Contention Window Size Adjustment in Unsaturated IEEE 802.11 WLANs

Chun-Hsien Sung[1(✉)] and Der-Jiunn Deng[2]

[1] School of Civil and Commercial Law, Beijing Institute of Technology,
Zhuhai, China
scotsung@gmail.com
[2] Department of Computer Science and Information Engineering,
National Changhua University of Education, Changhua, Taiwan
djdeng@cc.ncue.edu.tw

Abstract. In next generation mobile networks, more and more throughput of network is required under the dense environment. There are some researches discuss how to solve the predicament of throughput. But they usually analyze it under the saturated environment. Most of their contention window size are also not optimal to fetch the maximum throughput. This paper is the first one to fetch the fixed optimal window size under the unsaturated environment which is closer to the real network. It is based on the Distributed Coordination Function (DCF) in Medium Access Control layer of IEEE 802.11 Wireless LAN to control the contention window size for reducing the collision problem and improving the throughput. A simplified one-dimension Markov Chain with a new idle state is proposed to simulate the unsaturated model. Then the formula of transmission probability under the unsaturated model and the equation which is used to fetch the optimized contention window size are analyzed. Comparing with the related analysis model in the simulation of the throughput and the collision rate. The result shows that the proposed model under unsaturated environment is better than before.

Keywords: IEEE 802.11 · Optimal contention window · Dense environment
Collision rate

1 Introduction

The international standard IEEE 802.11 for Wireless Local Area Networks (WLANs) has been proposed [1] in 1985. This standard describes the physical layer (PHY) and medium access control sub-layer (MAC) specification for wireless connectivity which the nodes is fixed and movable in a local area. It has experienced tremendous growth with the proliferation of IEEE 802.11 devices in the last ten years. The IEEE 802.11 standard also experienced a number of amendments to improve. Recently, IEEE started a task group to investigate and deliver the technologies for the scenarios of dense networks with a large number of nodes and access point. In the previous amendments,

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they always focus on the higher speed physical layer (PHY) transmission. They emphasized increasing the link throughput, rather than efficient use of diverse. But in the scenarios of dense networks, the interference from neighboring devices will increase and there are severe collisions from channel contention. It will give rise to network performance degradation drastically and cause the whole networks disabled. From past experience, we found that the value of theoretical maximum throughput on the physical layer could not effectively reflect on the MAC layer. Therefore, the new 802.11ax amendment not only focuses on improving providing 4x the throughput of 802.11ac, it but also hopes to improve the metrics reflect the user experience. Unlike previous amendments, it measured the average throughput per node at the MAC data service access point. So we want to ameliorate the algorithm of the MAC layer to improve performance. Improvements will be made to support dense environments such as outdoor hotspot and stadiums [2]. In IEEE 802.11 standard, the backoff parameters of its collision avoidance mechanism is very inefficient. There are many ways to solve it; one of them is by appropriately tuning the contention window size and backoff algorithm.

In the past, there have many research literatures to study how to adjust the contention window size for the maximize throughput. But most of their analysis are not based on the optimal contention window size. They cannot effectively maximizes the throughput. And the other part of the analysis literatures are under the saturated environment. In the real network, the traffic is heterogeneous traffic. It is more like an unsaturated environment. The models they proposed can't be valid in real 802.11 WLANs. Hsiao's thesis [3] is the only one who has both these two characteristics. However, it is a pity that he did not complete the simulation. In this thesis, our contribution is to propose a one-dimensional model as unsaturated traffic model and compute the optimization of contention window size. Our thesis is the first one to fetch the maximize throughput under the unsaturated environment by the optimal contention window size.

2 Difficulties for Legacy 802.11 in Dense Environments

With the popularization of the Internet, people use the Internet has become increasingly frequent. More and more number of nodes connected to the Internet at the same time; the network has become a dense environment. When the network is congested, a node operating under the IEEE 802.11. And it will cause great challenges for the algorithm. From past experience we have learned that CSMA/CA and BEB algorithm generate some problems when running on the actual network. We will describe each of these issues below.

2.1 The Collision Problem

The first one is the collision problem. To begin with, after the successful transmission, the contention window size will set back to the initial value *CWmin*. It leads to a high probability of collisions when the next frame to be sent, then repeat retransmission collision problems will constantly occur. In order to successfully transfer, the small contention window size may have to take a long time to grow. But it is not fair to the large contention window size, too. Not only because of the large window size which is generated from previously failed many times spent a lot of time, but it also waits for a long time to count to zero. It will result in the phenomenon of starvation. And the characteristic of the BEB algorithm is always favor the last successfully transmitted node. It might lead to the fairness problem intensified, which result in the degradation of system throughput. Repeated retransmission acts also caused a lot of unnecessary waste of energy. For example, in Fig. 1 [4] is a network topology.

