Trends in Applied Sciences Research

ISSN 1819-3579

Academic
Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 9 (6): 275-289, 2014
ISSN 1819-3579 / DOI: 10.3923/tasr.2014.275.289

A Novel Adaptive Contention Window Scheme for IEEE 802.11 MAC Protocol

[1]Mohammad Saraireh, [2]Ja'afer AL-Saraireh and [3]Saleh Saraireh
[1]Mu'tah University, Karak, Jordan
[2]Applied Science University, Amman, Jordan
[3]Philadelphia University, Amman, Jordan

Corresponding Author: Mohammad Saraireh, Mu'tah University, Karak, Jordan

ABSTRACT

In this study, a novel approach is proposed. This approach is employed to improve the Quality of Service (QoS) for IEEE 802.11 MAC protocol, by adjustment of the Contention Window (CW) dynamically. The CW adjustment is based on Collision Rate (CR) and Collision Rate Variation (CRV). The proposed scheme classifies the application type into a high priority and a low priority traffic. This classification is used for providing QoS in single-hop wireless networks. By using the proposed approach, the average QoS for the high priority traffic is improved by 18.3 and 22.6% for the 5 and 10 connections, respectively. While the average QoS for the low priority traffic is improved by 11.6% and 17.8 for the 5 and 10 connections, respectively. The simulations results show that, the proposed method improves QoS in wireless network. Also, the proposed technique can be implemented without major modifications to the original IEEE 802.11 standard.

Key words: Quality of service, wireless networks, contention window, MAC

INTRODUCTION

The multimedia applications have strict requirements on network parameters, particularly, QoS parameters such as throughput, delay, jitter, packet loss and collision (Saraireh *et al.*, 2007; Dogman *et al.*, 2012). Time-sensitive applications were assigned as high priority traffic while time-insensitive applications were assigned as low priority traffic. Traffic differentiation can be achieved by accessing the Type of Service (ToS) field in the Internet Protocol (IP) header. In the ToS field up to six classes can be handled where class zero is assigned for high priority (Muller, 2003).

IEEE 802.11 MAC protocol is categorized into distributed and centralized control schemes (ISO/IEC 8802-11, 1999). The centralized scheme is not considered due to its complexity and lack of scalability. However, the distributed scheme is considered due to its simplicity, scalability, robustness and ease of implementation (i.e., each node can operate as a source, destination, or a router). For the distributed scheme, QoS support is classified as priority-based and fair scheduling-based (Pattara-Atikom *et al.*, 2003). In this work the priority-based is employed due to its simplicity.

The packets transmission in IEEE 802.11 MAC protocol is affected by many parameters. One of these parameters is the minimum contention window (CW_{min}). CW is considered as an integer number of time slots that a wireless device needs to wait before it can transmit a packet (ISO/IEC 8802-11, 1999). It is within range of two parameters of CW_{min} and CW_{max}. The IEEE 802.11 sets a default value of 31 and 1023 time slots for CW_{min} and CW_{max}, respectively. CW has the responsibility to determine the probability of medium collisions; therefore CW_{min} and CW_{max} should be set to realize the balance between collision probability and medium access efficiency.

The value of the CW is unchanged when a packet is successfully transmitted. But, if there is a collision between two or more packets due to more than one node simultaneously transmitting, the current value of CW is adjusted according to:

$$\text{New Contention window} = 2^{m} \times \text{CW-1} \qquad (1)$$

where, m is the number of transmission attempts and $CW = CW_{min}+1$ (Saraireh *et al.*, 2007) and (ISO/IEC 8802-11, 1999). Larger values of CW_{min} introduce an improvement to the performance of the transmission by reducing the packet drop probability and increasing throughput values but in some situations the packet delay may be increased (Chatzimisios *et al.*, 2005).

The IEEE 802.11 was proposed with minimal QoS provision and supports a best effort service. This minimal support is insufficient for transmitting multimedia applications.

RELATED WORKS

Several researches have been carried out to improve the performance of the IEEE 802.11 based on modifying the value of the CW. In Li and Battiti (2003) and Li *et al.* (2007) an analytical model has been proposed. Tt computes the throughput and packet transmission delays to support service differentiation. The proposed model employed the scaling of the CW_{min} value and the packet length according to the priority of each traffic flow. The simulation results of the proposed approach showed that good accuracy can be obtained to support the performance evaluations.

According to the results of the proposed analytical approach in (Chatzimisios *et al.*, 2005), the CW_{min}, CW_{max} size and the data rate considerably affects the performance of IEEE 802.11 protocol for channel access. The results showed that high values of CW_{min} size improved the performance in terms of lower packet drop probability and higher throughput values but packet delay in certain cases is increased.

In Pang *et al.* (2004) a self-adaptive CW adjustment as presented. The results indicated that the initial parameter settings affect the performance of the IEEE802.11 MAC protocol.

In Gannoune and Robert (2004) a dynamic for the CW_{min} was introduced to improve the performance of the IEEE 802.11. In this technique the channel utilization, throughputs were improved while the delay and jitter were reduced for the high priority traffic.

The studies in Li and Battiti (2003), Bononi *et al.* (2004), Cali *et al.* (2000), Wu *et al.* (2002) and Chen *et al.* (2003) showed a major enhancements in the network performance could be achieved by modifying the MAC protocol transmission parameters (e.g., CW_{min}, CW_{max}, number of retransmission). But the proposed methods only considered a fixed packet size, limited number of the QoS parameters and only one type of traffic.

Moreover, some of the proposed approaches were based on major modifications of the IEEE 802.11 standard as in (Liu and Hsu, 2005). The proposed approaches in (Wu *et al.*, 2002; Song *et al.*, 2003) were only effective when there are many active nodes in the same Independent

Basic Service (IBSS), (i.e., high competition between nodes and under heavily loaded networks). The adaptive mechanisms proposed in (Peng *et al.*, 2002) for adjusting the CW_{min} value were based on that all nodes have data packets ready for transmission and also based on estimating the number of contending nodes such as in (Chen and Wu, 2004). These assumptions are not appropriate for networks with burst traffic.

Wu *et al.* (2002), Chatzimisios *et al.* (2005), Song *et al.* (2003) and Aad *et al.* (2002) suggested decreasing the CW value with static scale, if a successful transmission occurs. The main issue in those schemes that, the network load is not considered.

