IOSR Journal of Mathematics (IOSR-JM)
e-ISSN: 2278-5728, p-ISSN: 2319-765X. Volume 10, Issue 5 Ver. VI (Sep-Oct. 2014), PP 41-47
www.iosrjournals.org

Computation of the Performance Analysis of IEEE 802.11 DCF in Non-Saturation Condition

S. Udayabaskaran[1], M. Reni Sagayaraj[2], C. Bazil Wilfred[3]
[1]*Department of Mathematics, Vel Tech University, Avadi, Chennai, India*
[2]*Department of Mathematics, Sacred Heart College (Autonomous), Tirupattur, India*
3Department of Mathematics, Karunya University, Coimbatore, India

Abstract: *The MAC performance of IEEE 802.11 DCF and the IEEE 802.11e EDCA is analyzed in non-saturated condition which means sometimes the device does not have a packet for transmission. In this paper we assume that there is no generation of flow while the previous flow is in service and the number of packets in flow is geometrically distributed. In the non-saturated condition, the first packet arriving at the idle station is transmitted without entering into backoff procedure. We attempt to model the stochastic behavior of one station as a discrete time Markov chain.*
Keywords: *DCF, discrete time Markov chain, MAC, non-saturation condition.*

I. Introduction.

The medium access control (MAC) of this wireless communication system employs a mandatory contention based channel access function called the Distributed Coordination Function (DCF), and an optional centrally controlled channel access function called Point coordination Function (PCF). DCF adopts a carrier sense multiple access with collision avoidance (CSMA/CA) with binary exponential back-off. According to the explosive growth of real time and multimedia application, quality of service (QoS) of these applications such as the guaranteed packet delay and packet loss probability is required. However 802.11 DCF protocol does not provide QoS support. A new Hybrid coordination function (HCF) in IEEE 802.11e is to provide the QoS support by combining and extending the DCF and the PCF of the MAC sub layer. The HCF consists of two channel access mechanisms: a contention based channel access (EDCA) providing a probabilistic QoS support and a controlled channel access (Hybrid Coordination function controlled channel access – HCCA) providing a parametric QoS support.

In general we have two classifications as Saturation condition and non-saturation condition. Though the evaluation of the performance and obtaining the throughput are highly complex in non-saturated condition comparing with that of saturated condition, keeping in mind the application in the real WLAN networks, non-saturation condition is analyzed.

Depending upon the arrival patterns or flows at stations the non- saturation mode is classified in three types.

Packets arrive and queue in a buffer at a station as in any queuing system. Here even during the service time of a packet the other packet can arrive.

A flow consisting of many packets arrive according to a Poisson process and each flow creates a new active station.

A flow is not generated during the service time of the previous flow. This is when a user with a device (cell phone or laptop etc.) tries to transmit a file in the WLAN area, the user makes a request to send (RTS) the file consisting of several packets. The packets in the file are transmitted by the IEEE 802.11 DCF protocol. In general the user does not generate a new request while flow is in service. Once the file transmission is completed the user takes a time period to prepare to send the next file or read the response. The time in between the completion of the first file and the beginning of the second file is for the user to be idle during which the station does not have packets to send.

Based on the third case mentioned in the non-saturation condition, we evaluate the performance analysis of IEEE 802.11 DCF. We model the stochastic behavior of one station as a discrete time Markov chain and obtain the channel throughput.

II. Performance analysis of IEEE 8201.11 DCF

1.1 Basic assumptions

Let n be the number of stations. Considering the third case of the non-saturation condition the station does not generate flows while the station has a flow in service. After completion of transmission of a flow the station goes to idle state and it takes exponential duration with rate λ for a station to generate a new flow. That is the inter arrival time of flow is exponentially distributed with rate λ. We assume each flow consists of geometrically distributed number of packets with mean $\frac{1}{1-\phi}$ that is the distribution of the number L of packets in a flow is given by $P(L=k)=\phi^{k-1}(1-\phi)$. The station generates a new packet with probability ϕ immediately after a previously packet has been transmitted and goes to idle state with probability $(1-\phi)$. To make our model to be a Markov chain we adopt the latter idea. All packets are assumed to have the same payload length.

