Optimization Study of the Contention Window in 802.11 DCF

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Abstract—**This paper first introduces the basic principle of IEEE 802.11 DCF and analyses the effect of the two system parameters, network size and minimize contention window, on the performance in terms of saturation throughput and probability of collisions. To overcome the shortcomings of the original 802.11DCF, the influence of the contention window's size was analyzed. 802.11DCF-SD (Success Decrease) method was proposed on the basis of the analytical results. This paper discusses the improved performance from two aspects -- saturation throughput and collision probability. Results indicate that the performance of 802.11 DCF-SD is much better than that of Barakat C's method, especially the collision probability which has been significantly reduced and maintained at a lower level. Meanwhile we discuss the impact of a continuous number N' of successful transmissions on the network performance before the contention window size has dropped by half. Experiments show that the overall performance of the network is optimal when N' takes the value of ten.**

Keywords-DCF; Contention Window; Network Size; Throughput

I. INTRODUCTION

With the development of communication technology, IEEE 802.11 [1] wireless local area networks have been widely used in campuses, shopping malls, companies, coffee shops, etc. Wireless local area networks have the advantages of being wireless and are easy to setup. However, compared with the wired network, there are many factors that can affect the performance of a wireless local area network, such as transmission medium in the physical layer and the access protocol of the MAC layer. The 802.11 MAC layer protocol is of significant importance in the performance of a wireless local area network. Therefore, in-depth studies are needed to improve the performance of the 802.11 MAC layer protocol.

The role of the MAC layer in wireless local area network is to provide effective scheduling mechanism to share limited resources in the radio channel. In the 802.11 protocol, there are two methods: distributed coordination function (DCF) and point coordination function (PCF). IEEE802.11DCF is the fundamental mechanism to share channel.

Currently, studies of the IEEE802.11DCF protocol start with the following two aspects: (1)[2-3] either propose a reasonable assumption, establish a two dimensional discrete Markov chain model, derive a formula for throughput and thus reflect the changes of the performance of the network; or (2)[4-6] make appropriate improvement of the binary exponential back-off (BEB) mechanism based on the primitive IEEE802.11DCF, and thus improve the performance of the network. In the 802.11DCF, the contention window (CW) will be reset as $CW_{\min}$ after a successful transmission or reach the retry limit. Some scholars, such as Barakat C[11] and Bharghavan V[12], think that a successful transmission cannot ensure a reduction in the collision probability, therefore, we should not reset the CW as the minimum.

Thus, they provide a mechanism for a slow decrease in CW, that is, CW will not reset to the minimum, but slowly decrease to the minimum based on a certain algorithm after a successful transmission. In Barakat C's opinion, CW should be reduced by a factor of 2^{-g} , that is to say, the contention **w**indow becomes $2^{-g} \cdot W_i$ after a successful transmission.

In this paper, an improved method 802.11 DCF-SD is provided based on Barakat C's paper. Our improved method is simple to control and easy to implement.

II. EFFECT OF SYSTEM PARAMETERS ON THE PERFORMANCE

A. System Parameters

In the IEEE 802.11 protocol, the method of collision avoidance is carrier sense in the PHY layer and virtual carrier sense; the BEB algorithm is used to adjust CW to solve the problem of collision.

Next, we explain the effect of system parameters on the network performance through experiments. Here we use the system parameters of IEEE 802.11, as shown in Table 1.We choose a simulation scene of 200m*200m and place nodes in the scene. Among all the nodes, there are g nodes that can establish an effective connection. The data transmission speed of the nodes is 1Mbps.

TABLE I. SYSTEM PARAMETERS OF IEEE 802.11

Packet Payload(bits)	8184	SIFS (μs)	28
MAC Header (bits)	272	DIFS (μs)	128
PHY Header	128	σ(μs)	1
ACK (bits)	240	δ(μs)	1
RTS (bits)	288	CTS (bits)	240

B. Data Analysis Results

Figs.1 and 2 show that the throughput of the network gradually descends as the number of the nodes in the network increases. The main reason for the descent of the throughput is the increase in the collision probability and retransmission number caused by the increased number of nodes. Thus, the number of effective transmissions in unit time has been reduced and the throughput has descended.

