Minimum Spanning Tree based Routing Strategy for Homogeneous WSN

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ABSTRACT

A Wireless Sensor Network (WSN) is composed of sensor nodes spread over the field to sense the data. The sensed data must be gathered & transmitted to Base Station (BS) for end user queries. The used sensor nodes being in- expensive having low computation power & limited energy so are not as much reliable as their expensive macro sensor counter parts but their size and cost enable hundred to thousand of micro sensors to achieve high quality fault tolerant system. In an environment where in each round all sensor nodes have to send data to base station, it is required to effectively utilize energy of sensor nodes so as to increase the life- time of the system. The use of data aggregation & fusion as proposed in LEACH increases system lifetime by a factor of 8 as compared to conventional routing protocols. In this paper along with data aggregation & fusion, we are trying to minimize reduction in system energy by first generating MST between all sensor nodes so as to minimize their transmission energy with in network and after that a node of highest energy among the top tier will transmit the aggregated data of whole network to base station which is situated in the center of network area. Keeping network topology same till any node of network dies another highest energy node from top most rank tier is chosen to communicate with BS. This technique achieves much improvement in system life time as compare to LEACH and PEGASIS.

KEYWORDS

WSN, energy efficient, data aggregation, routing algorithm, Base station, minimum spanning tree.

1. INTRODUCTION

A wide variety of inexpensive sensors are available those are capable of computational task and wireless communication [5, 6]. A sensor network consists of sensors that will collect useful information from environment depending on the application which can be of like measuring temperature, humidity etc.

The main constraint of sensor nodes is very low finite battery energy which limits the lifetime and quality of network, because of this fact the protocols must be designed in a way to efficiently utilize the energy of nodes to prolong the lifetime of the network. Since wireless communication consume significant amount of battery power, sensor nodes should spend as little energy as possible when receiving and transmitting data [7, 8, 9]. Network lifetime can be increased by reducing bandwidth consumption by using local collaboration among nodes & tolerate node failures.

The data generated by nodes in sensor network is too much for end user to process so methods are required to combine them into a small set of meaningful information. A simple way is data aggregation (sum, average, min, max, count) from different nods and a more elegant approach is

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data fusion which can be defined as combination of several unreliable data measurements to produce a more accurate signal by enhancing the common signal & reducing uncorrelated noise [1]. The classification performed on the aggregated data might be performed by human operator or manually.

The proposed approach named as Minimum Spanning Multi Tier Protocol (MSMTP) is based on multi hop data transmission nodes to those neighbour nodes which are connected to it in minimum spanning tree (MST) structure for all the nodes of the network and then a node of highest energy among highest rank tier will transmit the whole network aggregated data to base station, we keep on repeating this procedure.

2. BACKGROUND

The earliest and simple approach was direct transmission in which each sensor node will sense & transmit its data to BS individually. Since base station is located far away from sensor nodes resulting higher transmission cost. Because of this high cost transmission the energy of nodes drain off faster and thus having short system lifetime.

In order to solve the problem, clustering based protocols were proposed where a cluster is a group of sensor nodes, with a head node managing all other member nodes. The heads are responsible for coordinating member nodes, gathering data within the clusters, aggregating data and forwarding the aggregated data to the base station.

LEACH [1] is a cluster-based, distributed, autonomous protocol. The algorithm randomly chooses a portion of the sensor nodes as cluster heads, and lets the remaining sensor nodes choose their nearest heads to join. The cluster member's data is transmitted to the head, where the data is aggregated and further forwarded to the base station. The LEACH algorithm reduces the number of nodes that directly communicate with the base station. It also reduces the size of data being transmitted to the base station. Thus, LEACH greatly saves communication energy. Since the protocol randomly chooses cluster heads in each round, the energy consumption is theoretically evenly distributed among all sensor nodes.

TEEN [10] adopts a similar clustering mechanism as LEACH does. It sets two thresholds, a soft threshold and a hard threshold, during the data collecting stage to further reduce communication traffic.

In the PEGASIS protocol [2], a cluster is a chain based on geographical location. The PEGASIS protocol constructs all sensor nodes into a chain with the shortest length. Sensor nodes only communicate with their adjacent nodes so that they can send data at the lowest power level. In each round, the system randomly chooses a sensor node as the cluster head to communicate with the base station. Therefore, communication traffic is reduced.

