A Boundary of Saturated and Unsaturated Throughput in IEEE802.11 Wireless LAN Channel

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***Abstract*-Throughput is an important parameter that it is used to measure the performance of wireless local network (WLAN). In this research, we proposes a new discrete time Markov chain model to calculate the boundary of saturated and unsaturated throughput efficiencies in WLAN channel. Both throughput parameters are compared in fixed backoff stages and fixed contention window sizes (FBFC) technique by applying the global balance equation concept in steady-state distribution of discrete time Markov chain model. Also, the collision resolution method of transmitted packets through WLAN channel uses the Binary Exponential Backoff (BEB) algorithm based on Carrier Sense Multiple Accesses with Collision Avoidance (CSMA/CA) protocol. Our numerical results show that the throughput of unsaturated channel is higher than the saturated channel at light traffic load. On the contrary, the throughput of unsaturated channel is less than the saturated channel at high traffic loads condition.**

Keywords-CSMA/CA; Binary Exponential Backoff Algorithm; Discrete Time Markov Chain Model

I. INTRODUCTION

Basically, the performance analysis of wireless local area network channel is divided into two patterns: saturated channel and unsaturated channel. After the author in [1] introduced a new discrete time Markov chain model in saturated channel, this model becomes a popular technique that it is used to analyze the performance of distributed coordination function (DCF) in wireless local area network as well-known Bianchi's model. The distinction of Bianchi's model is low complexity, but its result is more accuracy. Similarly, many previous researches as in [2], [3], [4] and [5] extended Bianchi's model to analyze the throughput efficiency of WLAN system in saturated wireless channel condition. The saturated channel condition means that every timeslots of channel are used to send the data packets, or the wireless channel has the busy period only.

However, a real wireless channel may be consisted of two conditions: saturated and unsaturated condition, or busy and idle period. So that, this paper proposes a new discrete time Markov chain model to find the throughput performance of both saturated and unsaturated WLAN channel. The accuracy of throughput comparison is calculated in the same range of backoff stages and contention window sizes. Whereby the number of backoff stage or retransmission is varied from 0 to 7 stages, and the contention window size is varied from 0 to 1023 timeslots. In addition, all throughput results are calculated under the same physical layer parameters based on IEEE 802.11a standard with the CSMA/CA protocol. In this research, the collision resolution method uses Binary Exponential Backoff (BEB) algorithm.

II. SATURATED WLAN CHANNEL MODEL

In saturated WLAN channel, a proposed model can be showed in Fig.1. We use the global balance equation concept in steady-state condition of discrete time Markov chain theorem to derive the transmission probability (τ) parameter. From Fig. 1, parameter i is the number of backoff stage, k is the number of contention window size, p is the collision probability and P_F is the probability that a contending station suspends its count down process in backoff mode until the wireless channel is sensed idle more than distributed inter-frame space (DIFS) period, then the contention window size is counted down again. In retransmission process, before a data packet will be transmitted through WLAN channel, the contention window sizes must be counted down to zero. Firstly, when the backoff stage i is 0 and contention window size k is 7 timeslots, the state probability of $b_{0,7}$ is given by

$$\frac{\left(1-\frac{p}{15}\right)}{7}b_{0,0}+P_F b_{0,7}=\left(1-P_F\right)b_{0,7}$$

$$b_{0,7}=\frac{\left(1-\frac{p}{15}\right)}{7\left(1-2P_F\right)}b_{0,0} \tag{1}$$

When the backoff stage i is 0 and contention window size k is 6 timeslots, the state probability of $b_{0,6}$ is given by

$$\frac{\left(1-\frac{p}{15}\right)}{7}b_{0,0}+P_F b_{0,6}+\left(1-P_F\right)b_{0,7}=\left(1-P_F\right)b_{0,6}$$

$$b_{0,6}=\frac{\left(1-\frac{p}{15}\right)}{7\left(1-2P_F\right)}b_{0,0}+\frac{\left(1-P_F\right)}{\left(1-2P_F\right)}b_{0,7} \tag{2}$$

Substituting (1) into (2), we get

$$b_{0,6}=\frac{\left(1-\frac{p}{15}\right)}{7\left(1-P_F\right)}\frac{\left(1-P_F\right)}{\left(1-2P_F\right)}b_{0,0}+\frac{\left(1-\frac{p}{15}\right)}{7\left(1-P_F\right)}\frac{\left(1-P_F\right)^2}{\left(1-2P_F\right)^2}b_{0,7} \tag{3}$$

