Power Assignment Method for Wireless Sensor Networks

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Abstract

In this paper, we propose a local adaptive transmission power control method to improve the network connectivity and energy efficiency etc. for wireless sensor networks. Path loss exponent and energy control coefficient are studied carefully to show the minimum cover district of each node more accurately based on network environment and the application scenarios. Our proposed local adaptive power control method can also provide self-healing function which makes the network maintain the best performance for a long time when a few nodes exhaust their energy or a fresh batch of nodes are deployed. Simulation results show that our proposed method is very effective in establishing a good logical network structure and prolonging the network lifetime.

Keywords: *Power Assignment, Topology Control, Wireless Sensor Networks*

1. Introduction

A wireless sensor network (WSN) [1] is a kind of wireless network that consists of hundreds or thousands of randomly deployed static sensors. In a multi-hop and self-organized way, the sensors can monitor the physical environment such as temperature, sound, movement, etc. They cooperatively sense, process and transmit data, providing people with direct, real and effective information. To some extent, the physical world, information field and human society are therefore integrated.

The wireless sensor network is featured with large-scale deployment, dynamic topology, self-organization and so on. It is data-centric and application-oriented. The wireless sensor network can monitor wide areas while maintaining high precision. It is becoming increasingly useful in variety critical aspects, such as military field, environmental monitoring, agricultural technology, industrial manufacturing and medical care. It has broad application prospects.

Transmission power assignment (TPA) is an NP-completeness issue [2] for wireless sensor networks and it provides an effective solution to the network topology control. TPA can reduce node energy consumption and increase network capacity by carefully designing and coordinating nodes' transmission power.

The rest of this paper is organized as follows. Section 2 gives some related work about power assignment techniques. In Section 3, our proposed local adaptive power assignment approach is presented in detail with. Simulation results are presented in section 4 and section 5 concludes this paper.

2. Related Work

Paolo Santi organized these diverse strategies into two categories: homogeneous Critical Transmitting Range (CTR) and non-homogeneous topology control [3]. In the former case, all the network nodes must use the same transmitting range, and the topology control problem reduces to the simple problem of determining the minimum value of the transmitting range such that a certain network wide property is satisfied. In the latter case, nodes are allowed to choose different ranges.

The CTR for connectivity in stationary and mobile networks have been much investigated in past years, and it was found that determining the CTR for all the nodes in a distributed way is impossible [4]. Moreover, a few of isolated nodes can lead to a large CTR. As a result, the network performance is greatly reduced. In addition, in many scenarios, sensor nodes can change the transmit power level, then determining the transmit power level for every node to get a better network performance becomes preferred. This problem is known in the literature as the Range Assignment (RA) problem that was first studied by Kirousis et al. [5].

The RA problem can be tackled in a distributed manner, consequently it attracts much attention in recent years and some RA strategies are proposed erenow. Depending on the type of information that is used to compute the topology, RA strategies can be further classified into three categories: location based RA strategies, such as DRNG [6] and DLMST [7].

On the basis of the above analysis, this paper proposes a novel power control method named local adaptive transmit power assignment. It takes both the path loss exponent and the energy control coefficient into consideration in order to characterize the minimum cover district of each node more accurately and precisely according to network environment and application scenario of the network. Moreover, it provides a self-healing function that makes the network maintain the best performance for a long time when a few of the nodes exhaust their energy.

3. Our Proposed Local Adaptive Power Assignment Method

For every node u in the network, the operations are the same. A node in the network should mainly response to the following events.

(1) The placement finish event

The placement finish event can be trigger by a preset timer. When the timer expires, it means the deployment of the network is finished. And then each node in the network broadcasts a Hello message using the maximum transmit power, and the node ID and maximum transmit power should be contained in this message.

(2) The Hello message receive event

Upon receiving the Hello message, the node will compute the pass loss of the link and store it in the memory.

(3) The neighbor discovery finish event.