In Bianchi and Tinnirello (2004), Deng *et al.* (2008) and Bononi *et al.* (2004) the CW size was adjusted based on the estimated number of nodes. The main problem in this approach is high power consumption (Balador *et al.*, 2012). Deng *et al.* (2004) and Kwon *et al.* (2003) suggested to increase the CW value in any node overhearing a collision. In Lin *et al.* (2008), the size of CW was changed exponentially and linearly, according to the network load.

In Zhang *et al.* (2008), the CW sized was calculated according to the statistical data collected by each node and the number of successful sending.

The study proposed in Barry *et al.* (2001), Ayyagari *et al.* (2000), Chen *et al.* (2002), Gannoune (2006), Upadhyay *et al.* (2013) and Ghazvini *et al.* (2013) was based on CW differentiation (CWD). In Ayyagari *et al.* (2000), the small values of CW_{min} and CW_{max} were assigned to high priority traffic. While large values of CW_{min} and CW_{max} were assigned to low priority traffic. Another example that used the CWD scheme to provide service differentiation was proposed in (Chen *et al.*, 2002). In this approach the CW range was dynamically adjusted with respect to the variation in the number of active nodes.

In the CW Separation (CWS) scheme, the CW_{min} and CW_{max} values of high priority traffic are completely separated from the Cw_{min} and CW_{max} of low priority traffic. The scheme in (Deng *et al.*, 2004) is an example of the CWS. Two different CW values for high and low priorities were specified.

Significant research efforts were carried out but these studies experienced several drawbacks. For instance, some of these approach required exchange of control messages between nodes; others imposed sophisticated computations and significant adjustments to the structure of the IEEE 802.11 standard. Some of previous researches depended on the current network situations without considering the past history of the network. Most of the proposed approaches statically set the differentiation parameters. These parameters were only used at the initial transmission. The parameter settings were not based on the variations of the traffic load and did not lead to service differentiation. Some of the proposed approaches only considered one or two QoS metrics particularly delay and throughput. None of the proposed approaches evaluated the QoS of multimedia applications.

Therefore; the directions of interest in this study are: (1) MAC protocol parameter CW is dynamically adjusted, (2) different QoS metrics are evaluated such as throughput, delay, packet loss, jitter, MAC efficiency and collision rate.

DESCRIPTION OF THE PROPOSED SCHEME

The proposed approach is represented in Fig. 1. The first part is the classification, it classifies the traffic into high and low priorities. This is achieved by accessing the ToS bit pattern in the IP header. The second part is the recording part. Each node record the required information such as

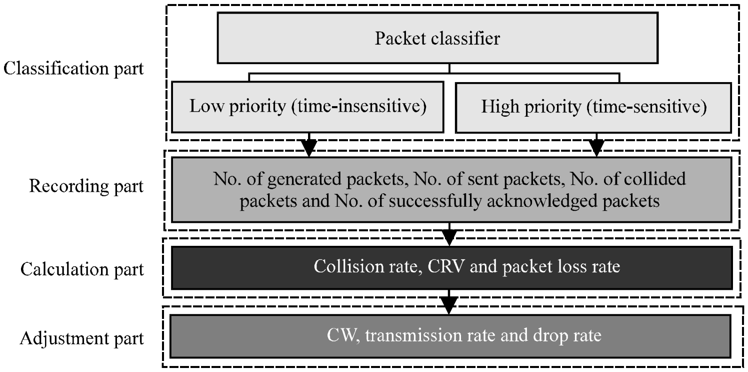

Fig. 1: Adaptive service differentiation scheme

the number of generating packets, sent packets, successfully acknowledged packets and collided packets. In the calculation part, CR, CRV and packet loss rate are computed and fed to the final part. The final part makes the decision on choosing appropriate parameter's values.

Contention window adjustment after successful transmission: The packet loss rate and CRV are required by each node to adjust the CW size. CR and the average collision ratio at the current history window wi, $R^{wi}_{average}$ values are computed using Eq. 2-3. The values are obtained when part of previous collisions are considered with the current CR:

$$R^{wi}_{current}[N] = \frac{Num(collisions_{wi}[N])}{Num(collisions_{wi}[N]) + Num(successful_{wi}[N])} \tag{2}$$

where, $Num(collisions_{wi}[N])$ is the number of collisions for node N that is extracted from the history window wi, $Num(successful_{wi}[N])$ represents the number of packets that have been successfully acknowledged for node N that is extracted from the same history window wi, $R^{wi}_{current}[N]$ is the current collision ratio of node N.

The sliding window wi is employed to keep continuous knowledge about transmission history. An Exponentially Weighted Moving Average (EWMA) (Crowder, 1989) is used to compute $R^{wi}_{current}[N]$ as in Eq. 3:

$$R^{wi}_{average} = (1-\lambda)\times R^{wi}_{current}+\lambda\times R^{wi-1}_{average} \tag{3}$$

where, $R^{wi}_{current}$ is the current collision ratio for node N; λ is a weighting factor which determines the memory size; $R^{wi-1}_{average}$ represents the previous average collision ratio that is computed from the previous history window (wi -1); while $R^{wi}_{average}$ is the average collision ratio at the current history window wi.

The packet loss rate of high priority node N_i, ($l[N_i]$) is calculated using Eq. 4. This is computed based on the number of successfully received acknowledgements $Num(success\_Ack[N_i])$ for a node N; i stands for high priority class and the number of generating packets at the sender $Num(gen\_packets[N_i])$. Packet loss rate is updated at a constant period of time. The update period is chosen to be sufficiently long in order to get good reactivity (i.e., provided the loss rate value when required) and not to be too short in order to avoid the complexity (i.e., Less computation):

$$l[N_i] = 1 - \frac{\text{Num}(\text{sucess\_Ack}[N_i])}{\text{Num}(\text{gen\_packets}[N_i])} \tag{4}$$

The packet loss rate is chosen since it provides a relevant indication of the application perceived QoS. Therefore, when the packet loss rate ($l[N_i]$) of a given high priority node exceeds a certain threshold ($l\_ths[N_i]$) (the value of this threshold is chosen to be 5% to meet the QoS for time-sensitive applications), the CW of the high priority node is rapidly decreasing as depicted in Eq. 5, in order to reduce the delay and to avoid excessive packet loss. As a result of the sharp decrease in the CW size of the high priority node, the high priority node becomes more aggressive to access the medium which in turn increases the probability of collisions over the medium:

$$CW_{new}[N_i] = CW_{new-1}[N_i] - \left(\frac{CW_{new-1}[N_i] * R^{wi}_{average}[N_i]}{f-1} \right) \tag{5}$$