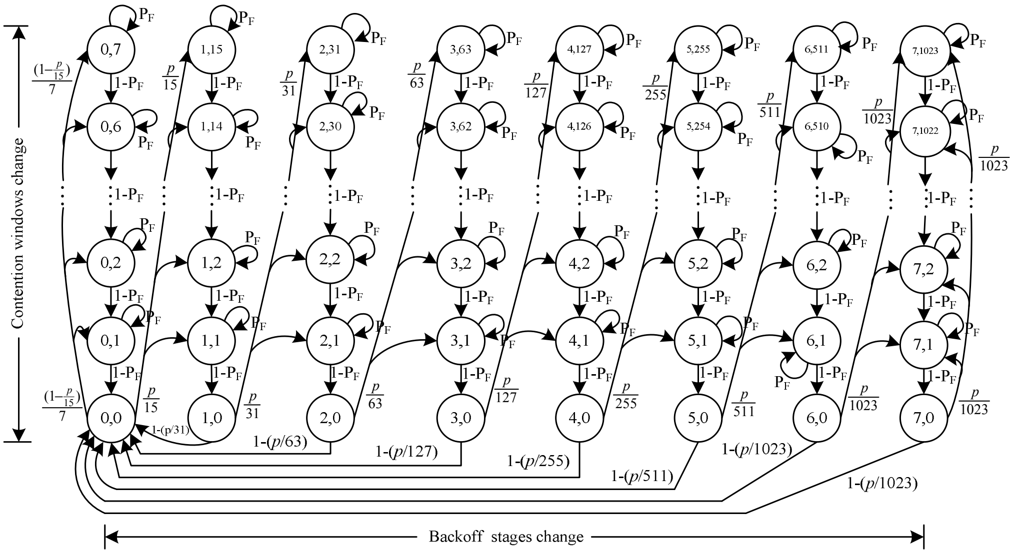

Fig. 1. A new discrete time Markov chain model of saturated WLAN channel in FBFC technique.

From (3), we let $B = (1-P_F)/(1-2P_F)$, then equation (3) can be rewritten by

$$b_{0,6} = \frac{\left(1-\frac{p}{15}\right)}{7(1-P_F)} B b_{0,0} + \frac{\left(1-\frac{p}{15}\right)}{7(1-P_F)} B^2 b_{0,7} = \frac{\left(1-\frac{p}{15}\right)}{7(1-P_F)} \sum_{L=1}^{2} B^L b_{0,0} \quad (4)$$

We use equations (1) and (4) to predict the state probability at backoff stage i = 0 and contention window size k = 1. The state probability of $b_{0,1}$ is given by

$$b_{0,1} = \frac{\left(1-\frac{p}{15}\right)}{7(1-P_F)} \sum_{L=1}^{7} B^L b_{0,0} \quad (5)$$

Next, when backoff stage i = 0, and contention window size k = 0, the state probability of $b_{0,0}$ is given by

$$b_{0,0} = \frac{7\times 15}{(15-8p)} (1-P_F) b_{0,1} \quad (6)$$

Substituting (5) into (6), the state probability of $b_{0,0}$ can be rewritten by

$$b_{0,0} = \frac{15\left(1-\frac{p}{15}\right)}{(15-8p)} \sum_{L=1}^{7} B^L\, b_{0,0} \quad (7)$$

Similarly, we use the same procedure of (1) to (7) to derive the state probability of $b_{1,0}$, $b_{2,0}$, $b_{3,0}$, $b_{4,0}$, $b_{5,0}$, $b_{6,0}$ and $b_{7,0}$, which are expressed by

$$b_{1,0} = (p/15)\sum_{L=1}^{15} B^L\, b_{0,0}, \qquad b_{2,0} = (p/31)\sum_{L=1}^{31} B^L\, b_{1,0} \quad (8)$$

$$b_{3,0} = (p/63)\sum_{L=1}^{63} B^L\, b_{2,0}, \qquad b_{4,0} = (p/127)\sum_{L=1}^{127} B^L\, b_{3,0} \quad (9)$$

$$b_{5,0} = (p/255)\sum_{L=1}^{255} B^L\, b_{4,0}, \qquad b_{6,0} = (p/511)\sum_{L=1}^{511} B^L\, b_{5,0} \quad (10)$$

$$b_{7,0} = (p/1023)\sum_{L=1}^{1023} B^L\, b_{6,0} + (p/1023)\sum_{L=1}^{1023} B^L\, b_{7,0} \quad (11)$$

