Journal of Theoretical and Applied Information Technology
31st December 2012. Vol. 46 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

MULTI-BEAM ANTENNA-BASED TOPOLOGY CONTROL ALGORITHM IN AD HOC NETWORKS

[1]NING YE, [2]QIAN SUN, [3]HAILONG WANG, [4]GENG YU

[1]College of Information Science and Engineering, Northeastern University, Shenyang, China

[2]Liaocheng Branch of China Unicom Network Communications Company, Shenyang, China

[3]Shenyang Aerospace University, Shenyang, China

Email: [1]liujun@ise.neu.edu.cn , [2]sunqian19891108@126.com ,

[3]yn265@126.com , [4]yug@sau.edu.cn

ABSTRACT

Multi-beam antenna is drawing attention due to its power-saving and interference-reducing. A topology control algorithm K-DRNG based on multi-beam antenna in heterogeneous wireless Ad Hoc network is proposed. The algorithm is mainly composed of three phases. In the stage of information collection, each node collects information of neighborhood by adjusting the transmitting power and controlling sector conversion. In the stage of topology construction, each node constructs directed relative neighborhood graph according to link weighs. In the stage of topology optimization, each node constructs subgragh of initial topology and adds or deletes directional links with neighborhood to guarantee bi-directional connectivity of topology. The simulation results show the proposed algorithm can reduce the average energy consumption of nodes, increase the spatial reuse of radio resource, thus improve integral network performance.

Keywords: *Ad Hoc Networks; Topology Control; Multi-Beam Antenna; Heterogeneous; NS2*

1. INTRODUCTION

The characteristics of wireless Ad Hoc network consist of heterogeneous nodes, limited resource, self-organization, dynamic topology, narrow transmission bandwidth etc, which make network performance closely related to network topology [1, -4]. Reasonable network topology can not only ensure end-to-end conmmunication, but also provide underlying transmission platform for the upper layer protocol. Thus, network topology can create the conditions for improving network performance. Recently, directional antennas is drawing attention , it can increase network capacity, reduce delay, lower energy cost. Based on these benefits, topology control using directional antenna gradually becomes a research hotspot , and more and more algorithms based on directional antenna are proposed.

2. RELATED WORKS

So far, most existing topology control algorithms assume that nodes use omni-directional antenna, such as RNG, GG, YG, DRNG [5, 6] and so on. With the development of directional antenna, topology control algorithms based on directional antenna are gradually increasing. The algorithm TCDPI based on multi-beam antenna proposed in [7] controls topology by reducing the power intensity directionally, resulting in saving power and reducing hop counts; The distributed algorithm DABTC based on multi-beam antenna proposed in [8] controls topology by controlling node transmitting power and changing the antenna direction. In addition, there are some other methods, such as CMPGA[9], SLTC[10], SLTC-E. In this paper, a distributed multi-beam antenna-based topology control algorithm K-DRNG is proposed; the algorithm can reduce the average energy consumption of nodes and increase the spatial reuse of radio resource.

3. TOPOLOGY CONTROL ALGORITHM

Information Collection. Due to the uneven distribution of nodes, network is divided into different regions depending on node density. Each region separately computes K value which can ensurethe network connectivity based on theorem

Journal of Theoretical and Applied Information Technology
31st December 2012. Vol. 46 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

1[11]. Then each node collects information from neighborhood by adjusting transmitting power and controlling sector conversion, and ultimately constructs the initial topology G.

Theorem 1: Let n represents node density, let G(n, k) be asymptotically connected, $\Theta(\log n)$ neighbors are necessary and sufficient. Specifically, there are two constants $0<c_1<c_2$ such that:

$$\lim_{n\to\infty} P\{G(n, c_1 \log n) \quad is \quad not \quad connected\}=1 \tag{1}$$

and

$$\lim_{n\to\infty} P\{G(n, c_2 \log n) \quad is \quad connected\}=1 \tag{2}$$

Information collection process is as follow:

Step 1: Each node sets initial transmitting power P(u)=ε;

Step 2: Each node sets N (N≥K) empty sectors of multi-beam antenna;

Step 3: Each node gradually increases transmitting power and randomly sends Hello messages to certain sector, and simultaneously collects ACK messages from other nodes. If node u finds a new node v, it will conserve node v into local neighbor set Ne (u) and mark the sector covering node v as a non-empty sector. Afterwards, stop searching in this sector;

Step 4: Convert the antenna sector and continue to repeat step 3. When Ne (u)=K or P(u)= $P(u)_{max}$, the algorithm is terminated.

Topology Construction. On the basis of the initial topology G, each node further reduces the number of neighborhood according to link weighs and then constructs directed relative neighborhood graph G_0.