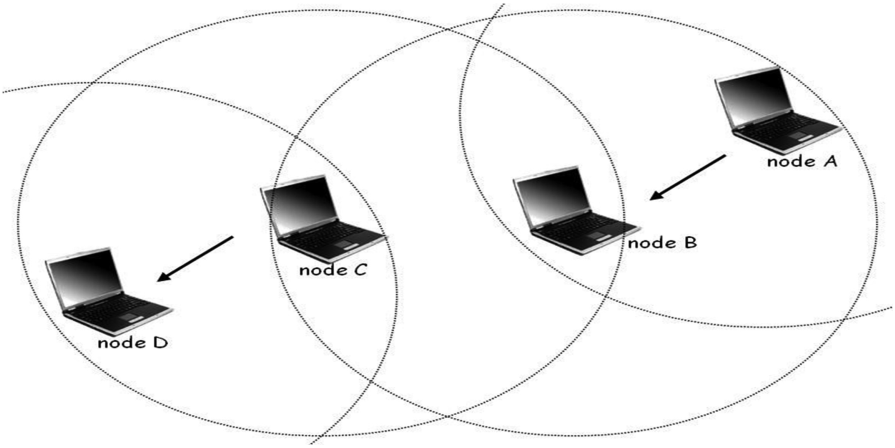


Fig. 1. The fair problem of wireless environments.

Node A wants to connect to node B and node C wants to connect to node D respectively. But node B will not receive data from node A. That is because node C will “grab” the channel by using a smaller contention window size.

2.2 The Interference Between Channels

The second one is the interference between channels. In the dense environment, we place more channels in a geographical area of network. With the distance between channels getting closer, and it causes more interference between each other. There are two types of the interference: One is the adjacent channel interference which is produced by its transmissions on adjacent or partially overlapped channels. And the other is the co-channel interference which is caused by the same frequency channel. Interference is the main reason why the capability of network cannot be fully utilized.

The interference of transmissions on adjacent or partially overlapped channels, which is called Overlapping Basic Service Set (OBSS) phenomenon. Figure 2 is a very simple illustration [5]. In the illustration, both the 80 MHz BSS and the 40 MHz OBSS have enough traffic to transmit all the time, so that they can take turns in winning the channel contention effectively. T is the nominal throughput of each, and the benchmark chosen is that of two separate non-overlapping 40 MHz channels. As can be seen, without the bandwidth adaptation, total throughput and individual throughputs of both BSS and OBSS are reduced. With bandwidth adaptation, 80 MHz throughput is increased, and total throughput is even double. If the 40 MHz OBSS overlapped with the primary 40 MHz of the 80 MHz channel, no matter with bandwidth adaptation or not, the 80 MHz transmission is completely blocked. It is cause that primary channels always need to be transmit, when the 40 MHz OBSS is transmitting, the 80 MHz channel have no opportunity to transmit. And the additional channel alignment issues also impact overall throughput.