Before a data packet will be transmitted through wireless LAN channel, the contention window in backoff process must be counted down to zero (k = 0). Similarly in [2], in steady-state condition, the transmission probability (τ) in saturated channel is given by

$$\tau_{Saturated} = 1/[b_{0,0} + b_{1,0} + b_{2,0} + b_{3,0} + b_{4,0} + b_{5,0} + b_{6,0} + b_{7,0}] \quad (12)$$

Substituting (7) to (11) into (12), the transmission probability is simplified by

$$\tau_{\text{Saturated}} = \frac{1}{\left[\begin{array}{l} A_0 + A_1 + A_1A_2 + A_1A_2A_3 + A_1A_2A_3A_4 + \\ A_1A_2A_3A_4A_5 + A_1A_2A_3A_4A_5A_6 + \\ A_1A_2A_3A_4A_5A_6A_7(1/(1-A_7)) \end{array}\right]} \quad (13)$$

Where by

$$A_0 = \frac{15\left(1-\frac{p}{15}\right)}{(15-8p)}\sum_{L=1}^{7} B^L,\ A_1 = (p/15)\sum_{L=1}^{15} B^L,\ A_2 = (p/31)\sum_{L=1}^{31} B^L,$$

$$A_3 = (p/63)\sum_{L=1}^{63} B^L,\quad A_4 = (p/127)\sum_{L=1}^{127} B^L,\ A_5 = (p/255)\sum_{L=1}^{255} B^L,$$

$$A_6 = (p/511)\sum_{L=1}^{511} B^L,\quad A_7 = (p/1023)\sum_{L=1}^{1023} B^L$$

The collision probability (p) of saturated WLAN channel is given by

$$p = 1 - (1-\tau_{\text{Saturated}})^{n-1} \quad (14)$$

In (14), parameter n is the number of contending stations in service area.