The PEDAP protocol [3] further extended the PEGASIS protocol. In the PEDAP protocol, all sensor nodes are constructed into a minimum spanning tree. PEDAP assumes that the base station knows the location information of all sensor nodes, and the base station can predict the remaining energy of any node based on some energy dissipation model. After certain rounds, the base station removes dead sensor nodes and re-computes routing information for the network. In the setup stage, all sensor nodes only need to receive the routing information broadcasted by the base station. Thus, the PEDAP consumes less energy than the LEACH and PEGASIS protocols in the setup stage.

In MSMTP [13] protocol all nodes of the network will transmit the sensed information or aggregated data to their neighbour which are connected in MST structure by multi hop communication. Whole network is divided into three tiers as described in section IV-A. A node of tier1 having highest energy will transmit network's fused data to base station, and similarly a node of highest energy from lowest possible tier id is selected to transmit data to base station &

in this way load is evenly distributed to all nodes of the sensor network. This will improve the overall system lifetime.

3. THE SYSTEM MODEL

3.1 Network Model

The protocol assumes that 100 sensor nodes are distributed randomly in the network area of diameter 100m. In addition to data aggregation, each node of the network has the capability to transmit data to other sensor nodes as well as to BS. The aim is to transmit the aggregated data to base station with minimum loss of energy which in fact increase system life time in terms of rounds. In this work we consider sensor network environment where:

- Each node periodically senses its nearby environment & likes to send this data to BS.
- Base Station is placed at a fix location.
- Sensor nodes are homogeneous & energy constrained.
- Sensor nodes are stationary & are uniquely identified.
- Data fusion & aggregation is used to reduce the size of message in the network. We assume that combining n packets of size k results in one packet of size k instead of size nk.

3.2 Radio Model

We use the same radio model as discussed in [3]. In this model, a radio dissipates E_{elec} = 50 nJ/bit to run the transmitter or receiver circuitry and E_{amp} = 100 pJ/bit/m2 for the transmitter amplifier. The radios have power control and can expend the minimum required energy to reach the intended recipients. The radios can be turned off to avoid receiving unintended transmissions. An r^2 energy loss is used due to channel transmission [10, 11]. The equations used to calculate transmission costs and receiving costs for a *k*-bit message and a distance *d* are shown below:

Transmitting

$E_{tr}(k,d) = E_{elec}(k) + E_{amp}(k,d)$

$= kE_{elec} + kE_{amp}d^2$

Receiving

ERx(k) = ERx-elec(k)

$E_{Rx}(k) = E_{elec} * k$

Receiving is also a high cost operation, therefore, the number of receives and transmissions should be minimal. LEACH and PEGASIS use the same constants (E_{elec}, E_{amp}, and k) for calculating energy costs; therefore the proposed protocol achieves energy savings by minimizing the distance and the number of transmissions and receives for each node. In our simulations, we used a packet length k of 2000 bits. It is assumed that the radio channel is symmetric so that the energy required to transmit a message from node i to node j is the same as energy required to transmit a message from node j to node i for a given signal to noise ratio (SNR).

3.3 Problem Statement

In this work, our main consideration is wireless sensor networks where the sensors are randomly distributed over an area of interest. The locations of sensors are fixed and the base station knows them all a priori. The sensors are in direct communication range of each other and can transmit to and receive from the base station. The nodes periodically sense the environment and have always data to send in each round of communication. The nodes fuse or aggregate the data they receive from the others with their own data, and produce only one packet regardless of how many packets they receive.

The problem is to find a routing scheme to deliver data packets collected from sensor nodes to the base station, which maximizes the lifetime of the sensor network under the system model given above. However, the definition of the lifetime is not clear unless the kind of service the sensor network provides is given. In applications where the time that all the nodes operate together is important, – since the quality of the system will be dramatically decreased after first node death – lifetime is defined as the number of rounds until the first sensor is drained of its energy. In another case, where the nodes are densely deployed, the quality of the system is not affected until a significant amount of nodes die, since adjacent nodes record identical or related data. In this case, the lifetime of the network is the time elapsed until half of the nodes or some specified portion of the nodes die. In general, the time in rounds where the last node depletes all of its energy defines the lifetime of the overall sensor network. Taking these different possible requirements under consideration, our work gives timings of all deaths for all algorithms in detail and leaves the decision which one to choose to system designers.