The increase in the number of collisions leads to an increase in the CRV value of low priority traffic (i.e., CRV $[N_j]>0$), this forces the low priority node to gently increase its CW size as described in Eq. 6:

$$CW_{new}[N_j] = CW_{new-1}[N_j] + \left(\frac{CW_{new-1}[N_j] * R^{wi}_{average}[N_j]}{f} \right) \tag{6}$$

where, $CW_{new}[N_i]$ is the new CW for high priority traffic and $CW_{new}[N_j]$ is the new CW for low priority traffic, $CW_{new-1}[N_i]$ and $CW_{new-1}[N_j]$ are the previous CW for high and low priorities, respectively. f is a scaling factor chosen based on extensive simulations for several scenarios, $R^{wi}_{average}[N_i]$ and $R^{wi}_{average}[N_j]$ represent the average collision ratio of high and low priority traffic, respectively.

To ensure that scale factor f parameter is carefully chosen, many simulations are executed using different topologies and traffic loads. Therefore; 10 nodes are used to transmit CBR traffic to 10 destinations.

In Fig. 2a-b, the relationship between the f and average delay and throughput are illustrated. As shown in Fig. 2a-b, the appropriate value f is around 3, since it provides trade-off between average delay and throughput. As a result, it will be considered in the simulations.

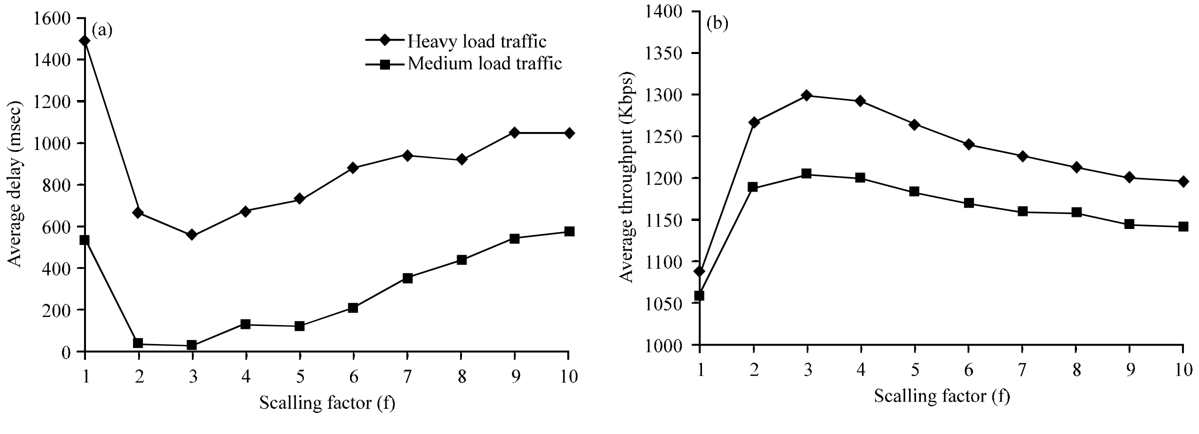

Fig. 2(a-b): (a) Average delay and (b) Average throughput

When the packet loss rate of high priority traffic goes below l_ ths[N_i], the CW of the high priority node is gently decreased as represented in Eq. 7:

$$CW_{new}[N_i] = CW_{new-1}[N_i] - \left(\frac{CW_{new-1}[N_i] * R^{wi}_{average}[N_i]}{f} \right) \tag{7}$$

The gradual decrease in the CW size of the high priority node leads to a reduction in the CRV value of low priority traffic, once the CRV value of low priority traffic becomes below zero (i.e., CRV [N_j]<0), a low priority node gradually decreases its CW as described in Eq. 8. The gradual decrease in the CW size of the low priority node provides more access opportunities. This in turn improves the whole network performance:

$$CW_{new}[N_j] = CW_{new-1}[N_j] - \left(\frac{CW_{new-1}[N_j] * R^{wi}_{average}[N_i]}{f+1} \right) \tag{8}$$

Note that, the CW size of low priority traffic is gradually changed according to the computed CRV value (CRV [N_j]). So, if CRV [N_j]>0, the low priority node assumes high contention over the network and gradually increases its CW using Eq. 6 to reduce the collisions. When CRV [N_j]<0, a low priority node assumes less contention and therefore decreases its CW using Eq. 7 to reduce the idle time slots.

Contention window adjustment after unsuccessful transmission: As in the case of successful transmission, the CR and the $R^{wi}_{average}$ values can be obtained using Eq. 2 and 3. Large values of $R^{wi}_{average}$ indicate that many nodes contend to access the medium, whereas, small values of $R^{wi}_{average}$ indicate fewer nodes contend to gain access to the medium.

Packet loss rate (l [N_i]) in Eq. 4 and packet loss threshold (l_ths[i]) is also used to maintain a high level of QoS for high priority traffic and to provide service differentiation. For low priority traffic, the obtained CR and $R^{wi}_{average}[N_j]$ values are used to limit the access of low priority traffic, particularly in overloaded networks. To achieve this goal, each high and low priority node computes its CR and $R^{wi}_{average}$ values, as the collision ratio value is an indication of the number of active nodes. Thus, low priority nodes use the CRV value to update their CW size. The CRV value determines whether the current collision ratio is smaller or larger than the previous one. High priority nodes use the packet loss rate (l [N_i]) and packet loss rate threshold (l_ths[i]) to update their CW size in order to maintain high throughput and less delay. For high priority traffic and after a collision, the packet loss rate value is examined. If the packet loss rate (l [N_i]) is greater than the packet loss rate threshold (l_ths[i]), the CW size is slightly increased in order to minimize the wasted time slots as described in Eq. 9:

$$CW_{new}[N_i] = CW_{new-1}[N_i] + \left(\frac{CW_{new-1}[N_i] * R^{wi}_{average}[N_i]}{f} \right) \tag{9}$$