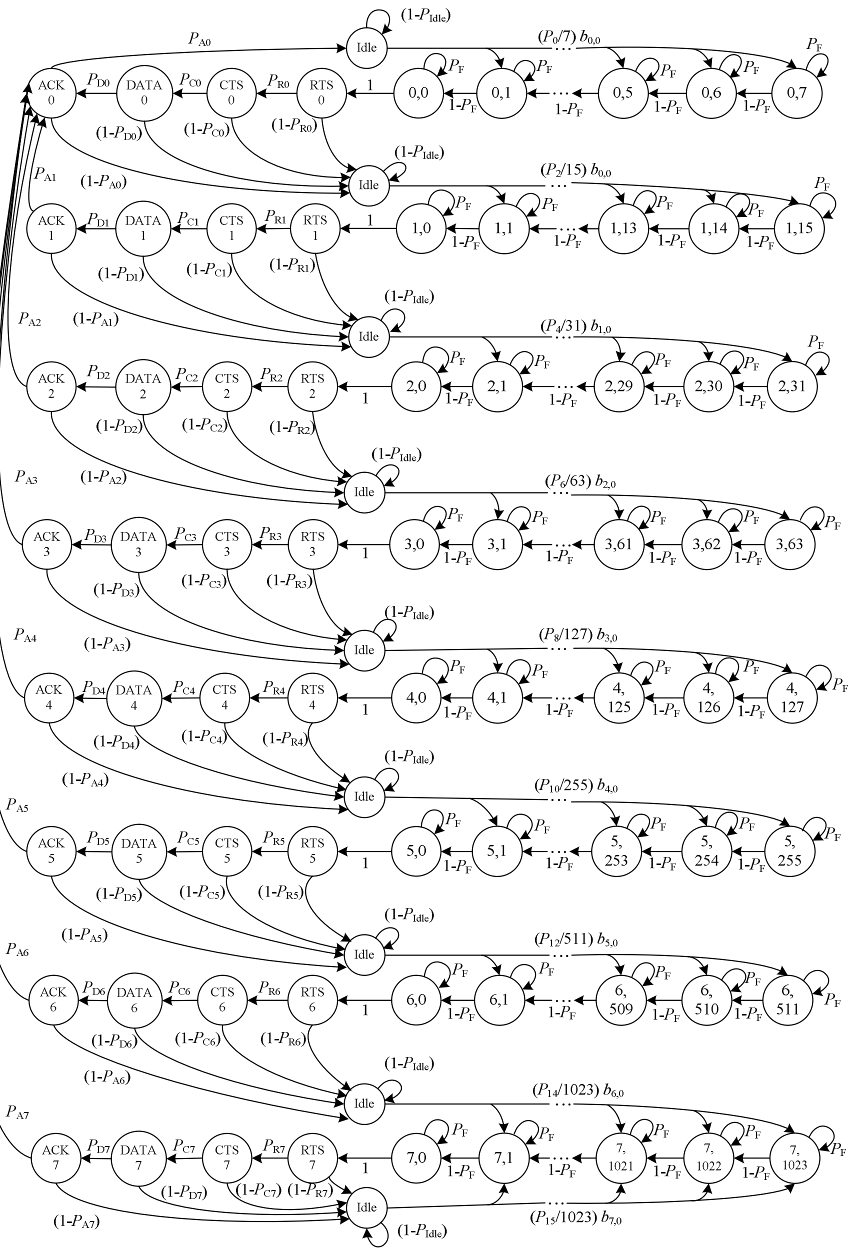

Fig. 2. A new discrete time Markov chain model of unsaturated WLAN channel in FBFC technique.

III. UNSATURATED WLAN CHANNEL MODEL

In unsaturated wireless LAN channel, we extend and remodel the works in [5], [6] and [7]. The time-period of channel is considered two conditions: busy period and idle period. In busy period, every timeslots are used to send the data packets. On the contrary, the idle period is not used to send the data packets. The proposed unsaturated channel model is clearly showed in Fig.2. In proposed model, P_{Idl} denotes the idle period probability of WLAN channel when it isn't used to transmit packets. Similarly previous Section, backoff stage is varied 0 to 7 stages, and contention window size is varied 0 to 1023 timeslots. Also, this research considers the effect of noise in wireless channel by applying the tree error probability diagram of CSMA/CA protocol in Basic mode and Request-to-Send, Clear-to-Send mode (RTS CTS) as shown in Fig.3. The noise of wireless channel is calculated in team of bit error rate (BER) probability based on Additive White Gaussian Noise (AWGN), and the BER is fixed at 10^{-5}. From Fig.3, RTS is the request-to-send frame, CTS is clear-to-send frame, MSDU is the MAC service data unit frame, and ACK is the acknowledgement frame. The difference between Basic and RTS CTS mode of CSMA/CA protocol is that Basic mode does not have the RTS and CTS control frame. Similarly in [5], the error probabilities of RTS, CTS, DATA and ACK frames due to AWGN can be calculated by

$$P^{\mathrm{RTS}}_{\mathrm{Success}} = (1-BER)^{\mathrm{RTS}} = P_{R0} = P_{R1} = \cdots = P_{R7} \tag{15}$$

$$P^{\mathrm{RTS}}_{\mathrm{Error}} = 1 - P^{\mathrm{RTS}}_{\mathrm{Success}} = 1-(1-BER)^{\mathrm{RTS}} = (1-P_{R0}) = (1-P_{R1}) = \cdots = (1-P_{R7}) \tag{16}$$

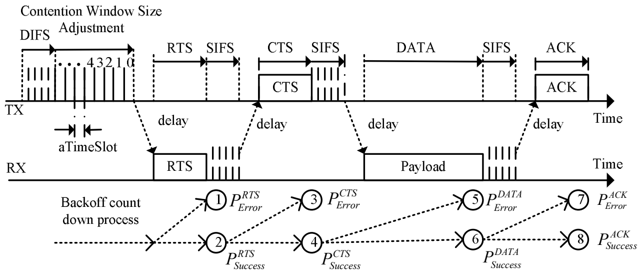

Fig. 3. Transmission periods and error tree diagram of CSMA/CA protocol.

$$P_{\text{Success}}^{\text{CTS}} = (1-BER)^{\text{RTS}}(1-BER)^{\text{CTS}} = P_{C0} = P_{C1} = \cdots = P_{C7} \quad (17)$$

$$P_{\text{Error}}^{\text{CTS}} = (1-BER)^{\text{RTS}}[1-(1-BER)^{\text{CTS}}] = (1-P_{C0}) = (1-P_{C1}) = \cdots = (1-P_{C7}) \quad (18)$$

$$P_{\text{Success}}^{\text{DATA}} = (1-BER)^{\text{RTS}}(1-BER)^{\text{CTS}}(1-BER)^{\text{Payload}} = P_{D0} = P_{D1} = \cdots = P_{D7} \quad (19)$$

$$P_{\text{Error}}^{\text{DATA}} = (1-BER)^{\text{RTS}}(1-BER)^{\text{CTS}}[1-(1-BER)^{\text{Payload}}] = (1-P_{D0}) = (1-P_{D1}) = \cdots = (1-P_{D7}) \quad (20)$$

$$P_{\text{Success}}^{\text{ACK}} = (1-BER)^{\text{RTS}}(1-BER)^{\text{CTS}}(1-BER)^{\text{Payload}}(1-BER)^{\text{ACK}} = P_{A0} = P_{A1} = \cdots = P_{A7} \quad (21)$$

$$P_{\text{Error}}^{\text{ACK}} = (1-BER)^{\text{Payload}}(1-BER)^{\text{RTS}}(1-BER)^{\text{CTS}}[1-(1-BER)^{\text{ACK}} = (1-P_{A0}) = (1-P_{A1}) = \cdots = (1-P_{A7})] \quad (22)$$