The neighbor discovery finish event can also be trigger by a preset timer. When the timer expires, it means the node has received the Hello message from all its physical neighbors. And then the node will compute a total order of all its physical neighbors according to pass loss of the links. In addition, the node should broadcast its computed order to all its physical neighbor nodes.

(4) The total order receive event.

Upon receiving the total order message, the node will store it in the memory. When the node has received total order from all its neighbor nodes, the node will select nodes from its physical neighbor set to form the logical neighbor set. For this purpose, a node u traverses according to the link quality in descending order.

(5) The logical structure establish event.

When the timer representing the logical structure establish event expires, each node will select a transmit power level which can just cover all the nodes which belong to its logical neighbor set.

(6) The logical neighbor set change event.

The logical neighbor set change event is usually caused by death of old nodes or deployment of fresh nodes. Of course, sometimes the mobility of the nodes can lead to a variation of the logical neighbor set too. When the logical neighbor set change event happens, the node should set a random back-off time. If the node receives a connect message before the back-off time expires, it accepts the connection invitation and then continues previous work. Otherwise, node decreases the energy control coefficient with a step of 0.1 and re-determines its logical neighbor set. It is repeated until the node's logical neighbor set increases or gets minimum value. Finally, the node broadcasts a connect message to its logical neighbors.

4. Simulation Results

We use OMNET++ platform to evaluate the performance of our proposed LA-TPA algorithm. In all the simulations, the nodes are randomly distributed in an 800m*500 m^2 rectangular area. The number of the sensors varies from 50 to 100. The radio transmission range corresponding to the maximum transmit power is 200m when the pass loss exponent is 2.

In this paper, we use the average node degree, the average local path hop and the average transmit power to evaluate the performance of topology control algorithms. In fact, the average node degree is the average number of nodes in the logical neighbor set. It can reflect the severity of the network's signal conflict, which have an influence on the network's throughput. The average local path hop is the average hop count for a node to transmit a packet to the sink node. It can not only reflect the energy consumption for a node, but also affects the transmit delay of the packet. It can be said that the topology with a smaller average local path hop has a better network performance. The average transmit power is vital for the energy efficiency and network capacity. It is measured by its corresponding transmit range in this paper. In addition, all data displayed below are average of 100 repeated simulations.

Next, we present a simulation study of our proposed local adaptive transmission power approach (LA-TPA) and XTC and STC [8] algorithms. STC algorithm is added as another comparison object here because it also takes the pass loss exponent into consideration.

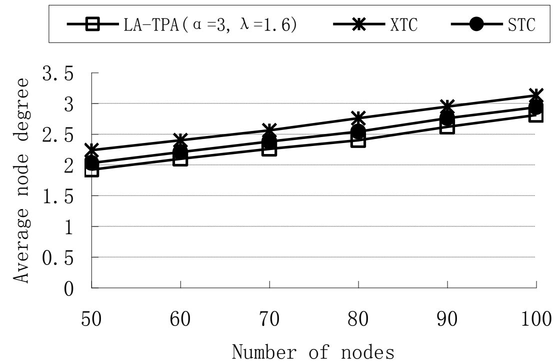

Figure 1. Comparision of the Average Node Degree

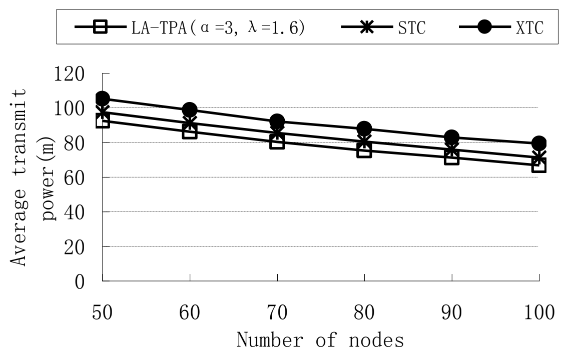

Figure 2. Comparision of the Average Transmit Power

Figure 1 and 2 show the average node degree and the average transmit power of the three algorithms mentioned above when the number of the nodes deployed in the rectangular area varies from 50 to 100.