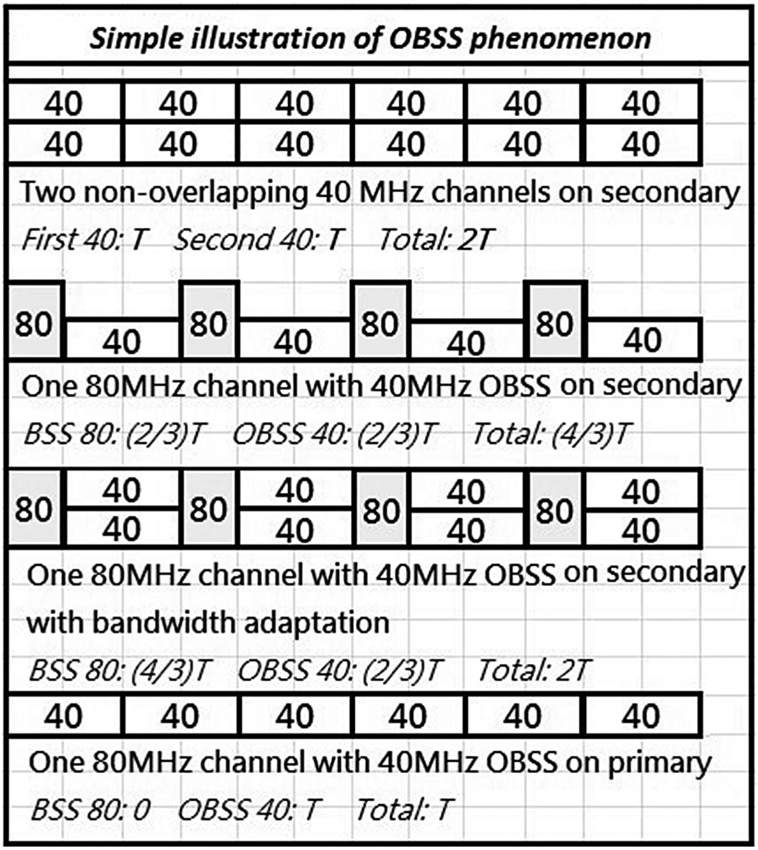


Fig. 2. Simple illustration of OBSS phenomenon.

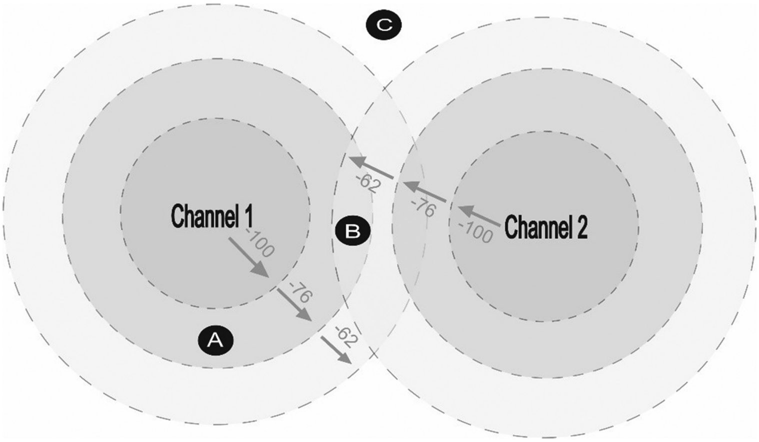


Fig. 3. The co-channel interference of wireless environments.

Considering Fig. 3 [6], it is the co-channel interference which is caused by the same frequency channel in dense environment. Node A is in the range of Channel 1 and node b is in the range of both Channel 1 and Channel 2. But the transmission of node b will not better than node a's transmission since the interference between the same frequency Channel 1 and Channel 2. There is also likely to have a dead angle. Node c is not in the range of any channel, so it will have no transmission. The throughput of network will get worse.

Now, these issues have surfaced. The increased interference from the co-channel problem and severe collisions from channel contention in dense environments give rise to network performance degradation. It always cause the whole networks disabled. When entering the next internet generation 802.11ax, WLAN devices are increasingly required to support a variety of applications such as voice, video, cloud access, and traffic offloading. And the 802.11ax amendment hope to enable supporting at least four times improvement in the average throughput per node in a dense deployment scenario, while maintaining or improving the power efficiency per node. Therefore, we must proposed an improved method to solve those problems.

In [7], the authors computed a theoretical upper bound of IEEE 802.11 distributed coordination function on achievable throughput. They pointed out that by appropriately tuning the backoff algorithm to control the contention window size, the scheme can achieve better performance and operate close to the theoretical limit. However, the proper adjustment of the contention window is often very complex calculation, especially in the dense environment. Bianchi [8] also proposed that the optimal window size is fixed under the saturated environment. Although the saturated environment is not consistent with the real network environment. But we can calculate the new algorithm to fetch the optimal window size through his methods.