The failure transmission probabilities P_2, P_4, P_6, P_8, P_{10}, P_{12}, P_{14} and P_{15} due to the collision phenomenon and error of transmitted packets are given by

$$P_2 = P_4 = P_6 = P_8 = P_{10} = P_{12} = P_{14} = P_{15} = P_{\text{Idle}}\left(1-P_{\text{Success}}^{\text{RTS}}\right)\left(1-P_{\text{Success}}^{\text{CTS}}\right)\left(1-P_{\text{Success}}^{\text{DATA}}\right)\left(1-P_{\text{Success}}^{\text{ACK}}\right)P_{\text{Collision}} \quad (23)$$

Also, the successful transition probabilities P_0, P_1, P_3, P_5, P_7, P_9, P_{11} and P_{13} are given by

$$P_0 = P_1 = P_3 = P_5 = P_7 = P_9 = P_{11} = P_{13} = P_{\text{Idle}}\, P_{\text{Success}}^{\text{RTS}}\, P_{\text{Success}}^{\text{CTS}}\, P_{\text{Success}}^{\text{DATA}}\, P_{\text{Success}}^{\text{ACK}}\left[1-P_{\text{Collision}}\right] \quad (24)$$

Parameters $P_{\text{Success}}^{\text{RTS}}$, $P_{\text{Success}}^{\text{CTS}}$, $P_{\text{Success}}^{\text{DATA}}$, $P_{\text{Success}}^{\text{ACK}}$, $P_{\text{Error}}^{\text{RTS}}$, $P_{\text{Error}}^{\text{CTS}}$, $P_{\text{Error}}^{\text{DATA}}$ and $P_{\text{Error}}^{\text{ACK}}$ are the successful and error transmission probability of the Request-to-Send, Clear-to-Send , Data and Acknowledgement frame. $b_{i,k}$ is the state probability of backoff stage i and contention window size k. The global balance equation concept in discrete Markov chain is used to derive the transition probability (τ). The transition probability of $b_{0,0}$, $b_{1,0}$, $b_{2,0}$, $b_{3,0}$, $b_{4,0}$, $b_{5,0}$, $b_{6,0}$ and $b_{7,0}$ are defined by

$$b_{0,0} = (P_0/7)\sum_{L=1}^{7} B^L\, b_{0,0},\quad b_{1,0} = (P_2/15)\sum_{L=1}^{15} B^L\, b_{0,0} \quad (25)$$

$$b_{2,0} = (P_4/31)\sum_{L=1}^{31} B^L\, b_{1,0},\quad b_{3,0} = (P_6/63)\sum_{L=1}^{63} B^L\, b_{2,0} \quad (26)$$

$$b_{4,0} = (P_8/127)\sum_{L=1}^{127} B^L\, b_{3,0},\quad b_{5,0} = (P_{10}/255)\sum_{L=1}^{255} B^L\, b_{4,0} \quad (27)$$

$$b_{6,0} = (P_{12}/511)\sum_{L=1}^{511} B^L\, b_{5,0} \quad (28)$$

$$b_{7,0} = (P_{14}/1023)\sum_{L=1}^{1023} B^L\, b_{6,0} + b_{7,0} = (P_{15}/1023)\sum_{L=1}^{1023} B^L\, b_{7,0} \quad (29)$$

Similarly in [1], Bayes' theorem is used to derive the transmission probability (τ) in backoff stages i (i = 0, 1, 2…7)

$$\tau_{\text{Unsaturated}} = P(Tx) = 1/[\sum_{i=0}^{7} b_{i,0}] = 1/\begin{bmatrix} b_{0,0}+b_{1,0}+b_{2,0}+b_{3,0}+ \\ b_{4,0}+b_{5,0}+b_{6,0}+b_{7,0}\end{bmatrix} \quad (30)$$