1) Define link weight

In order to improve link reliability and lower bite error rate, each link is weighted by link quality indicator (LQI) which represents the ability to receive data frame. LQI can be expressed by equation (3),

$$LQI = \min \begin{cases} (P_r / P_{rt}) \times 128 \\ (P_r / P_{rs}) \times 255 \end{cases} . \tag{3}$$

Where Pr stands for receiving power, Prt is receiving power threshold, Prs is defined as the sum of the received power in current channel. Given two links (u_1, u_1) and (u_2, v_2), link weights are donated by w (u_1, v_1) and w (u_2, v_2). If LQI (u_1, u_1)>LQI (u_2, v_2), then we can judge w (u_1, v_1)>w (u_2, v_2).

2) Construct directed relative neighborhood graph

Node v is a neighbor of node u in topology G if there does not exist a third node p which is a neighbor of node u such that *w(u,p)<w(u,v) and w(p,v)<w(u,v), d(p,v)*$\leq R_p$; otherwise, node v is not a neighbor of node u. As shown in Figure 1, node v is not a neighbor because of node p while node q is a neighbor.

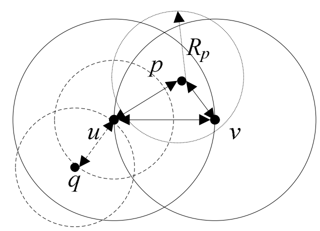
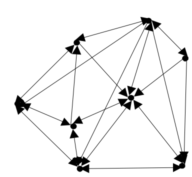


Figure 1 Schematic Chart Of Constructing Directed Relative Neighbor Graph

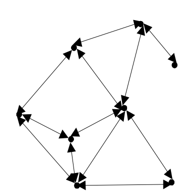
Topology Optimization. To ensure the bi-directional connectivity of heterogeneous wireless Ad Hoc network, topology optimization is performed.

1) Construct the subgragh G' of initial topology G

Given two nodes u and v, the distance between them is denoted by d. When $d\leq R_u$ and $d\leq R_v$, link (u, v) should be added to topology G'. As a result, bi-directional and connected topology is generated. Figure2 illustrates the process, the optimal subgragh G' (Figure2 (b)) of initial topology G (Figure 2(a)) is bi-directional and connected.



(A) Initial Topology G



(B) Topology Subgragh G'

Figure 2 Construction Of Original Topology Subgraph

Journal of Theoretical and Applied Information Technology
31st December 2012. Vol. 46 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

2) Adding or removing directional links

For the region where node density is larger (K value is larger), in order to enhance network capacity, removal mechanism is employed to preserve bi-directional connectivity. For the region where node density is smaller (K value is smaller), in order to void parting network, addition mechanism is employed to preserve bidirectional connectivity.

4. PERFORMANCE ANALYSIS

We use network simulator NS2 to measure the performance of our algorithm. We simulate a system of 16 nodes in accordance with random distribution of the non-uniform probability density on 750×750m^2 area. A source node selects its destination randomly and sends CBR traffic through UDP. Each packet carries 512 bytes of data payload. Communication radius changes randomly in [250m, 300m]. Multi-beam or omni-directional antennas are configured for nodes.

4.1 Node Average Energy Consumption

It is shown in Figure3 that compared with the other two algorithms using omni-directional antenna, the average energy consumption of network is the smallest under the control of K-DRNG algorithm, which means energy consumption of transmitting information can be effectively saved. Firstly, multi-beam antenna is applied to save transmitting power by changing sector directions. Secondly, the proper topology control reduces the number of neighbors, leading to transmitting power further reduced. Therefore, the proposed algorithm lowers significantly average energy consumption, thus enhances network survivability.

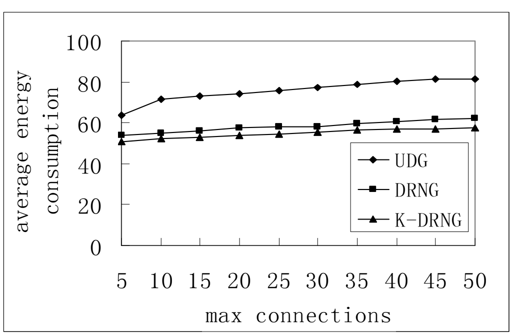


Figure 3 Compare Of Average Energy Cost Vs. Max Connections

4.2 Delivery Delay

Figure4 reflects that delivery delay changes with max connections. When max connections is smaller, delivery delay under the control of K-DRNG algorithm is the maximum. The simplification of the network topology reduces communication radius and increases transmission hop counts, leading to the increase of delivery delay. With the max connections increasing, the delivery delay with the use of K-DRNG algorithm is less than that under UDG and DRNG algorithm. It is because that the proposed algorithm makes use of sector conversion mechanism to reduce communication interference, which can decrease the collisions and the probability of retransmission in packet transmission. Additionally, topology control effectively simplifies the dense topology and improves the performance of delay.