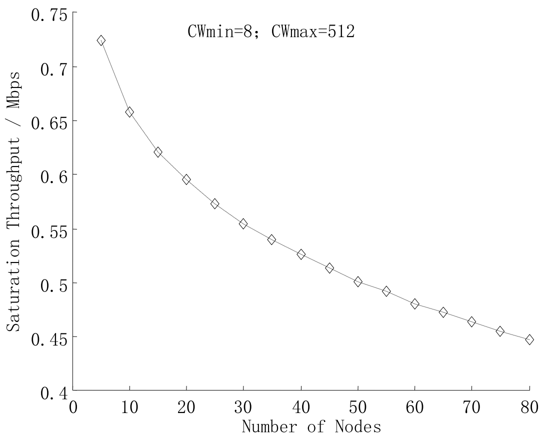

Fig.1 Impact of Number of Nodes on Throughput

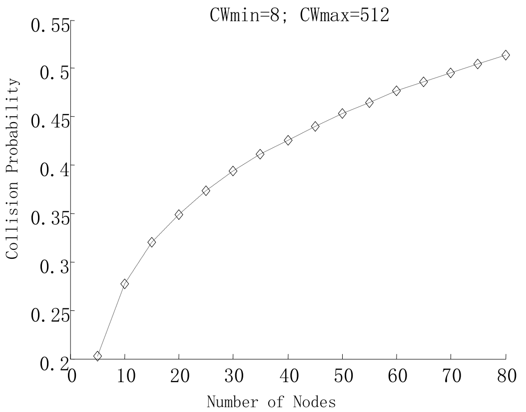

Fig.2 Impact of Number of Nodes on Collision Probability

Because the size of the contention window directly affects how rapidly nodes can access a channel, the size of the contention window plays a vital role on network performance.

Figs.3 shows that when the number of nodes is small, the throughput increases gradually, up to a maximum, and then gradually decreases along with the increasing of the size of contention window. In the process of changing the CW, if the contention window is small, throughput is small due to the magnitude of the collision probability. If the contention window is large, throughput is small because the idle time is too long. Therefore, in order to improve the network performance, the size of the contention window should take the appropriate value. When the number of nodes is large, and if the contention window is small then collisions happen frequently. When the contention window is large, the collision probability is small and the throughput is large.

Therefore, in order to effectively reduce the number of collisions and improve the network performance, the size of contention window should take a large value.