$P(T_X)$ is the probability that a contending station is being transmitting a frame into a time slot. Substituting (25) to (29) into (30), the transmission probability of unsaturated model is simplified by

$$\tau_{\text{Unsaturated}} = 1/\begin{bmatrix} C_0 + C_1 + C_1C_2 + C_1C_2C_3 + C_1C_2C_3C_4 + C_1C_2C_3C_4C_5 \\ + C_1C_2C_3C_4C_5C_6 + C_1C_2C_3C_4C_5C_6C_7(1/(1-C_8))\end{bmatrix} \quad (31)$$

Where by

$$C_0 = (P_0/7)\sum_{L=1}^{7} B^L,\quad C_1 = (P_2/15)\sum_{L=1}^{15} B^L,$$

$$C_2 = (P_4/31)\sum_{L=1}^{31} B^L,\quad C_3 = (P_6/63)\sum_{L=1}^{63} B^L,$$

$$C_4 = (P_8/127)\sum_{L=1}^{127} B^L,\, C_5 = (P_{10}/255)\sum_{L=1}^{255} B^L,$$

$$C_6 = (P_{12}/511)\sum_{L=1}^{511} B^L,\quad C_7 = (P_{14}/1023)\sum_{L=1}^{1023} B^L,$$

$$C_8 = (P_{15}/1023)\sum_{L=1}^{1023} B^L$$

The collision probability of unsaturated WLAN channel is given by

$$P_{\text{Collision}} = 1-(1-\tau_{\text{Unsaturated}})^{n-1} \quad (32)$$

Equation (32) can be solving by numerical method.

IV. THROUGHPUT CALCULATION

Throughput efficiency is an important parameter that it is used to compare the performance saturated and unsaturated condition. Similarly in [1], this research uses the carrier sense multiple access with collision avoidance (CSMA/CA) protocol for controlling the medium access in wireless LAN channel. In calculation process, the time periods of CSMA/CA protocol are considered in two cases: Basic and RTS CTS mode. In our programming, parameter P_S is the successful transmission probability, P_{tr} is the transmission probability, P_C is the unsuccessful transmission probability, T_S is the successful transmission period, and T_C is the collision transmission period. Throughput parameters can be calculated from a transmitted data divided by transmission cycle which are given by

$$T_{\mathrm{S\rightarrow Basic\ mode}} = T_{\mathrm{DIFS}} + T_{\mathrm{SIFS}} + 2T_{\mathrm{delay}} + T_{\mathrm{Data}} + T_{\mathrm{ACK}} \quad (32)$$

$$T_{\mathrm{S\rightarrow RTS\ CTS\ mode}} = T_{\mathrm{DIFS}} + T_{\mathrm{RTS}} + T_{\mathrm{CTS}} + 3T_{\mathrm{SIFS}} + 4T_{\mathrm{delay}} + T_{\mathrm{Data}} + T_{\mathrm{ACK}} \quad (33)$$

$$T_{\mathrm{C\rightarrow Basic\ mode}} = T_{\mathrm{DIFS}} + T_{\mathrm{delay}} \quad (34)$$

$$T_{\mathrm{Data}} = \frac{\mathrm{MSDU} \times 8\ \mathrm{(bits)}}{\mathrm{Data\ rate\ (Mbps)}} \quad (35)$$

$$T_{\mathrm{C\rightarrow RTS\ CTS\ mode}} = T_{\mathrm{RTS}} + T_{\mathrm{DIFS}} + T_{\mathrm{delay}} \quad (36)$$

$$P_{\mathrm{tr\rightarrow Sat}} = 1 - (1 - \tau_{\mathrm{Saturated}})^{n} \quad (37)$$

$$P_{\mathrm{tr\rightarrow Unsat}} = 1 - (1 - \tau_{\mathrm{Unsaturated}})^{n} \quad (38)$$

$$P_{\mathrm{S\rightarrow Sat}} = \frac{n\tau_{\mathrm{Saturated}}(1-\tau_{\mathrm{Saturated}})^{n-1}}{1-(1-\tau_{\mathrm{Saturated}})^{n}} \quad (39)$$

$$P_{\mathrm{S\rightarrow Unsat}} = \frac{n\tau_{\mathrm{Unsaturate\ d}}(1-\tau_{\mathrm{Unsaturate\ d}})^{n-1}}{1-(1-\tau_{\mathrm{Unsaturate\ d}})^{n}} \quad (40)$$

$$P_{\mathrm{C\rightarrow Sat}} = 1 - P_{\mathrm{S\rightarrow Sat}} \quad (41)$$

$$P_{\mathrm{C\rightarrow Unsat}} = 1 - P_{\mathrm{S\rightarrow Unsat}} \quad (42)$$