1.2 Mathematical modeling.

The backoff counter decrement is freezed when the channel is sensed busy. Embedded points of the Markov chain are epochs where the backoff counter of the tagged station decrements and so a slot is classified as an idle slot, a successful transmission slot, and a collision slot. Therefore the time interval between two consecutive slot may be much longer than the idle slot time size σ, as it could be the duration of a packet transmission. For convenience we denote $W=CW_{\min}$ and $W_i=\min\{2^i W, 2^N W\}$ where N is the maximum backoff stage [2].

The state space of our Markov chain are;

i. Idle: the state in which the station has no packet to transmit

ii. $(-1,d), 1\le d\le 3$: The states in which the station monitors the channel activities during DIFS when the first packet of a flow arrives. Since $DIFS=SIFS+2\cdot\sigma$,
$(-1,1)$,is the state of sensing channel during SIFS,
$(-1,2)$, and $(-1,3)$ denote the states of two slot next SIFS period.

iii. (i,k): the states in which the station is in backoff procedure. i denotes the backoff stage with $0\le i\le M$ where M is retransmission limit excluding initial attempts. So a packet can experience $M+1$ transmission attempts. If a packet is not successfully transmitted at the $(M+1)$ th attempt, the packet is discarded. The backoff stage is reset to 0 and the contention window is reset to $CW_{\min}$ after every successful packet transmission or packet discard. k denotes the backoff counter with $0\le k\le W_i$.

The three cases that the first packet of the flow of our tagged station can experience are as below;

a) The first packet arrived at the idle station is immediately transmitted without backoff procedure after it senses the channel being idle during DIFS period. Figure a.

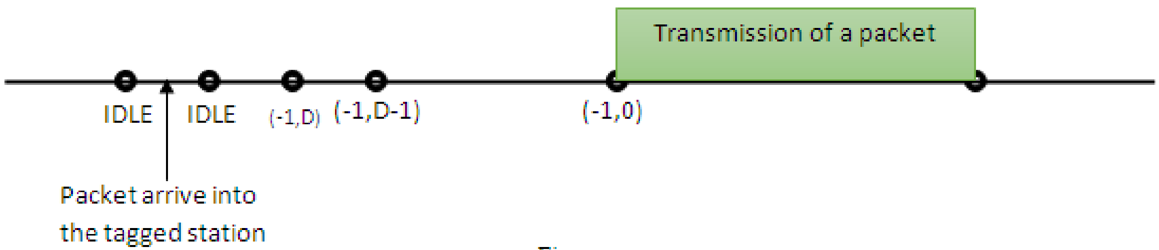


Fig. a

b) The channel is occupied by other stations during which the tagged station services channel condition during DIFS period after packet arrival. In this case, the tagged station starts a back off procedure after DIFS period following the other station's transmission. Figure b.

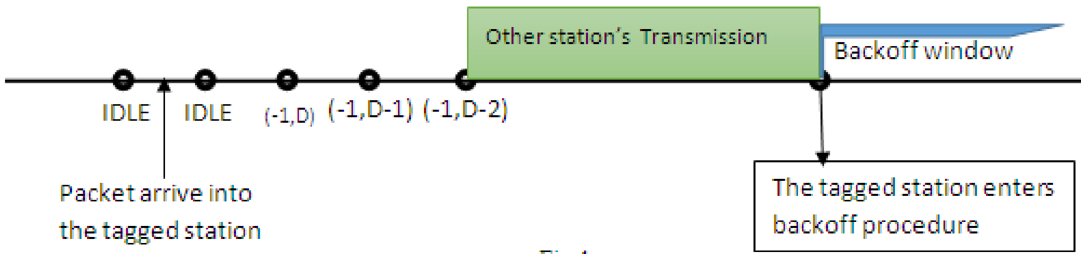


Fig. b

c) The first packet of the tagged station arrives during busy slot. The tagged station postpones a backoff procedure until the channel is idle during DIFS period. On the other hand, the ordinary packets are always transmitted through backoff procedure. Figure c.