3.4 Sensor Node Information

MSMTP protocol partitions all sensor nodes into different tiers, in according to the distance towards the base station. The system assigns a tier ID to each node during the initialization stage. Those sensor nodes having the same tier ID are treated to be in the same tier. They approximately have the same distance towards the base station, and they consume approximately the same energy to communicate with the base station. Nodes closer to the base station are assigned lower tier IDs. Section IV-A describes the details how tier ID are assigned. For a sensor node in the proposed system, adjacent nodes with lower tier IDs are called its upper tier nodes (closer to the base station), while adjacent nodes with higher tier IDs are called down tier nodes (farther off the base station), nodes with the same tier ID are called peer nodes (approximately the same distance to the base station). Data trace-back will forward a node's data to its upper tier nodes, where the data is aggregated and further forwarded to even upper nodes. Basic information of a sensor node includes location of node, node ID, tier ID, energy contained by that node, energy threshold defined, distance of node from base station & energy required by the node to transmit data to BS, which is represented in the figure 1

X	**Y**	**Tier_id**	**Node_id**	**Energy**	**Threshold**	**Distance**	**Transmission energy**

Figure 1. Structure of the node

Where X, Y represents the location of the node in the network, node ID is globally assigned and is unique; the tier ID represents the distance towards the base station, and it is determined during the system initialization; energy of node records current remaining energy of the node; the energy threshold is used to decide whether or not the node has enough energy to communicate with the base station, distance contains distance of node from base station, and transmission energy contains amount of energy required to transmit data to BS. Some factors like location of node, node ID and the tier ID, distance, transmission energy are static, remains unchanged during the lifetime of the sensor node. The remaining energy will change during its lifetime. The energy threshold is dynamically set by the base station, which is least energy required by a node to transmit data to BS and is redefined time to time and is half of its previous value.

4. PROTOCOL DESCRIPTION

4.1 Tier Partitioning

The system partition the whole network into three tiers based on the distance from the base station. The least possible distance d1 (from middle of that side which is towards base station)

& largest distance d2 (from that corner of the network which is on other side of base station) is calculated, and after their difference is calculated as:
Diff= largest distance – least distance

Now the nodes are assigned tier id based on their distance from base station as:
For **Tier 1,** distance is in range d1 & d1+diff/3
For **Tier 2,** distance is in range d1+diff/3 & d1+2*diff/3
For **Tier 3,** distance is in range d1+2*diff/3 & d2

4.2 Data Transmission to BS

In this protocol, each sensor node forwards its sensed, aggregated data to that neighbour node which is connected to it in MST structure. Then a node of top most rank will transmit the aggregated data of all nodes of the network to the base station as shown in figure 2 below:

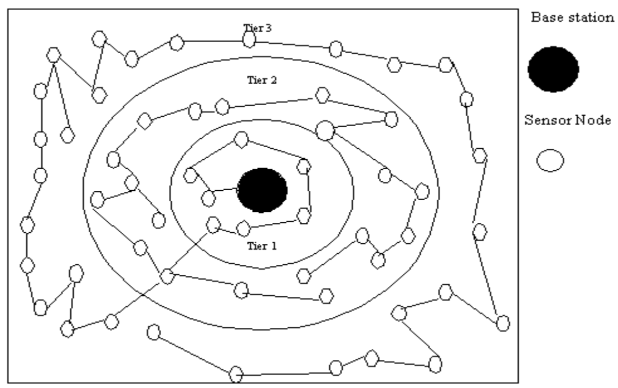

Figure 2. Proposed Architecture when transmission is through tier1 node

Nodes of tier1 continues to transmit aggregated data to base station until all nodes of tier1 have energy greater than defined threshold level, when all nodes of tier1 have energy below threshold energy then nodes of tier2 will transmit data to base station and same procedure will be shifted to nodes of tier3. This procedure is known as TOP TIER SHIFTING as depicted in figure 3. When all nodes of tier3 have energy below threshold energy then a new threshold is defined. This procedure is continued until threshold goes below dead energy, at that moment all nodes of network are dead so the network is assumed to be dead.