$$TH_{\mathrm{Sat}} = \frac{P_{\mathrm{S\rightarrow Sat}} P_{\mathrm{tr\rightarrow Sat}} (MSDU \times 8)}{\left[(1-P_{\mathrm{tr\rightarrow Sat}})T_{\mathrm{aTimeSlot}} + P_{\mathrm{tr\rightarrow Sat}} P_{\mathrm{S\rightarrow Sat}} T_{\mathrm{S}} + P_{\mathrm{tr\rightarrow Sat}} P_{\mathrm{C\rightarrow Sat}} T_{\mathrm{C}}\right]} \quad (43)$$

$$TH_{\mathrm{Unsat}} = \frac{P_{\mathrm{S\rightarrow Unsat}} P_{\mathrm{tr\rightarrow Unsat}} (MSDU \times 8)}{\left[(1-P_{\mathrm{tr\rightarrow Unsatt}})T_{\mathrm{aTimeSlot}} + P_{\mathrm{tr\rightarrow Unsat}} P_{\mathrm{S\rightarrow Unsat}} T_{\mathrm{S}} + P_{\mathrm{tr\rightarrow Unsat}} P_{\mathrm{C\rightarrow Unsat}} T_{\mathrm{C}}\right]} \quad (44)$$

In our programming, saturated and unsaturated throughputs are calculated by applying Algorithm 1, and physical layer parameters of CSMA/CA in Basic and RTS CTS modes are listed in Table I.

Algorithm 1: Throughput calculation

Begin

Step: 1 To fixe parameter $P_{\mathrm{F}} := 0.05$, $P_{\mathrm{Idle}} := 0.95$, BER: $= 10^{-5}$, $n := 1,2,3..20$, RTS = 352 bits, CTS = ACK = 304 bits, MSDU = 1024 bytes

Step: 2 To calculate $T_{\mathrm{S\rightarrow Basic\ mode}}$, $T_{\mathrm{S\rightarrow RTS\ CTS\ mode}}$, $T_{\mathrm{C\rightarrow Basic\ mode}}$, $T_{\mathrm{C\rightarrow RTS\ CTS\ mode}}$, $P_{\mathrm{tr\rightarrow Sat}}$, $P_{\mathrm{tr\rightarrow Unsat}}$, $P_{\mathrm{S\rightarrow Sat}}$, $P_{\mathrm{S\rightarrow Unsat}}$, $P_{\mathrm{C\rightarrow Sat}}$, $P_{\mathrm{C\rightarrow Unsat}}$

Step: 3 To calculate the Saturated (TH_{Sat}) and Unsaturated (TH_{Unsat}) throughputs

End

TABLE I. THE TIME PERIODES OF CSMA/CA PROTOCOL

Parameters of IEEE 802.11a standard at data rate 24-Mbps	**The kinds of WLAN channel**	
	Saturated channel	***Unsaturated channel***
T_{SIFS}	16 µs	16 µs
T_{DIFS}	34 µs	34 µs
$T_{\mathrm{aTimeslot}}$	9 µs	9 µs
T_{delay}	1 µs	1 µs
T_{RTS}	27 µs (352 bits)	27 µs (352 bits)
T_{CTS}	25.5 µs (304 bits)	25.5 µs (304 bits)
T_{ACK}	25.5 µs (304 bits)	25.5 µs (304 bits)
MSDU	1024 bytes	1024 bytes
P_{F}	-	0.05
P_{Idle}	-	0.95
BER (AWGN)	-	10^{-5}
Data rate (MSDU)	24-Mbps	24-Mbps
Control frame speed (RTS , CTS and ACK)	1-Mbps	1-Mbps

V. NUMERICAL RESULTS

Firstly, Fig.4 compares the throughput boundaries between saturated and unsaturated condition based on IEEE802.11a standard under CSMA/CA protocol in basic mode. At a few contending station (1 station), our numerical results show that the throughput of unsaturated condition is higher than the saturated condition. However, when the contending stations are more than 2 stations, the saturated condition become higher than the unsaturated wireless channel condition. Notably, the throughputs of unsaturated condition seem to be reduced quickly when the number of contending stations are increased more 3 stations.