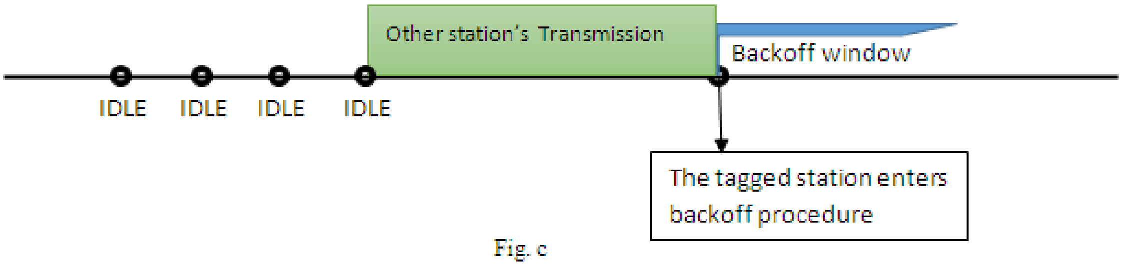


Fig. c

1.3 Markov Chain modelling.

The following figure d is the one-step transition probability of the Markov chain model describing backoff procedures for the tagged station in non-saturation condition. In Fig. d, p is the conditional collision probability which is assumed as constant regardless of the backoff stage. Let p_0, p_1 and p^* be the conditional probabilities that a randomly chosen slot is an idle slot, a successful transmission slot and a collision slot, given that the tagged station has no packets to transmit, respectively. Then,

$$p_0 = (1-\tau)^{n-1} \quad (1)$$

$$p_1 = (n-1)\tau(1-\tau)^{n-2} \quad (2)$$

$$p^* = 1 - p_0 - p_1 \quad (3)$$

where τ is the probability that the tagged station transmits in a randomly chosen slot.

Let p_a and p_b be the probabilities of packet arrival in an idle slot and a busy slot of channel when the tagged station has no packet to transmit respectively. Since inter-arrival time of flows is exponentially distributed with rate λ as mentioned p_a and p_b are calculated as,

$$p_a = p_0 \cdot (1 - e^{-\lambda \cdot \sigma}) \quad (4)$$

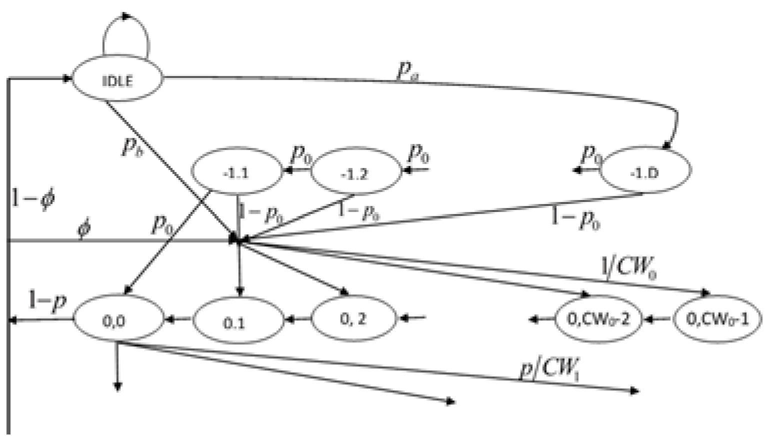
$$p_b = p_1 \cdot (1 - e^{-\lambda \cdot T_S}) + p^* \cdot (1 - e^{-\lambda \cdot T_C}) \quad (5)$$

T_S and T_C the durations that the channel is sensed busy during a successful transmission and a collision respectively, is calculated by

$$T_S = T_0 + T_p + SIFS + T_a + DIFS \quad (6)$$

$$T_C = T_0 + T_{p^*} + DIFS \quad (7)$$

where T_0 and T_a denote the durations to transmit overhead (PHY overhead + MAC overhead) and ACK packet, respectively. T_p is the average transmission time of data payload and T_{p^*} is the average transmission time of the longest data payload involved in a collision. Since we assume that all packets have the same payload size, $T_{p^*} = T_p$.



