconds. But in the decreasing graph at some points, it is seen small downward spikes and immediate increase. That is due to the fact that some nodes will go to sleep mode from active state and some nodes become active from sleep state in a cyclic manner according to the dynamic scheduling algorithm. During this transit, there will be a very small increase in energy consumption. This is the reason behind those spikes. For this 100 milliseconds simulation, the energy consumption of the WSN decreased from 15.26mJ to 15.12mJ.

But the CDS tree is not a self-organized tree. The CDS tree once formed does not always give the reduced energy consumption. Because in the same graph there is not this much decreases elsewhere.

Self-Organizing Tree

The sink node assigns itself as root node and coordinates with all other sensor nodes. The data communication takes place through phases – Initial Phase, Tree construction phase and the Information Exchange phase.

Initial Phase

In this phase, the distributed cluster formation occurs. The initial Cluster Head (CH) circulates token among its neighbors [15]. Those nodes which are in its range are detected by this method and clusters are formed using K-means clustering. The data travels from the node where it is first sensed to the sink. If the time consumption for this transfer is more, then the data from the CH travels through the intermediate CHs and reach the sink.

Tree Construction Phase

In this phase, the tree is constructed based on the neighbor node information. Every parent node maintains a record of its child nodes. If a node does not have a child node then it defines itself as leaf node.

Information Exchange Phase

In this phase, all the parent nodes transmit their data to the root node. If a child node is about to die, it discharges its' data to next immediate active node. In short time, the tree has to be reconstructed using this information. While forming the clusters [16], threshold value is used to have a check over the cluster size. When the CH receives (Join-message) sent by the ordinary node, it will compare the size of the cluster with the threshold to accept new member and update the count of cluster nodes. If the request is rejected and that node already has a CH, then the clustering process ceases. Otherwise, it finds another appropriate cluster to join. During every round, the clustering takes place and the details of the re- elected CHs are informed to the sink. The following figure in Fig.3 gives the flow of this routing technique.

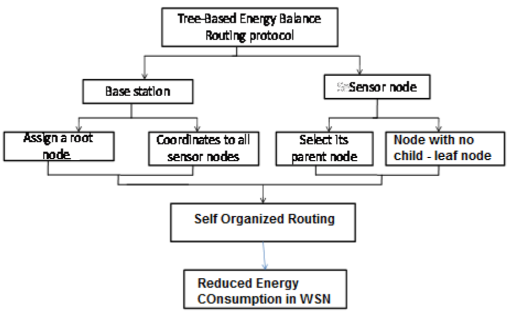

Figure 3: The Routing architecture of the proposed method

To avoid the messages sent by misbehaved nodes, certificates are used. Cluster based certificate revocation for enlisting and removing the certificates of nodes that have been detected to launch attacks on the neighborhood are the techniques used for security.

RESULTS AND DISCUSSION

The experiment is carried out to evaluate the performance of the proposed approach. The details of simulation parameters are as follows: In an area of 25*25 m, 50 sensor nodes are deployed. First 41 nodes got clustered into six clusters. They are shown in the Table II.

TABLE II: CLUSTER FORMATION USING PROPOSED METHOD

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
0(CH)	35(CH)	13(CH)	21(CH)	26(CH)	5(CH)
1	39	12	31	23	10
2	36	18	32	37	9
41	3	11	30	25	6
7		17	34	28	24
8		38	19	27	
4		16	20		
		14	22		
		15	33		

After the cluster formation, Tree construction [17-18] takes place. Using the tree, the initial information exchange occurs. Then the tree becomes self-organized [19]. The packet loss which occurred during the data transmission using this self-organized tree construction is shown in the following graph (Fig.4) and it is compared with the LEACH [20].

Figure 4: Packet Loss comparison of the proposed method with the LEACH

This graph is the evidence showing that the self organizing tree outperforms the existing protocols [21-22].

CONCLUSION

The WSN is a simple network architecture used in critical applications which involves constant monitoring. For the WSN in environmental monitoring applications more nodes are deployed. The need for clustering and scheduling is must in these types of densely deployed sensor nodes. A moderately optimal algorithm has been proposed with the self-organizing capacity. By using this, the nodes will not get depleted easily. Since the node with least energy is given priority here, the overall energy consumption of the network greatly reduces. The graph presented shows that this type of tree construction is the best suitable one for Wireless Sensor Networks deployed in places where they cannot be continuously monitored.

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REFERENCES

[1] Homola and Jiri. 2006. Surface plasmon resonance based sensors. Vol. 4. Springer, 2006.

[2] Mainwaring, Alan, et al. 2006. Wireless sensor networks for habitat monitoring. In the Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications. ACM, 2002:88-97. doi: 10.1145/570738.570751.

[3] Cardell-Oliver, Rachel, et al.2004. Field testing a wireless sensor network for reactive environmental monitoring [soil moisture measurement]. In the Proceedings of the IEEE Intelligent Sensors, Sensor Networks and Information Processing Conference, 2004: 7-12. doi: 10.1109/ISSNIP.2004.1417429.