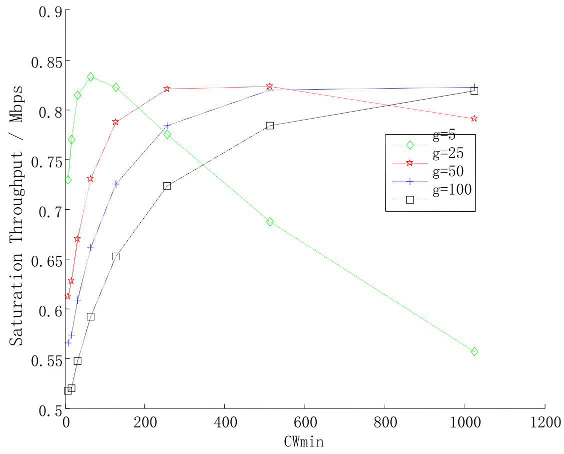

Fig.3 Impact of Size of CW on Throughput

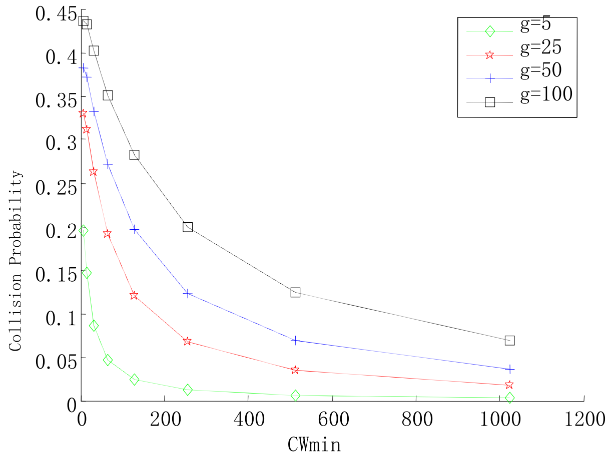

Fig.4 Impact of Size of CW on Collision Probability

III. 802.11DCF-SD

Fig.4 shows that it prone to collision when the number of nodes is large (g=100) and the minimum contention window is 8($g > CW_{min}$), thus lead to the decrease of the throughput and the degradation of network performance. To solve this problem, Barakat C has provided an improvement method, in which the contention window doubles in the back-off process and halves immediately after transmitting a data frame successfully. This method improves the network performance to a certain extent. However, we found that the network performance can be further improved. To this end, we propose 802.11DCF-SD.

The change of contention window in the mechanism of 802.11DCF-SD is illustrated in Fig.5. The specific process of window adjustment is as follows:

- Idle back-off: The back-off time counter is decremented as long as the channel is sensed idle. The node transmits when the back-off time counter reaches zero;

- Successfully send: When the transmitting node receives the ACK transmitted by the destination node, the node does not change the contention window CW to the minimum immediately, but count the number of the consecutive sent successfully N in a counter unit. If the N reaches a fixed value N', contention window will be halved. Otherwise, contention window will continue to maintain the original size. Actually, when $N^{'}=1$, this is the method in the article of Barakat C, in which contention window halves immediately after transmitting a data frame successfully;
- Node collision: When the data frames happen to collision, the contention window CW are doubled and the back-off time counter is uniformly chosen in the range of $(0, CW_{i+1})$. Here, the consecutive sent successfully N will be set as zero. In addition, when the node reaches the maximum number of retransmissions, if still a collision, the data frame will be dropped, at the same time, the contention window will be set to the minimum value $CW_{\min}$.

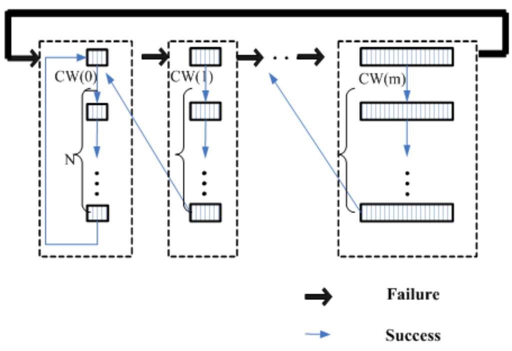

Fig.5 Change Process of CW in 802.11DCF-SD

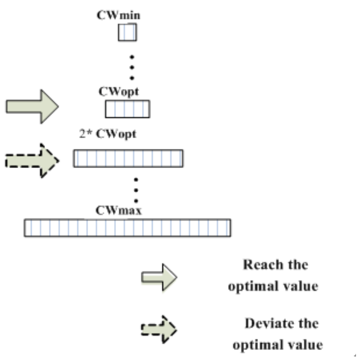

Fig.6 Process of Finding the Optimal CW in 802.11DCF-SD

IV. Simulation Analysis Results

Through the above description about the process of window adjustment, we can see 802.11DCF-SD as a search process for the optimal contention window, as shown in Fig. 6. Compared with Barakat C's method, the advantage of IEEE 802.11 DCF-SD is that the contention window can approach the optimal contention window gradually and remain unchanged at the value for consecutive times $N^{'}$. As thus, network performance is improved.

Here, we run simulation about the window adjustment mechanism performance of 802.11DCF-SD, which is proposed above. We chose the simulation scene of 200m*200m and set nodes in the scene. Among all the nodes, there have g nodes can set up effective connection. The data transmission speed of nodes is 1Mbps. The simulation results are shown below:

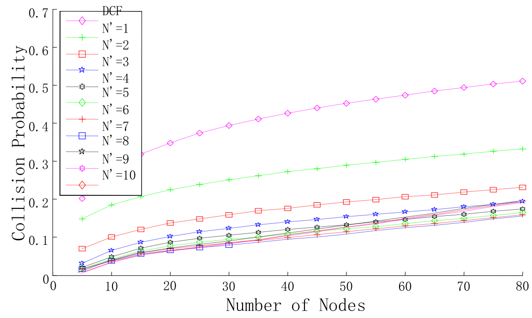

Fig.7 Change of Collision Probability in 802.11DCF-SD ($N' \in [2,10]$)