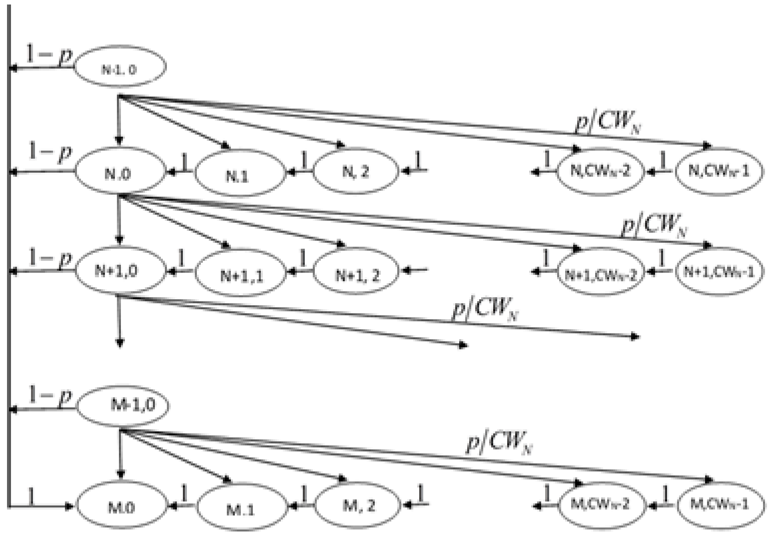


Fig. d.

1.4 Computation of stationary probabilities.

Computation of the stationary probabilities namely b_{idle}, $b_{-1,d}$ and $b_{i,k}$, of the Markov chain.

For the state b_{idle}

$$b_{00}(1-p)(1-\phi)+b_{1,0}(1-p)(1-\phi)+...+b_{M-1,0}(1-p)(1-\phi)+b_{M,0}(1-p)(1-\phi)=b_{idle}(p_a+p_b)$$

$$[b_{00}+b_{1,0}+...+b_{M-1,0}](1-p)(1-\phi)++b_{M,0}(1-\phi)=b_{idle}(p_a+p_b)$$

$$[b_{00}+pb_{0,0}+p^2b_{0,0}+...+p^{M-1}b_{0,0}](1-p)(1-\phi)+p^Mb_{00}(1-\phi)=b_{idle}(p_a+p_b)$$

$$b_{00}[1+p+p^2+...+p^{M-1}](1-p)(1-\phi)+p^Mb_{00}(1-\phi)=b_{idle}(p_a+p_b)$$

$$b_{00}\left(\frac{1-p^M}{1-p}\right)(1-p)(1-\phi)+p^Mb_{00}(1-\phi)=b_{idle}(p_a+p_b)$$

$$b_{00}(1-\phi)-p^Mb_{00}(1-\phi)+p^Mb_{00}(1-\phi)=b_{idle}(p_a+p_b)$$

$$\therefore b_{idle}=\frac{b_{00}(1-\phi)}{(p_a+p_b)} \qquad (8)$$

For the state $b_{-1,D}$

$$b_{idle}p_a=b_{-1,D}\left[(1-p_0)+p_0\right]$$

$$b_{-1,D}=b_{idle}p_a$$

For the state $b_{-1,1}$

$$b_{-1,1}=b_{-1,2}p_0$$

$$b_{-1,2}=b_{-1,3}p_0$$

$$b_{-1,1}=b_{-1,3}p_0p_0$$

$$=b_{idle}{p_0}^2\cdot p_a$$

$$b_{-1,2}=b_{idle}p_a\cdot p_0$$

$$=b_{idle}p_0\cdot p_a$$

$$b_{-1,3}=b_{idle}{p_0}^0\cdot p_a$$

$$b_{-1,d}=b_{idle}{p_0}^{3-d}\cdot p_a \qquad \text{if } d\in[1,3] \qquad (9)$$

For the state $b_{i,0}$, $b_{i,0}$: $1 \le i \le M$

$$b_{i,1} + b_{i-1,0}\frac{p}{cw_i} = b_{i,0}1$$

$$b_{i,2} + b_{i-1,0}\frac{p}{cw_i} = b_{i,1}$$

$$b_{i,3} + b_{i-1,0}\frac{p}{cw_i} = b_{i,2}$$

.