[4] Brekke, Camilla, and Anne HS. 2005. Oil spill detection by satellite remote sensing in the Remote Sensing of Environment 2005,95 (1): 1 - 13. doi: 10.1.1.134.9804.

[5] Kim, Sukun, et al. 2007. Health monitoring of civil infrastructures using wireless sensor networks. In the 6th International IEEE Symposium on Information Processing in Sensor Networks. IPSN 2007: 254-263. doi: 10.1109/IPSN.2007.4379685.

[6] Zhu Yong, Qing Peia, A Energy-Efficient Clustering Routing Algorithm Based on Distance and Residual Energy for Wireless Sensor Networks. Procedia Engineering 29 (2012) 1882 – 1888.

[7] SHA Chao, WANG Ru-chuan , HUANG Hai-ping, SUN Li-juan, Energy efficient clustering algorithm for data aggregation in wireless sensor networks. The Journal of China Universities of Posts and Telecommunications, December 2010, 17(Suppl. 2): 104–109.

[8] R.Rathna and A.Sivasubramanian. TDMA Based Low Energy Consuming MAC Protocol for Wireless Sensor Networks in Environmental Monitoring Applications, in the proceedings of the Springer CCIS International Conference on Parallel, Distributed Computing Technologies and Applications (PDCTA-2011) , sep 2011, Volume 203, Part 1, Pages. 420-427.

[9] Heinzelman, Wendi B., Anantha P. Chandrakasan, and Hari Balakrishnan. 2002. An application-specific protocol architecture for wireless microsensor networks. IEEE Transactions on Wireless Communications, 2002: 660-670. doi: 10.1109/TWC.2002.804190.

[10] Po-Jen Chuang, Yao-Cheng Yu and Chih-Shin Lin. 2013. Reliable and Congestion-Controlling Transport in Wireless Sensor Networks in the Journal of the Chinese Institute of Engineers (JCIE). 36(1): 2-16. doi: 10.1080/02533839.2012.726021.

[11] B. Krishnamachari, D. Estrin, and S. Wicker. 2002. The impact of data aggregation in wireless sensor networks, in the Proceedings of the International Workshop of Distributed Event Based Systems, 2002: 575-578. doi: 10.1109/ICDCSW.2002.1030829.

[12] Min, Manki, et al. 2006. Improving construction for connected dominating set with Steiner tree in wireless sensor networks in the Journal of Global Optimization 35(1):111-119. doi: 10.1007/s10898-005-8466-1.

[13] Liao, Wen-Hwa, Yucheng Kao, and Chien-Ming Fan. 2008. Data aggregation in wireless sensor networks using ant colony algorithm. in the Journal of Network and Computer Applications : 387-401. doi: 10.1016/j.jnca.2008.02.006.

[14] Blum, Jeremy, et al. 2005. Connected dominating set in sensor networks and MANETs. in the Handbook of combinatorial optimization. Springer US.: 329-369. doi: 10.1007/0-387-23830-1_8.

[15] Yung-Fa Huang, Neng-Chung Wang and Ming-Che Chen. 2008. Performance of a Hierarchical Cluster-Based Wireless Sensor Network, Sensor Networks, In the proceedings of the IEEE International Conference on Ubiquitous and Trustworthy Computing, 2008. SUTC '08::349-354. doi: 10.1109/SUTC.2008.37.

[16] Abbasi, Ameer Ahmed, and Mohamed Younis.2007. A survey on clustering algorithms for wireless sensor networks. in the Computer communications :2826-2841. doi: 10.1016/j.comcom.2007.05.024.

[17] Cuomo, F.; Della Luna, S.; Cipollone, E.; Todorova, P.; Suihko, T., Topology Formation in IEEE 802.15.4: Cluster-Tree Characterization, in Sixth Annual IEEE International Conference on Pervasive Computing and Communications PerCom 2008, vol., no., pp.276-281, 17-21 March 2008.

[18] W. Fang, S. Li, X. Liang, Z. Li. Cluster-based Data Gathering in Long-Strip Wireless Sensor Networks. Advances in Electrical and Computer Engineering, vol.12, no.1, pp.3-8, 2012, doi:10.4316/AECE.2012.01001.

[19] Zhao Han; Jie Wu; Jie Zhang; Liefeng Liu; Kaiyun Tian. A General Self-Organized Tree-Based Energy-Balance Routing Protocol for Wireless Sensor Network in Nuclear Science, IEEE Transactions on , vol.61, no.2, pp.732-740, April 2014.

[20] Mu Tong; Minghao Tang. LEACH-B: An Improved LEACH Protocol for Wireless Sensor Network in Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on , pp.1-4, 23-25 Sept. 2010.

[21] Lakshmanan M Noor Mohammed V. An Adaptive Energy Efficient Mac Protocol For Wireless Sensor Networks in the International Journal on Intelligent Electronic System, Sathyabama Uniuversity. Vol.3. no.2, 2009.

[22] Godwin Premi, M.S.,Martin, B.,Maflin Shaby, S. Efficient set routing for continuous patient monitoring wireless sensor network with mobile sensor nodes in the Advances in Intelligent Systems and Computing (Springer). pp 613-618. Vol.339. 2015.