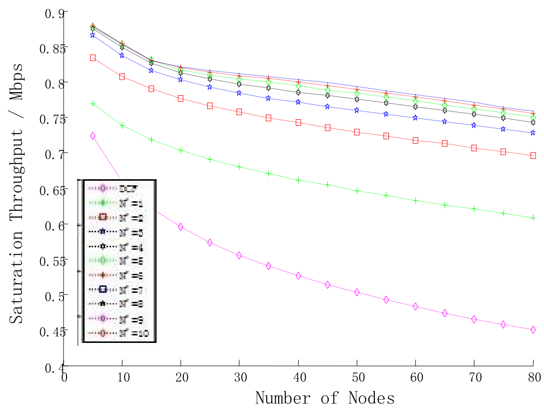

Fig.8 Change of Saturation Throughput in 802.11DCF-SD ($N' \in [2,10]$)

From the Fig.7, when the value N' is small ($N' \in [2,10]$), with the increase of the number of nodes, collision probability of the network showing a gradually increasing trend. But compared with the original 802.11 DCF and Barakat C, as N increases, the collision probability of network decreases gradually, followed by the collision delay reduces gradually.

From the Fig.8, when the value $N^{'}$ is small ($N' \in [2,10]$), with the increase of the number of nodes, saturation throughput of the network reduces gradually. But compared with the original 802.11 DCF and Barakat C, the saturation throughput performance of 802.11 DCF-SD has improved greatly. In addition, when the value $N^{'}$ in the range [2, 10], as N increases, the saturation throughput performance showing a gradually increasing trend, which is mainly because of the great decline of the collision probability of network. However, as $N^{'}$ increases, the change between adjacent curves is more and more small. If increase $N^{'}$ further, we got another group of curves as shown in Figs.9 and 10.

From the Fig.9, when the value $N^{'}$ is large ($N' \in [10,50]$), with the increase of the number of nodes, collision probability of the network increases gradually. As N increases, the collision probabilities of the adjacent curves change little, and overall tend to a fixed value. But from Fig.10, we can easily found that there is a crossover point in the curves. That is, when the number of nodes is small, the smaller the value $N^{'}$ is, the greater the saturation throughput is. This is not consistent with the results we obtained when the value $N^{'}$ is small.

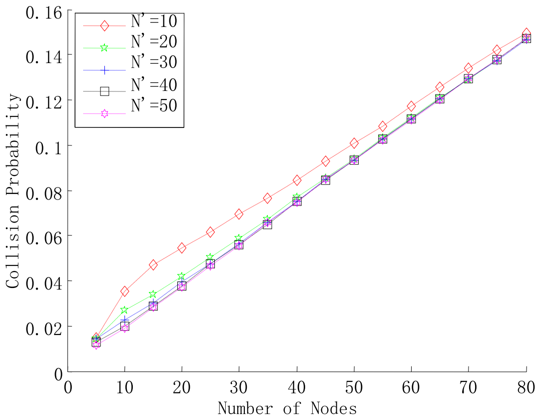

Fig.9 Change of Collision Probability in 802.11DCF-SD ($N' \in [10,50]$)

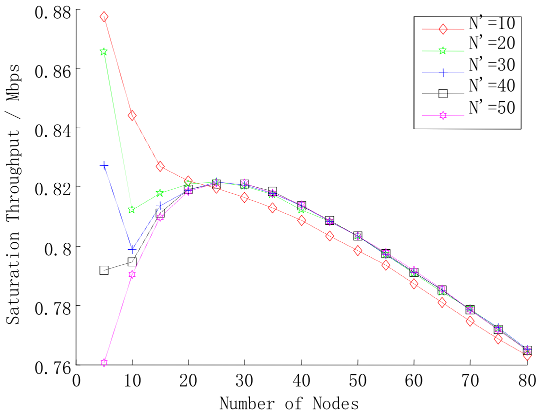

Fig.10 Change of Saturation Throughput in 802.11DCF-SD ($N' \in [10,50]$)

In this connection, we run simulation specifically about the network performance when the number of nodes ranges from 2 to 30. From Fig.12, when the number of nodes is 23, the throughput of network has a crossover point. Accordingly, we can divide the network into large-size and small-size network. When the number of nodes is less than 23, the network is called as the small-size network; when the number of nodes is greater than or equal to 23, the network known as the large-size network.