If the packet loss rate (l [N_i]) is smaller than the packet loss rate threshold (l_ths[i]), then the CW size is rapidly increasing to reduce the collision and the retransmission of the collided packets as described in Eq. 10:

$$CW_{new}[N_i] = CW_{new-1}[N_i](1+R^{wi}_{average}[N_i]\times f) \tag{10}$$

For low priority traffic and after unsuccessful transmission, the CRV $[N_j]$ value is examined. If the CRV $[N_j]$ is greater than zero, the value of CW is sharply increased by a multiplication factor (f+2) to reduce the collisions and to protect the high priority traffic from degradation as in Eq. 11:

$$CW_{new}[N_j] = CW_{new-1}[N_j](1+R^{wi}_{average}[N_j]\times(f+2)) \tag{11}$$

If the CRV $[N_j]$ value is less than zero, the CW size of low priority traffic is also increased by a smaller multiplication factor as shown in Eq. 12:

$$CW_{new}[N_j] = CW_{new-1}[N_j](1+R^{wi}_{average}[N_j]\times(f+1)) \tag{12}$$

In order to ensure that the CW sizes of the two classes do not go below the CW_{min} or do not exceed the CW_{max}, the following conditions are set:

- If $(CW_{new}[N_i]$ or $CW_{new}[N_j])<CW_{min}$ then $(CW_{new}[N_i]$ and $CW_{new}[N_j]) = CW_{min}$
- If $(CW_{new}[N_i]$ or $CW_{new}[N_j])>CW_{max}$ then $(CW_{new}[N_i]$ and $CW_{new}[N_j]) = CW_{max}$

The high priority traffic gains smaller values of CW than low priority ones. This enables a high priority node to gain more access to the wireless medium which results in a smaller delay and a smaller packet loss rate. Simultaneously, low priority is not ignored. The value of CW for both priorities is varied in an adaptive manner, in which service differentiation is provided. High priority traffic has small values of delay and packet loss rate and low priority traffic has high throughput and fewer drops at the buffer.

To avoid starvation for low priority traffic, after each update of the CW, the adaptive contention windows differentiation approach examines the values of this parameter. If CW experiences high values (these values were determined by extensive simulations), the proposed scheme sets this parameter as shown in Eq. 13 and 14.

A full description of the adaptive contention windows differentiation schemes is provided in Fig. 3:

$$\text{if(priority = high) then } CW_{new}[N_i] = Cw_{min} \tag{13}$$

$$\text{if(priority = low) then } CW_{new}[N_j] = CW_{new-1}[N_j] - \left(\frac{CW_{new-1}[N_j]*R^{wi}_{average}[N_j]}{f+1}\right) \tag{14}$$

The proposed approach tries to narrow the gap between the two priorities in normal operating conditions and extend this gap when the network becomes overloaded.

This can be described as follows: Smaller values of packet loss rate and collision ratio indicate that the network operates in normal conditions. As a result, high priority nodes increase slightly their CW in order to give low priority nodes more opportunities to access the channel. Simultaneously, due to the increase in CW of high priority nodes, the CRV values of low priority nodes decrease and go below zero. Because the current collision ratio is less than the previous collision ratio and low priority nodes decrease their CW value, this improves their access to the medium and finally achieve better overall performance. This in turn reduces the differentiation between low and high priorities. For a heavily loaded network, when the packet loss rate of high priority nodes exceeds the packet loss rate threshold (i.e., $l[N_i]>l\_ths[N_i]$), high priority nodes decrease their CW value as they attempt to reduce their delay and to avoid excessive packet losses.

```
Adaptive Contention Window (ACW) differentiation scheme
after successful transmission

If (priority is high) {

    If (packet loss rate of high priority<packet loss threshold) {
        Update CW uses Eq. 7

    } Else if (packet loss rate of high priority>packet loss threshold)
        {Update CW uses Eq. 5
    }}
If (priority is low) {

    If (Collision Rate Variation (CRV) of low priority>0)
        {Update CW uses Eq. 6

    } Else if (Collision Rate Variation (CRV) of low priority < 0){
        Update CW using Eq. 8
    }}
ACW after unsuccessful transmission
If (priority is high) {

    If (packet loss rate of high priority<packet loss threshold)
        {Update CW uses Eq. 10

    } Else if (packet loss rate of high priority>packet loss threshold)
        {Update CW uses Eq. 9
    }}
If (priority is low) {

    If (Collision Rate Variation (CRV) of low priority>0)
        {Update CW uses Eq. 11

    } Else if (Collision Rate Variation (CRV) of low priority<0){
        Update CW using Eq. 12
    }
}
```

Fig. 3: Description of proposed scheme

Hence, after, the reduction in the CW of high priority nodes, results in more collisions. Subsequently, this increases the CRV values of low priority nodes which in turn make low priority nodes increase their CW value. This increases the service differentiation gap between high and low priorities in order to protect high priority traffic from the impact of low priority traffic at overloaded conditions.

Simulation model: To evaluate the validity of the proposed service differentiation scheme and compare their functionalities with the standard IEEE 802.11 DCF scheme, a network models with different scenarios have been proposed for the simulations.

The proposed model uses 40 fixed nodes which are randomly arranged in an area of 100×100 m to represent a wireless *ad-hoc* network as shown in Fig. 4. The nodes in this model are classified into high priority nodes that transmit high priority CBR traffic and low priority nodes that

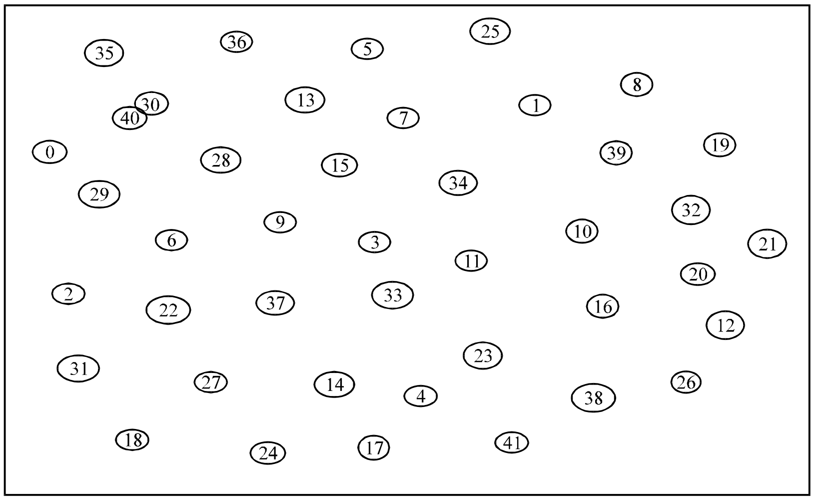

Fig. 4: Random IBSS single-hop topology

transmit low priority CBR traffic. All nodes in this model could hear each other's transmission. The packet sizes for CBR traffic are 512 and 800 bytes for high and low priority traffic, respectively. Each high priority node generates 192 kbps. Each low priority node generates 480 and 160 kbps as high and low bit rate, respectively. The simulation time lasts 300 sec and 10 simulation runs in order to obtain an accurate and consistent result in a steady state condition.