.

$$b_{i,c_{w_i}-1} + b_{i-1,0}\frac{p}{cw_i} = b_{i,c_{w_i}-2}$$

$$b_{i-1,0}\frac{p}{cw_i} = b_{i,c_{w_i}-1}$$

Adding

$$\sum_{j=1}^{c_{w_i}-1} b_{i,j} + b_{i-1,0}\frac{p}{cw_i} = \sum_{j=0}^{c_{w_i}-1} b_{i,j}$$

$$b_{i-1,0}\cdot p = b_{i,0}$$

$$b_{i,0} = b_{i-1,0}\cdot p, \qquad i \ge 1$$

$$b_{i-1,0} = p \cdot b_{i-2,0}$$

.

.

.

$$b_{1,0} = p \cdot b_{0,0}$$

Therefore $b_{i,0} = p^i \cdot b_{0,0}$ (10)

<u>For the state</u> $b_{i,k}$

$$b_{i,k} = b_{i.k-1} - b_{i-1,0}\frac{p}{cw_i}$$

$$\sum_{k=1}^{c_{w_i}-1} b_{i,k} = \sum_{k=0}^{c_{w_i}-1} b_{i,k-1} - (cw_i - 1)b_{i-1,0}\frac{p}{cw_i}$$, for, $1 \le k \le cw_i - 1$

$$= \sum_{k=0}^{c_{w_i}-2} b_{i,k} - (cw_i - 1)b_{i-1,0}\frac{p}{cw_i}$$

$$\sum_{k=1}^{c_{w_i}-1} b_{i,k} = b_{i,0} + \sum_{k=1}^{c_{w_i}-2} b_{i,k} - (cw_i - 1)b_{i-1,0}\frac{p}{cw_i}$$

$$b_{i,c_{w_i}-1} = b_{i,0} - (cw_i - 1)\frac{b_{i-1,0}}{p}\frac{p}{cw_i}$$

$$= b_{i,0} - \left(\frac{cw_i - 1}{cw_i}\right)b_{i,0}$$

$$= b_{i,0} - \left(\frac{cw_i - 1}{2^i w_0}\right)b_{i,0}$$

$$cw_i = 2^i w_0$$

$$b_{i,k} = b_{i,k-1} - \frac{b_{i,0}}{p}\frac{p}{cw_i}$$

$$b_{i,k} = b_{i,k-1} - \frac{b_{i,0}}{cw_i}$$

$$b_{i,k-1} = b_{i,k-2} - \frac{b_{i,0}}{cw_i}$$

$$b_{i,k-2} = b_{i,k-3} - \frac{b_{i,0}}{cw_i}$$

$$b_{i,1} = b_{i,0} - \frac{b_{i,0}}{cw_i}$$

Adding

$$b_{i,k} = b_{i,0} - \frac{k}{cw_i} b_{i,0}$$

$b_{i,k} = b_{i,0} - \frac{k}{2^i N} b_{i,0}$, for $N+1 \le i \le M$

$b_{i,k} = b_{i,0}\left(1 - \frac{k}{2^i N}\right)$, for $i \in [1, N]$ (11)

Similarly we get

$b_{i,k} = b_{i,0}\left(1 - \frac{k}{2^i N}\right)$, for $i \in [N+1, M]$ (12)

To find $b_{0,k}$

$$b_{0,k} = b_{i,k+1} + b_{idle}\frac{p_b}{CW_0} + \sum_{j=1}^{D} b_{-1,j}(1-p_0)\frac{1}{CW_0} + \sum_{i=0}^{D} b_{i,0}(1-p)\phi\frac{1}{CW_0} + b_{M,0}\cdot\phi\frac{1}{CW_0}$$

$$b_{0,k+1} = b_{i,k} - b_{idle}\frac{p_b}{CW_0} - \sum_{j=1}^{3} b_{-1,j}\frac{(1-p_0)}{CW_0} - \sum_{i=0}^{M-1} b_{i,0}(1-p)\phi\frac{1}{CW_0} - b_{M,0}\cdot\phi\frac{1}{CW_0}$$