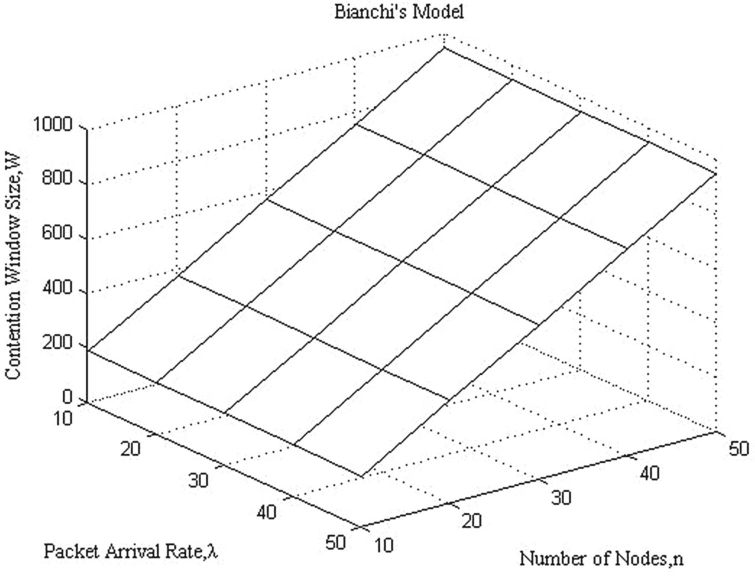
3 Simulation Results

In this chapter, our proposed model compared with Bianchi's analytical model in [8] and the legacy backoff mechanism of 802.11 DCF. To validate our model, we adopt NS-2 as the tool of our simulation. NS-2 is a discrete-event driven and object oriented network simulator which is written in the C++ and OTcl programming language. The data rate is adopt the IEEE 802.11g standard. The system parameters which are used to obtain numerical results as following Table 1:

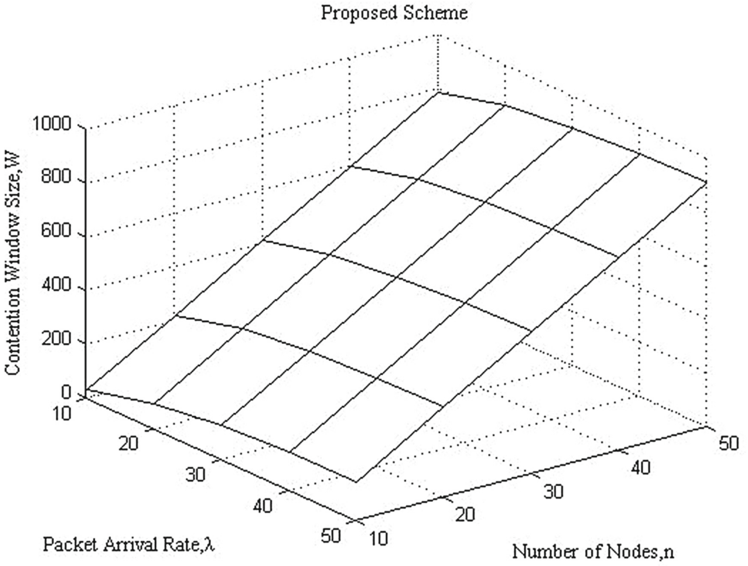
Table 1. Default attribute values used in the simulation

MAC packet payload	8192 bits
MAC header	272 bits
PHY header	128 bits
ACK frame size	112 bits + PHY header
PHY data rate	54 Mbit/s
Propagation delay	1 μs
Slot time	9 μs
SIFS duration	16 μs
DIFS duration	34 μs
Minimum CW size	32
m	5
Transmission method	OFDM
Frequency	5 GHz
Channel bandwidth	80 MHz
Spectral efficiency	21.665 bps/Hz (4 × 4, 80 MHz)
EIRP	22–29 dBm
OFDM symbol duration	4 ms (800 ns guard interval)

In Fig. 4, we show the relation between λ value, nodes number and fixed optimal contention window size. If the contention window size is fixed at the optimal contention window value, it can get the maximum throughput. We compare contention window size of our model in different λ values with Bianchi's derivation. We can see that the contention window size is linear increasing while the nodes increase no matter in our model or Bianchi's model. And in any case of identical node number, the contention window size of Bianchi's model is bigger. In our model when the λ value increase then the optimal contention window size increases. But it remains the same in Bianchi's model. That is because his model was developed in the saturated environment.



(a) Bianchi's Model



(b) Proposed Scheme

Fig. 4. Contention window size under different λ value and nodes.

4 Conclusions

We provide a simple and useful analytical one-dimension model to describe the behavior of the backoff mechanism in IEEE 802.11 DCF. We add the idle state to describe the state under the unsaturated environment, and use the Poisson Process to compute the probability that there is at least one packet arrives the waiting queue to be transmitted. For getting maximum throughput, we computed the optimal contention window size which is fixed. This paper is the first one analysis the optimal and fixed contention window size under the unsaturated environment. In the simulation result, we found out the packets arriving rate can affect the optimal contention window size and throughput. After that, we pointed out that the throughput of our model is indeed better than the Legacy 802.11 model and the Bianchi's model. And we also ameliorate the performance of collision rate effectively. For the IEEE 802.11ax standard, our contribution is not only making the throughput better to support the dense environments, but also decreasing the collision rate which will be able to effectively improve the utilization rate.

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