The simulations were performed for the following two scenarios:

- The first scenario contains five connections, two high priority connections and three low priority connections
- The second scenario involves 10 connections, five high priority connections and five low priority connections

They total offered load in each scenario is more than 110% of the effective channel capacity (i.e., it is considered 1.6 Mbps without considering the protocol overhead) and more than 90% of the total channel capacity (i.e., 2 Mbps, with considering the impact of protocol overhead).

RESULTS AND DISCUSSION

For the first scenario, Fig. 5a plots the cumulative distribution of packets that have delay below certain values. For time-sensitive application, these values should not exceed 400 msec to meet the minimum QoS requirements. The distribution of delay for high priority packets is clearly better than the distribution of delay for low priority packets. More than 80% of high priority packets have values of delay less than 400 msec while less than 70% of low priority packets have a delay of less than 400 msec. Thus, the proposed scheme reduces the delay for high priority traffic and hence provides service differentiation between high and low priority packets as shown in Fig. 5b. In Fig. 5b, the QoS of low priority traffic is also improved. The three low priority connections have good QoS levels with mean values equal to 43.9, 53.2 and 44.6% for the 1st, 2nd and 3rd connections, respectively. At the same time, high priority nodes maintain excellent QoS levels by means of 73 and 71.6% for the 1st and 2nd high priority connections, respectively. It can be observed that the average QoS of high priority connections is 25.1% higher than the average QoS of low priority connections. This confirms the capability of the proposed scheme in providing service

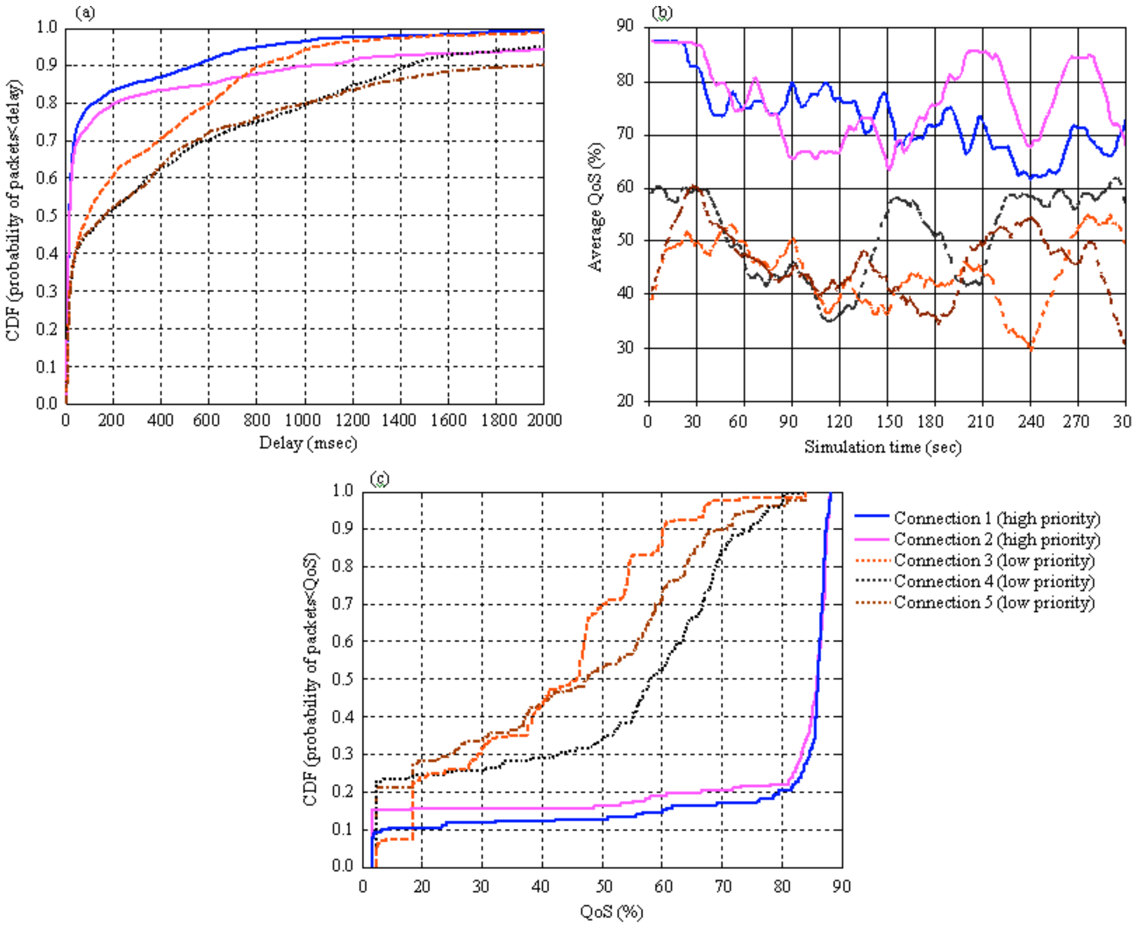

Fig. 5(a-c): Adaptive CW differentiation for 5 connections (high and low priority nodes), (a) Cumulative distribution of delay, (b) Average QoS and (c) Cumulative distribution of QoS

differentiation as shown in Fig. 5c. The mean values of delay, jitter, throughput, MAC efficiency and the assessed QoS of each connection are summarized in Table 1.

Table 2 summarizes the QoS results for the proposed approach as compared with the standard IEEE 802.11 protocol for 5 connections. These results are also shown in Fig. 6. The average of QoS of proposed scheme increased from 54-72.3% for the high priority connections and from 35.6-47.2% for the low priority connections. These results show that the use of the proposed approach enhances QoS in wireless networks.