$$b_{0,k} = b_{i,k-1} - b_{idle}\frac{p_b}{CW_0} - \sum_{j=1}^{3} b_{-1,j}\frac{(1-p_0)}{CW_0} - \sum_{i=0}^{M-1} b_{i,0}(1-p)\frac{\phi}{CW_0} - b_{M,0}\cdot\frac{\phi}{CW_0}$$

$$b_{0,1} = b_{0,0} - b_{idle}\frac{p_b}{CW_0} - \sum_{j=1}^{3} b_{-1,j}\frac{(1-p_0)}{CW_0} - \sum_{i=0}^{M-1} b_{i,0}(1-p)\frac{\phi}{CW_0} - b_{M,0}\cdot\frac{\phi}{CW_0}$$

$$b_{0,k} = b_{0,0} - \frac{k}{w_0} p_b \cdot b_{idle} - \frac{k}{CW_0}\left[(1-p_0)\sum_{j=1}^{3} b_{-1,j} + \sum_{i=0}^{M-1} b_{i,0}(1-p)\phi + b_{M,0}\cdot\phi\right]$$

$$b_{0,k} = b_{0,0} - \frac{k}{w_0} p_b \cdot b_{idle} - \frac{k}{w_0}\left[(1-p_0)\sum_{d=1}^{3} b_{-1,d} + \sum_{i=0}^{M-1} b_{i,0}(1-p)\phi + b_{M,0}\cdot\phi\right]$$

$$= b_{0,0} - \frac{k}{w_0}\left[p_b \cdot b_{idle} + (1-p_0)\sum_{d=1}^{3} b_{-1,d}\right] - \frac{k}{w_0}\left[(1-p)\phi\left\{\frac{1-p^M}{1-p}\right\} b_{0,0} + \phi p^M b_{0,0}\right]$$

$$= b_{0,0} - \frac{k}{w_0}\left[p_b \cdot b_{idle} + (1-p_0)\sum_{d=1}^{3} b_{-1,d}\right] - \frac{k}{w_0}\left[\phi b_{0,0}\right]$$

$$b_{0,k} = b_{0,0} - \frac{k}{w_0}\left[p_b \cdot b_{idle} + (1-p_0)\sum_{d=1}^{3} b_{-1,d} + \phi b_{0,0}\right] \quad (13)$$

Equations (8),(9),(10),(11) and (12) give the stationary probabilities of the Markov Chain. Thus we have expressed all the probabilities in terms of $b_{0,0}$. $b_{0,0}$ is determined by the normalization condition. As any transmission occurs when the backoff time counter is equal to zero, the probability τ is given by $\tau = \sum_{i=0}^{M} b_{i,0}$ and τ is a function of p . The conditional collision probability p is the same as probability that, in a time slot, at least one of the $n-1$ remaining stations transmit. Therefore, the probability p can be written as $p = 1-(1-\tau)^{n-1}$. Thus the two equations represent a nonlinear system of two unknown variables, from which we obtain τ and p by using numerical techniques.

III. Conclusion.

In this paper we have developed an analytical model to evaluate the performance of the IEEE 802.11 DCF in non-saturation condition. We have constructed a discrete time Markov chain to describe the stochastic behavior of one station and the stationary probabilities are evaluated.

References

[1]. G. Bianchi, "Performance Analysis of the IEEE 802.11 Distributed Coordination Function," IEEE Journal on Selected Areas in Communications, Vol. 18, No. 3, pp. 535–547, Mar. 2000.

[2]. Tae Ok KIM, Kyung Jae KIM, Bong Dae CHOI, "Performance analysis of IEEE 802.11 DCF and IEEE 802.11e EDCA in non-saturation condition", IEICE Trans. Communication., VOL. E91-B, No.4 April 2008.

[3]. IEEE, "International Standard Information technology-Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," IEEE 802.11-1999, 1999.

[4]. IEEE, "IEEE Standard for Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Amendment 8 Medium Access Control (MAC) quality of service (QoS) enhancements," IEEE P802.11e-2005, 2005.