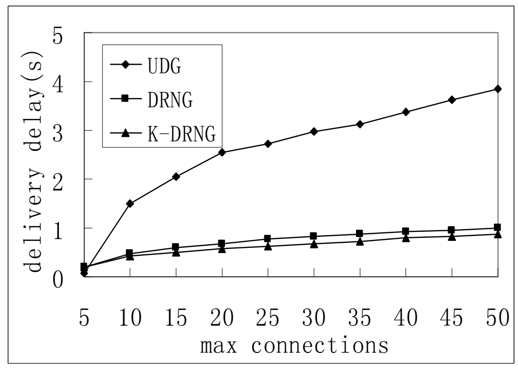


Figure 4 Compare Of Delay Vs. Max Connections

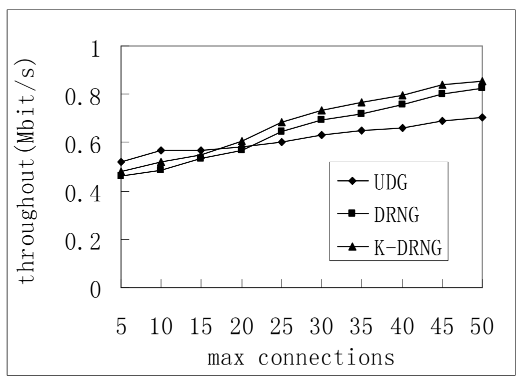


Figure 5 Compare Of Throughput Vs. Max Connections

4.3 Network Throughput

Figure5 shows the comparison of network throughput in various max connections. The results indicate that the proposed algorithm can enhance network throughput when network load is heavier. Due to the use of multi-beam antenna, signal interference can be decreased to a large extent and hence the efficiency of the channel utilization is improved. Besides, the reduction of neighborhood

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

after topology control is of great significance for enhancing network throughput.

What's more, compared with other exsiting algorithms, such as DABTC, CMPGA, SLTC, SLTC-E, the proposed algorithm K-DRNG is better than them. Because the K-DRNG algorithm not only uses directional antenna to reduce interference, but also makes use of the DRNG rule to further reduce the neighbor nodes. Both of ways make contributions to improve network performance.

5. CONCLUSION

Based on the characteristics of wireless Ad Hoc network, we proposed a multi-beam antenna-based topology control algorithm K-DRNG. Nodes firstly collect information by adjusting the transmitting power and controlling sector conversion, and then nodes construct directed relative neighborhood graph on the basis of link weighs, and finally network topology is further optimized. Simulation results demonstrate the algorithm can save energy consumption, increase the spatial reuse, and thus improve network performance. In future work, we will consider the impact of node mobility and failure , thus further optimize network performance.

REFERENCES

[1] Paolo Santi, Topology control in wireless ad hoc and sensor networks, ACM Computing Surveys. 37 (2005) 164-194.

[2] Tao Zhang, Kun Yang, Hsiao-hwa Chen, Topology control for service-oriented wireless mesh networks, IEEE Wireless Communications. 16 (2009) 64-71.

[3] Kejie Lu, Tao Zhang, Yi Qian, Shengli Fu, A Novel Topology Control Scheme for Future Wireless Mesh Networks, IEEE GLOBECOM. 12 (2008) 1–5.

[4] Milner S, Llorca J, Davis C, Autonomous reconfiguration and control in directional mobile ad hoc networks, IEEE Circuits and Systems Magazine. 16 (2009) 10–26.

[5] Jeng, A A K, R H Jan, The r-neighborhood gragh: an adjustable structure for topology control in wireless ad hoc networks, Journals & Magazines. 18 (2007) 536-549.

[6] Ning Li, Jennifer C, Localized topology control algorithms for heterogeneous wireless networks, IEEE/ACM Transactions on Networking. 13 (2005) 1313-1324.

[7] Zhuochuan Huang, Chien-Chung Shen, Multi-beam antenna-based topology control with directional power intensity for ad hoc networks, IEEE Transactions on Mobile Computing. 5 (2006) 508-517.

[8] He peng, Li Jian-dong, Cheng Yan-hui, Distributed topology tontrol algorithm for ad hoc network using directional antennas, Journal of Software. 18 (2007) 1308-1318.

[9] Namboodiri V, Gao L X, Janaswamy R, Power efficient topology control for wireless networks with switched beam directional antennas, IEEE International Conference on Mobile Ad Hoc and Sensor System. 32 (2005) 3-11.

[10] Lu Xiao-ling, Research on topology control algorithm for ad hoc network using beam directional antennas. Hunan, Hunan University, 2010.

[11] Xue F, Kumar P R, The number of neighbors needed for connectivity of wireless networks, Wireless Networks. 10 (2004) 169-181.