In the second scenario, the proposed scheme improves the performance when the number of high and low priority connections is increased to 10. For instance, Fig. 7a shows that more than 80% of high priority packets meet the QoS requirements for the time-sensitive applications. Figure 7b-c indicate that more than 70% of high priority packets maintain an excellent QoS with an average of 72.7%. This is at the cost of average QoS of low priority nodes which have an average QoS equal to 36.7%. The reason for this is that in an overloaded condition, it is critical for high priority traffic to get faster access to the medium than low priority traffic. The proposed

Table 1: QoS parameter values for the proposed scheme

Bit rate/ connection (Kbps)	Connection/priority	Average delay (msec)	Average jitter (msec)	Average throughput (Kbps)	Average MAC efficiency (%)	Average QoS (%)
192	1/high	213.7	9.7	190.1	92.5	73.0
	2/high	218.2	10.2	176.9	93.5	71.6
480	3/low	381.4	9.3	302.4	94.0	43.9
	4/low	549.0	11.6	314.9	96.6	53.2
	5/low	412.2	10.0	338.0	94.4	44.6

Table 2: Comparison of IEEE 802.11 DCF QoS with proposed scheme for 5 connections

Bit rate/ connection (Kbps)	Connection/priority	Average QoS (%) proposed	Average QoS (%) standard	Average QoS (%) improvement
192	1/high	73.0	56.4	16.6
	2/high	71.6	51.6	20.0
	Average	72.3	54.0	18.3
480	3/low	43.9	31.8	12.1
	4/low	53.2	43.4	9.8
	5/low	44.6	31.7	12.9
	Average	47.2	35.6	11.6

Table 3: QoS parameter values for the proposed scheme using 10 connections

Bit rate/ connection (Kbps)	Connection/priority	Average delay (msec)	Average jitter (msec)	Average throughput (Kbps)	Average MAC efficiency (%)	Average QoS (%)
192	1/high	210.7	10.5	183.3	91.6	74.7
	2/high	258.2	11.1	174.5	92.3	73.4
	3/ high	300.2	12.2	165.6	92.7	71.4
	4/high	300.1	12.5	168.6	91.6	70.4
	5/high	229.7	11.5	169.1	91.6	73.6
160	6/low	2188.1	46.5	69.0	93.1	37.0
	7/ low	2242.4	51.2	88.1	93.8	39.5
	8/low	3193.2	65.5	69.5	93.7	35.1
	9/low	2299.4	50.4	94.8	93.1	36.0
	10/low	2222.1	49.9	90.9	93.0	35.7

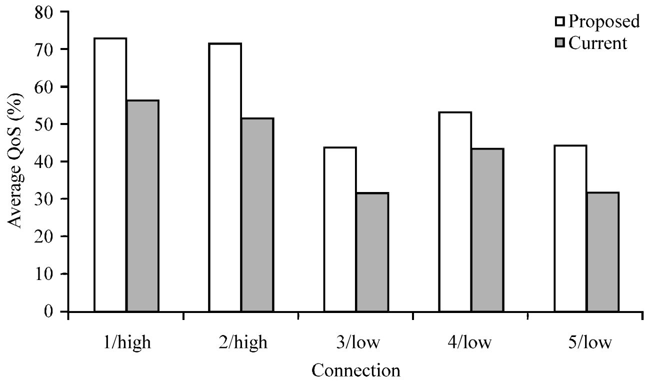

Fig. 6: Comparison of IEEE 802.11DCF QoS with proposed scheme for 5 connections

scheme assigns a larger CW size for low priority traffic and a smaller CW size for high priority. This enables high priority traffic to gain an earlier access to the medium before low priority traffic and therefore achieves higher QoS and smaller delays. The results are presented in Table 3.