Then, we analyze another reason caused changes in network throughput: average access time. From the curves of the average access time (Fig. 13), in small-size networks, when the value $N^{'}$ is large ($N' \in [10,50]$), as $N^{'}$ increases, the collision probability changes little, but the average access time increases gradually. Therefore, the average access time is the main factor to affect the network throughput reduced.

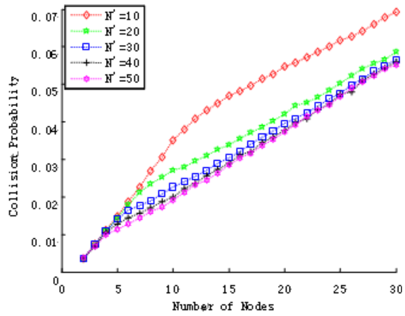

Fig.11 Change of Collision Probability ($g \in [2,30]$)

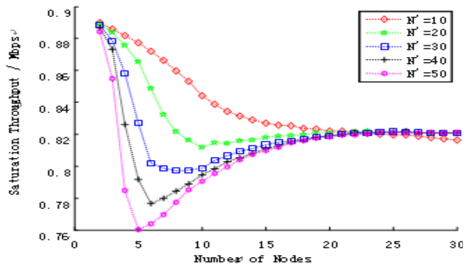

Fig.12 Change of Saturation Throughput ($g \in [2,30]$)

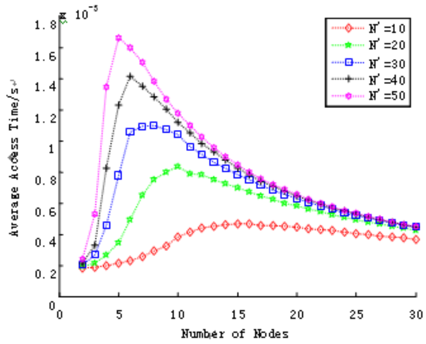

Fig.13 Change of Average Access Time ($g \in [2,30]$)

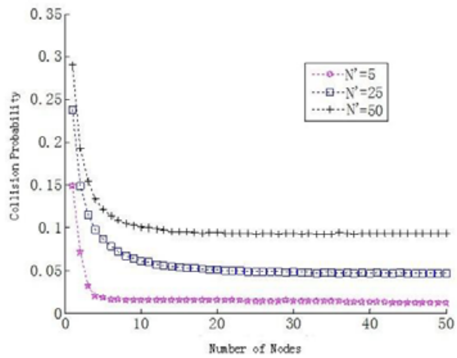

Fig.14 Impact of $N^{'}$ on Collision Probability

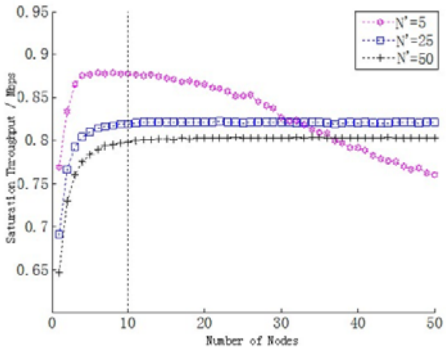

Fig.15 Impact of $N^{'}$ on Saturation Throughput

For different networks, select g for 5, 25 and 50, consider the change of network performance in the case of different values of $N^{'}$. Figs.7, 9 and 14 show that as the increase of the value $N^{'}$, the collision probability of the network of large-size and small-size gradually decrease, the collision delay also decreases gradually. But from Figs.8, 9 and 15, we can see that the saturation throughput of small-size network approaches the maximum value when $N^{'}=10$, and the throughput decrease gradually when $N^{'}>10$. Similarly, the saturation throughput of large-size network approaches the maximum value when $N^{'}=10$, and the throughput changes little when $N^{'}>10$. In summary, considering various performance indicators of network, the continuous number of successful transmission N' takes 10 as the optimal value in 802.11DCF-SD. We can also from another aspect to understand why the value of $N^{'}$ is not better if it is bigger. This is because when the value of $N^{'}$ is too large, once happen to collision at the optimal contention window, the contention window will take a long time to approach the optimal value, thus affecting the throughput of network.