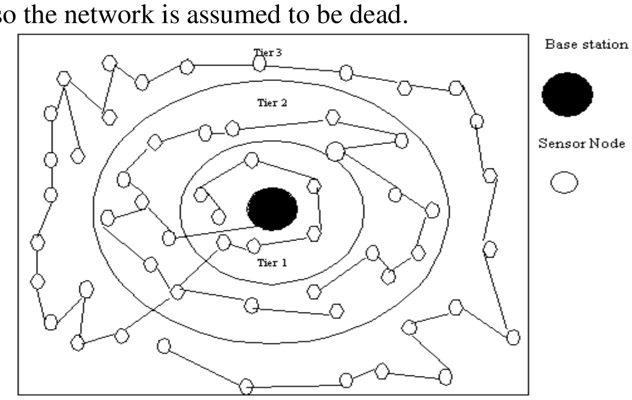

Figure 3. Proposed Architecture in top tier shifting approach

5. RESULTS

In order to evaluate the performance of MSMTP protocol, we simulated it on 100 node network. The simulations are done in c++. The BS is located at (0,-100) in a field of diameter 100m. We run the simulation to determine the round in which every node is died. Parameters used are same as that of [3]. Once a node dies it is considered dead for the rest of simulation, and our results shows much better system stable lifetime (period when all nodes of network are alive) because it balances energy dissipation among sensor nodes by using all nodes as cluster head with equal priority (highest energy node will serve as head node) thus maximizing stable life time & achieves better results than PEDAP.

Table 1. Timings of node deaths; base station is in the center.

Energy (J)	Protocol	FND	HND	LND
0.25	DIRECT	596	1147	4836
	LEACH	297	1247	2223
	PEGASIS	439	2259	2667
	PEDAP	1228	2334	4836
	MSMTP	821	1592	2825
0.5	DIRECT	1192	2293	9672
	LEACH	1036	2927	4362
	PEGASIS	774	4496	5175
	PEDAP	2455	4668	9672
	MSMTP	1642	3121	5368
1.0	DIRECT	2383	4586	19343
	LEACH	2627	5603	7747
	PEGASIS	1428	9036	10443
	PEDAP	4910	9336	19343
	MSMTP	3298	4884	10192

Table 2. Timings of node deaths; base station is distant from the field.

Energy (J)	Protocol	FND	HND	LND
0.25	DIRECT	61	104	223
	LEACH	60	255	632
	PEGASIS	184	1856	2190
	PEDAP	213	2135	2674
	MSMTP	625	1496	2117
0.5	DIRECT	121	208	445
	LEACH	123	661	2134
	PEGASIS	1070	3767	4344
	PEDAP	426	4271	5337
	MSMTP	1246	3095	4377
1.0	DIRECT	242	416	889
	LEACH	351	1983	3961
	PEGASIS	1332	7309	8536
	PEDAP	851	8544	10665
	MSMTP	2500	5380	8249

Table I and Table II summarize the results for two different base station locations and for three different initial energy levels in a network of diameter 100 m. as the table shows life time of the proposed system improves by 200% to 400% as compare to LEACH. In these tables, FND and

LND stand for the times at which the first and the last node die. HND stands for the time at which half of the nodes die, results of previous protocols in table is referred from [3].
Figure 4 shows the comparison graph between various protocols when base station is located in the center of the field and nodes are deployed with 0.5J as initial energy and shows when first, half and last node of the system is died, and figure 5 shows the results for the same network parameters except location of base station which is placed in the center of the field.

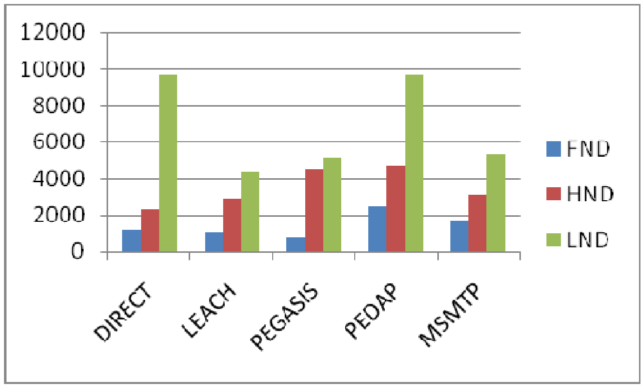

Figure 4. Timings of node deaths in a network of 100m diameter - The base station is in the center