We can see that the performance metrics of the target topologies constructed by the three algorithms just have a small deviation. Consequently, in order to demonstrate the superiority of the proposed algorithm, we give a comparison of an additional significant performance metrics, namely the maximum number of death nodes. The maximum number of death nodes is the threshold when the network becomes isolated just recently.

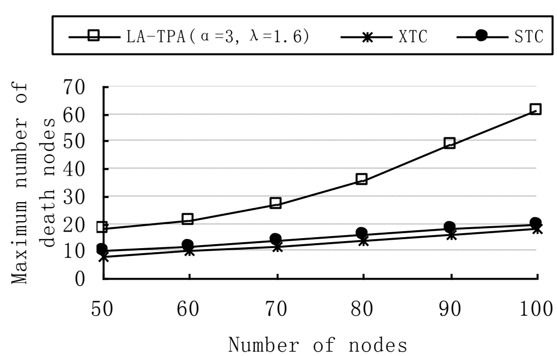

Figure 3. Comparision of the Maximum Number of Death Nodes

The maximum number of death nodes of the three algorithms is as Figure 3 shows. We can see that the LA-TPA algorithm can tolerate more death nodes than XTC and STC algorithms when the number of nodes in the network varies from 50 to 100. Moreover, the maximum number of death nodes corresponding to the LA-TPA algorithm increases more sharply than the other two algorithms. The maximum number of death nodes corresponding to the LA-TPA is about 60 when there are 100 nodes in the network, which is much larger than 20 and 18 corresponding to the STC and XTC separately. Consequently, we believe that our proposed novel LA-TPA approach can prolong the lifetime of the network effectively.

5. Conclusion

A local adaptive power assignment method is proposed in this paper. It takes the path loss exponent and energy control coefficient into consideration to characterize the minimum cover district of each node more accurately and precisely according to the network environment and the application scenario to achieve better performance. Moreover, it provides a self-healing function which makes the network maintain the best performance for a long time when a few of the nodes exhaust their energy

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References

[1] Akyildiz IF, Su W, Sankarasubramaniam Y and Cayirci E, “A survey on sensor networks”, IEEE Communications Magazine, vol. 40, no. 8, **(2002)**.

[2] Cheng X, Narahari B, Simha R, Cheng MX and Liu D, “Strong minimum energy topology in wireless sensor networks: NP-Completeness and heuristics”, IEEE transactions on mobile computing, vol. 2, no. 3, **(2003)**.

[3] Santi P (Editor), “Topology Control in Wireless Ad Hoc and Sensor Networks”, John Wiley and Sons, Chichester, UK **(2006)**.

[4] Narayanaswamy S, Kawadia V, Sreenivas R and Kumar P, “Power control in ad hoc networks: theory, architecture, algorithm and implementation of the compow protocol”, Proc. European Wireless, **(2002)** February 25-28; Florence, Italy.

[5] Kirousis L, Kranakis E, Krizanc D and Pelc A, “Power consumption in packet radio networks”, Theoretical Computer Science, vol. 243, **(2000)**.

[6] Li N and Hou JC, “Localized topology control algorithms for heterogeneous wireless networks”, IEEE/ACM Transactions on Networking, vol. 13, no. 6, **(2005)**.

[7] Li N and Hou JC, “Topology control in heterogeneous wireless networks: Problems and solutions”, Proc 13th Joint Conf on IEEE Computer and Communications Societies, **(2004)** March 7-11; Hong Kong, China.

[8] Sethu H and Gerety T, “A new distributed topology control algorithm for wireless environments with non-uniform path loss and multipath propagation”, Ad Hoc Networks, vol. 8, no. 3, **(2010)**.

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