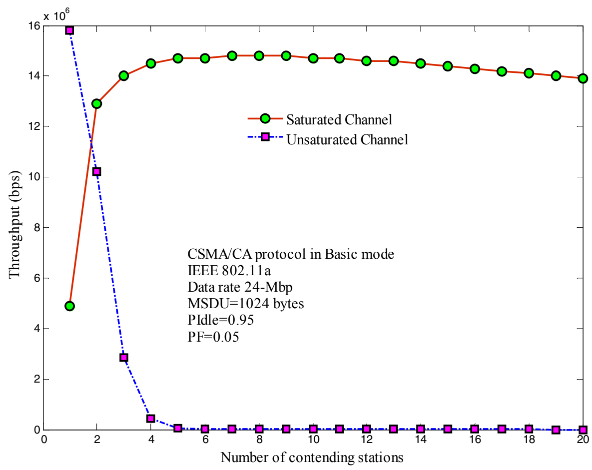

Fig. 4. Throughput boundaries of CSMA/CA protocol in Basic mode.

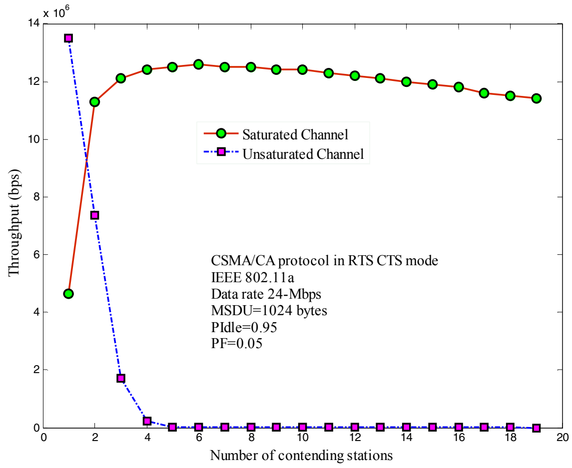

Fig. 5. Throughput boundaries of CSMA/CA protocol in RTS CTS mode.

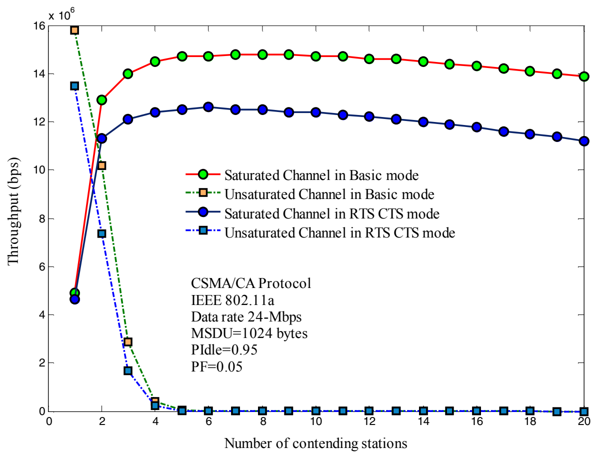

Fig. 6. Throughput boundaries of CSMA/CA protocol in Basic and RTS CTS mode.

Secondly, when the time periods of CSMA/CA protocol are change into RTS CTS mode, the throughput comparison results are shown in Fig.5. Similarly, the numerical results still confirm that the throughput performance of saturated condition is better than the unsaturated condition at high traffic load (more than 2 stations).

Finally, the theoretical throughput efficiency of CSMA/CA protocol between Basic and RTS CTS mode in saturated and unsaturated wireless channel condition have been combined as shown in Fig.6. The difference of results illustrates that the throughput of CSMA/CA protocol in Basic mode is higher than the RTS CTS mode in both saturated and unsaturated channel condition. The gap of throughput boundary between saturated and unsaturated channel is about 12 Mbps when we consider the numerical results at high traffic load condition (more than 5 stations). Surprisingly, the throughputs of unsaturated channel reach to zero rapidly when the contending stations are varied from 5 to 20 stations.

VI. Conclusion

In this research, we have introduced the boundaries of saturated and unsaturated throughputs of IEEE802.11 wireless local area network. Moreover, the accuracy of throughput results were compared by using a new discrete time Markov chain model that its maximum backoff stage was fixed at 8 stages and the maximum of contention window size was fixed at 1024 timeslots. Our numerical results have clearly shown that the throughput of unsaturated condition was high under light traffic load condition (1 station). On the other hand, at the traffic load more than 3 stations, the throughput of saturated condition became over than the unsaturated condition. Furthermore, the throughput performance of CSMA/CA in Basic mode was higher than the RTS CTS mode when we ignored the effect of hidden station phenomenon. In unsaturated channel, the throughput efficiency was decreased quickly when the number of contending station was increased.

In future work, we will evaluate unsaturated throughput of wireless LAN channel based on QoS IEEE 802.11e and very high throughput IEEE 802.11ac standards.

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