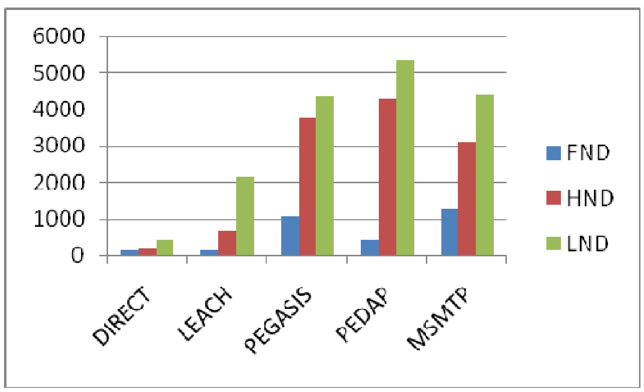

Figure 5. Timings of node deaths in a network of 100 m diameter- The base station is distant from the field

6. CONCLUSION AND FUTURE SCOPE

In this paper a routing strategy based on minimum spanning tree and tier formation of nodes is proposed, and through simulation system stable lifetime is proved to be better than existing protocols. Generation of minimum spanning tree in each round of communication tries to balance the load among the nodes. The distribution of load evenly to all nodes has a great impact on system stable lifetime.

In the presented work we have taken homogeneous WSN which is randomly deployed, some nodes are regularly used in communication becomes key nodes for transmission to BS as well as within the network. These nodes have short lifetime; our future work will be finding those key nodes and providing them extra energy so as to increase system lifetime.

REFERENCES

[1] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan,"Energyefficient communication protocol for wireless microsensor networks," in 33rd Annual Hawaii International Conference on System Sciences,2000, pp. 3005 – 3014.

[2] S. Lindsey and C. S. Raghavendra, "Pegasis: Power-efficient gathering in sensor information systems," in IEEE Aerospace Conference, March 2002, 924-955.

[3] HO. Tan, "Power efficient data gathering and aggregation in wireless sensor networks," SIGMOD Record, 2003, 32(4): 66 -71

[4] Xin Liu, Quanyu Wang and Xuliang Jin, "An Energy-efficient Routing Protocol for Wireless Sensor Networks", Proceedings of the 7th World Congress on Intelligent Control and Automation June 25 - 27, 2008, Chongqing, China, page 1728-1733.

[5] D. Estrin, R. Govindan, J. Heidemann, and Satish Kumar. Next Century Challenges: Scalable Coordination in Sensor Networks. In Proceedings of Mobicom' 99, 1999.

[6] J. Kulik, W. Rabiner, and H. Balakrishnan. Adaptive Protocols for Information Dissemination in Wireless Sensor Networks. In Proceedings of Mobicom' 99, 1999.

[7] W. Mangione-Smith and P.S. Ghang. A Low Power Medium Access Control Protocol for Portable Multi- Media Systems. In Proceedings 3rd Intl. Workshop on Mobile Multimedia Communications. Princeton, NJ, Sept. 25-27, 1996.

[8] K. M. Sivalingam, M. B. Srivastava and P. Agrawal. Low Power Link and Access Protocols for Wireless Multimedia Networks. In Proceedings IEEE Vehicular Technology Conference VTC'97, May 1997.

[9] M. Stemm, P. Gauthier, D. Harada and R. Katz. Reducing Power Consumption of Network Interfaces in Hand-Held Devices. In Proceedings 3rd Intl. Workshop on Mobile Multimedia Communications, Sept. 25-27, 1996, Princeton, NJ.

[10] T. S. Rappaport. Wireless Communications. Prentice-Hall, 1996.

[11] R. Steele. Mobile Radio Communications. Pentech Press, London, 1992.

[12] A. Manjeshwar, DP. Grawal, "TEEN: A protocol for enhanced efficiency in wireless sensor networks," In: Proceedings of the 15th Parallel and Distributed Processing Symposium. San Francisco: IEEE Computer Society, 2001. 2009_2015.

[13] Devendra prasad, Gaurav Bathla, "An Energy- efficient Routing Protocol for Homogeneous Wireless Sensor Networks", M R international journal of Engineering and Technology, Vol 2 No 2, December 2010.

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