V. CONCLUSION

In this paper, we have evaluated the impact of the system parameters on performance in wireless network. From the experimental results, we can see that the collision probability increases and the throughput decreases gradually with the increase of the number of network nodes. In 802.11DCF, the back-off mechanism does not take the impact of the number of nodes on the network performance into account, but use a fixed minimum contention window. Therefore, in small-size network, with the increase of the minimum contention window, the throughput of network is a parabolic curve; in large-size network, with the increase of the minimum contention window, the throughput of network increase gradually.

Aimed to overcome the deficiency of the original method, we propose the improvement measure 802.11DCF-SD. We also make analysis about the change process of the size of contention window and the performance optimization. It can be seen in the detailed analysis of 802.11 DCF-SD that the method is better because of its collision probability has been greatly reduced and maintained at a lower value. In addition, we evaluate the impact of the continuous number $N^{'}$ of successful transmission before the CW backward on the network performance and conclude that the network performance achieve optimal when $N^{'}=10$.

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REFERENCES

[1] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification[S]. IEEE 802.11-1997.pp70-97.

[2] G. Bianchi. Performance analysis of IEEE 802.11 distributed coordination functions[J]. IEEE J.Sel.Areas Commun.2000,18(3):535-547.

[3] K. Ghaboosi, B. Khalaj, Y. Xiao, and M. Latva-aho. Modeling IEEE 802.11 DCF using parallel spacetime Markov chain[J]. IEEE Trans. Veh. Technol., 2008,57(4): 2404-2413.

[4] H. Wu, Y. Peng, K. Long, S. Cheng, and J. Ma. Performance of reliable transport protocol over IEEE 802.11 wireless LAN: analysis and enhancement[J]. Proc. IEEE International Conference on Computer Communications , New York, 2002, 599-607.

[5] LI H W, WU J P, MA H,et al.. Performance optimization for IEEE 802.11 based on The range of contention station number[J].Journal of Software,2004,15:1850-1859.

[6] Li Y, Ji H. et al.. A New Cooperative Communication MAC Strategy for Wireless Ad Hoc Network [C].Proceedings of IEEE International Conference on Computer and Information Science, Melbourne, Australia,2007,4:569-574.

[7] Holloway, R. ,Beyah, R., Covert DCF: A DCF-Based Covert Timing Channel in 802.11 Networks[C]. Mobile Adhoc and Sensor Systems (MASS), USA ,2011,570-579.

[8] Simo Reigadas, J., Ramos-Lopez, J., Seoane-Pascual, J. et al..Modeling and Optimizing IEEE 802.11 DCF for Long-Distance Links[J]. IEEE TRANSACTIONS ON MOBILE COMPUTING, 2010,9(6):881-896.

[9] Qinglin Zhao,Tsang, D.H.K., Sakurai, T. et al.. Modeling Nonsaturated IEEE 802.11 DCF Networks Utilizing an Arbitrary Buffer Size[J].IEEE TRANSACTIONS ON MOBILE COMPUT-ING, 2011,10(9):1248-1263.

[10] Sugimoto, T., Komuro, N. , Sekiya, H. , Sakata, S. ,Yagyu, K. et al.. Maximum throughput analysis for RTS/CTS-used IEEE 802.11 DCF in wireless multi-hop networks[C]. Computer and Communication Engineering (ICCCE), Japan, 2010:1-6.

[11] Ni Q, Aad I, Barakat C et al.. Modeling and analysis of slow CW decrease for IEEE 802.11 WLAN[C].Proc of IEEE PIMRC, France,2003,2:1717-1721.

[12] Bharghavan V, Demers A, Shenker S et al.. MACAW:a media access protocol for wireless LANs [C].Proc of the Conference on Communications Architectures,Protocols and Applications, ACM, 1994.