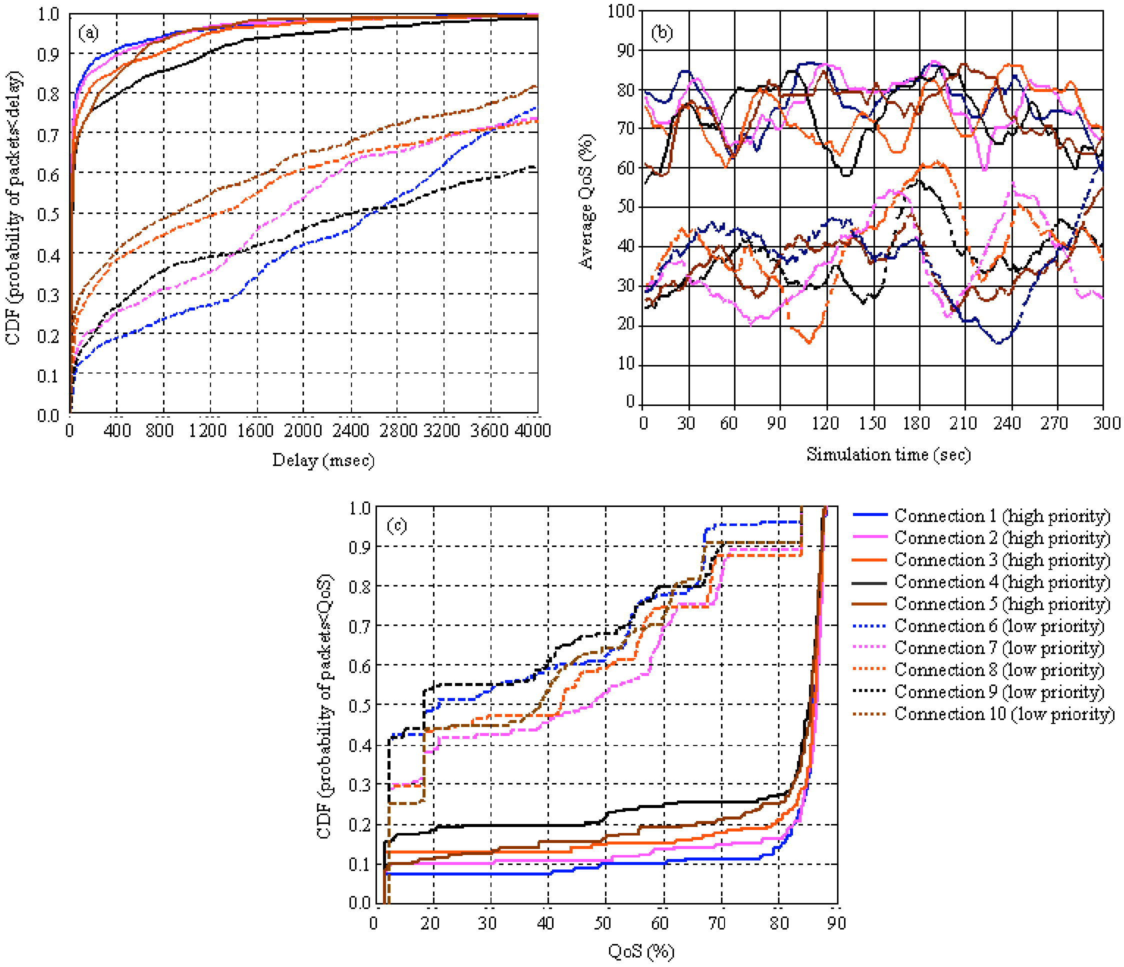

Fig. 7(a-c): Adaptive CW differentiation for 10 connections (5 high priority nodes transmitted 192 kbps and 5 low priority nodes transmitted 160 kbps), (a) Cumulative distribution of delay, (b) Average QoS and (c) Cumulative distribution of QoS

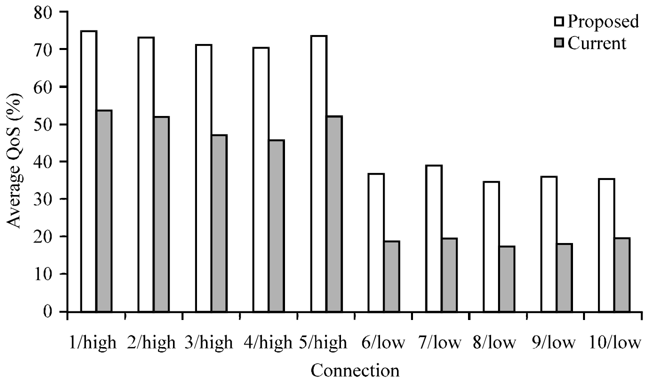

Fig. 8: Comparison of IEEE 802.11 DCF QoS with proposed scheme for 10 connections

Table 4 summarizes the QoS results achieve using the proposed approach as compared with the standard IEEE 802.11 DCF protocol for 10 connections. These results are also shown Fig. 8. The

Table 4: Comparison of IEEE 802.11 DCF QoS with proposed scheme for 10 connections

Bit rate/ connection (kbps)	Connection/priority	Average QoS (%) proposed	Average QoS (%) standard	Average QoS (%) improvement
192	1/high	74.7	53.8	20.9
	2/high	73.4	51.7	21.7
	3/ high	71.4	47.2	24.2
	4/high	70.4	45.6	24.8
	5/high	73.6	52.2	21.4
	Average	72.7	50.1	22.6
160	6/low	37.0	18.9	18.1
	7/ low	39.5	20.0	19.5
	8/low	35.1	17.8	17.3
	9/low	36.0	18.4	17.6
	10/low	35.7	19.8	15.9
	Average	36.7	18.9	17.8

use of the proposed mechanism as part of IEEE 802.11 DCF increases the average QoS from 50.1-72.7% for the high priority connections and from 19.8-36.7% of the low priority connections. These results indicate that the use of the proposed mechanism improves QoS in wireless networks.

CONCLUSION

In this study, an extension to the IEEE 802.11 DCF scheme to support QoS and provide service differentiation has been proposed. The service differentiation scheme is based on adjustment the CW at runtime. The adjusted CW parameter includes the application types that have been employed for providing service differentiation at MAC layer in single-hop networks.

The variation of CW value for time-sensitive applications has been implemented in an adaptive manner that attempts to meet the QoS requirements of those applications. For time-insensitive applications the variation of CW parameter is related to achieving high throughput regardless of the amount of delay they might experience taking into account less packet drops at the buffer.

The findings reveal that the CW of the standard IEEE 802.11 MAC protocol requires dynamic adaptation to improve its performance. The results indicated that using CW for service differentiation improves the performance of high and low priority classes compared to the standard IEEE 802.11 DCF scheme.

The simulations results indicate that the average of QoS for the high priority traffic is enhanced by 18.3 and 22.6% for the 5 and 10 connections, respectively. And for the low priority traffic is improved by 11.6% and 17.8 for the 5 and 10 connections, respectively.

REFERENCES

Aad, I., Q. Ni, C. Castelluccia and T. Turletti, 2002. Enhancing IEEE 802.11 performance with slow CW decrease. IEEE 802.11e Working Group Document 802.11-02/674r0.

Ayyagari, A., Y. Bernet and T. Moore, 2000. IEEE 802.11 quality of service-white paper. IEEE 802.11-00/028, pp: 1-10.

Balador, A., A. Movaghar, S. Jabbehdari and D. Kanellopoulos, 2012. A novel contention window control scheme for IEEE 802.11 WLANS. IETE Technical Rev., 29: 202-212.

Barry, M., A.T. Campbell and A. Veres, 2001. Distributed control algorithms for service differentiation in wireless packet networks. Proceeding of the IEEE 20th Annual Joint Conference of the IEEE Computer and Communications Societies, Volume 1, April 22-26, 2001, Anchorage, AK., USA., pp: 582-590.

Bianchi, G. and I. Tinnirello, 2004. Kalman filter estimation of the number of competing terminals in an IEEE 802.11 network. Proceedings of the 25th Annual Joint Conference of the IEEE Computer and Communications Societies, March 30-April 3, 2003, San Francisco, California, USA., pp: 844-852.

Bononi, L., M. Conti and E. Gregori, 2004. Runtime optimization of IEEE 802.11 wireless LANs performance. IEEE Trans. Parallel Distrib. Syst., 15: 66-80.

Cali, F., M. Conti and E. Gregori, 2000. Dynamic tuning of the IEEE 802.11 protocol to achieve a theoretical throughput limit. IEEE/ACM Trans. Network., 8: 785-799.

Chatzimisios, P., A.C. Boucouvalas and V. Vitsas, 2005. Performance analysis of the IEEE 802.11 MAC protocol for wireless LANs. Int. J. Commun. Syst., 8: 545-569.

Chen, W.T., B.B. Jian and S.C. Lo, 2002. An adaptive retransmission scheme with QoS support for the IEEE 802.11 MAC enhancement. Proceedings of the IEEE 55th Vehicular Technology Conference, Volume 1, May 6-9, 2002, Birmingham, AL., USA., pp: 70-74.

Chen, Y., Q.A. Zeng and D.P. Agrawal, 2003. Performance analysis and enhancement for IEEE 802.11 MAC protocol. Proceedings of the 10th International Conference on Telecommunications, Volume 1, February 23-March 1, 2003, Papeete, Tahiti, French Polynesia, pp: 860-867.

Chen, J. and W. Wu, 2004. Dynamic contention window selection scheme to achieve a theoretical throughput limit in wireless networks: A fuzzy reasoning approach. Proceedings of the 60th IEEE Semiannual Vehicular Technology Conference, Volume 5, September 26-29, 2004, Los Angeles, California, USA., pp: 3196-3200.

Crowder, S., 1989. Design of exponentially weighted moving average schemes. J. Qual. Technol., 21: 155-162.

Deng, J., P.K. Varshney and Z. Haas, 2004. A new backoff algorithm for the IEEE 802.11 distributed coordination function. Proceedings of the Communication Networks and Distributed Systems Modeling and Simulation Conference, January 18-22, 2004, San Diego, California.

Deng, D.J., C.H. Ke, H.H. Chen and Y.M. Huang, 2008. Contention window optimization for IEEE 802.11 DCF access control. IEEE Trans. Wireless Commun., 7: 5129-5135.

Dogman, A., R. Saatchi and S. Al-Khayatt, 2012. Quality of service evaluation using a combination of fuzzy c-means and regression model. Int. J. Electron. Electr. Eng., 6: 58-65.

Gannoune, L. and S. Robert, 2004. Dynamic tuning of the contention window minimum (CW_{min}) for enhanced service differentiation in IEEE 802.11 wireless *ad-hoc* networks. Proceedings of the 15th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, Volume 1, September 5-8, 2004, Barcelona, Spain, pp: 311-317.

Gannoune, L., 2006. A comparative study of dynamic adaptation algorithms for enhanced service differentiation in IEEE 802.11 wireless *ad hoc* networks. Proceedings of the International Conference on Internet and Web Applications and Services/Advanced International Conference on Telecommunications, February 19-25, 2006, Guadeloupe, French Caribbean, pp: 31-37.

Ghazvini, M., N. Movahedinia and K. Jamshidi, 2013. A game theory based contention window adjustment for IEEE 802.11 under heavy load. Int. J. Commun. Networks Inform. Security, 5: 93-103.

ISO/IEC 8802-11, 1999. IEEE standard for wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications. ISO/IEC 8802-11:1999E.

Kwon, Y., Y. Fang and H. Latchman, 2003. A novel MAC protocol with fast collision resolution for wireless LANs. Proceedings of the IEEE Societies 22nd Annual Joint Conference of the IEEE Computer and Communications, Volume 2, March 30-April 3, 2003, San Francisco, CA., pp: 853-862.

Li, B. and R. Battiti, 2003. Performance analysis of an enhanced IEEE 802.11 distributed coordination function supporting service differentiation. Proceedings of the 4the International workshops on Quality of Future Internet Services, October 1-2, 2003, Stockholm, Sweden, pp: 152-161.

Li, B., R. Battiti and Y. Fang, 2007. Achieving optimal performance by using the IEEE 802.11 MAC protocol with service differentiation enhancements. IEEE Trans. Vehicular Technol., 56: 1374-1387.

Lin, C.H., C.K. Shieh, W.S. Hwang and C.H. Ke, 2008. An exponential-linear backoff algorithm for contention-based wireless networks. Proceedings of the International Conference on Mobile Technology, Applications and Systems, September 10-12, 2008, National Ilan Unviersity, I-Lan, Taiwan.

Liu, Y.S. and T.H. Hsu, 2005. MAC protocols for multi-channel WLANs. IEICE Trans. Commun., E88-B: 325-332.

Muller, N.J., 2003. IP A to Z. McGraw-Hill, New York, ISBN: 9780071410861, Pages: 578.

Pang, Q., S.C. Liew, J.Y.B. Lee and S.H.G. Chan, 2004. A TCP-like adaptive contention window for WLAN. Proceedings of the IEEE International Conference on Communications, Volume 6, June 20-24, 2004, Paris, France, pp: 3723-3727.

Pattara-Atikom, W., P. Krishnamurthy and S. Banerjee, 2003. Distributed mechanisms for quality of service in wireless LANs. IEEE Wireless Commun. Mag., 10: 26-34.

Peng, Y., H. Wu, S. Cheng and K. Long, 2002. A new self-adapt DCF algorithm. Proceedings of the IEEE Global Telecommunications Conference, Volume 1, November 17-21, 2002, Taipai, Taiwan, pp: 87-91.

Saraireh, M., R. Saatchi, S. Al-Khayatt and R. Strachan, 2007. Assessment and improvement of quality of service in wireless networks using fuzzy and hybrid genetic-fuzzy approaches. Artif. Intell. Rev., 27: 95-111.

Song, N., B. Kwak, J. Song and L.E. Miller, 2003. Enhancement of IEEE 802.11 distributed coordination function with exponential increase exponential decrease backoff algorithm. IEEE VTC., 4: 2775-2778.

Upadhyay, R., P.D. Vyavahare and S. Tokekar, 2013. Collision resolution schemes with nonoverlapped contention slots for heterogeneous and homogeneous WLANs. J. Eng. 10.1155/2013/852959

Wu, H., S. Cheng, Y. Peng, K. Long and J. Ma, 2002. IEEE 802.11 Distributed Coordination Function (DCF): Analysis and enhancement. Proceedings of the IEEE International Conference on Communications, Volume 1, April 28-May 2, 2002, New York, USA., pp: 605-609.

Zhang, M., C. Gong and Y. Lu, 2008. Dynamic priority backoff algorithm for IEEE 802.11 DCF. Proceedings of the International Conference on Computer Science and Software Engineering, Volume 4, December 12-14, 2008, Wuhan, Hubei, pp: 956-958.