

IMPROVING IEEE 802.11G MAC TO SUPPORT QUALITY OF SERVICE FOR MULTIMEDIA APPLICATIONS IN WIRELESS NETWORKS

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Abstract

This paper investigates, describes and propose better techniques to provide QoS by assigning new metrics to the DCF access method, involving the DCF Interframe Space (DIFS), Contention Window values and the maximum data packet size to high priority nodes, which will bias towards high priority multimedia traffic to support QoS. A simulation is done using Network Simulator 2 (NS-2) and comparisons were made between different sets of network simulation scenarios. Improvements on throughput, delay and jitter can clearly be seen and further analysis is then presented.

Keywords

QoS, wireless networks, IEEE 802.11g

1. INTRODUCTION

Multimedia based applications are now being used very widely. With the emergence of applications on video streaming and Voice over IP (VoIP) which is categorized as time-bounded high priority traffic, it is seen that pervasive high-speed wireless data services are both compelling and inevitable. Based on this motivation, this paper investigates and describes the techniques proposed to support Quality of Services (QoS) in IEEE 802.11g, focusing on the Distributed Coordination Function (DCF) to provide better speed for multimedia traffic.

Research by [5] from end users and IT network administrators of more than 300 U.S.-based organizations has shown that wireless network usage has grown encouragingly which saw increased productivity as much as 22%. One of the main reason of the popularity of wireless network is the nature of it being unwired and unattached. This increases the flexibility of the users to gain information without physical barrier especially network cables.

Since the emergence of LAN and multimedia technology across networks, network usage had increased exponentially and thus congestions occurs which leads to the need on providing QoS in the network itself. Over the past few years, researchers had come with various solutions to provide QoS. These include QoS provisioning on layer two such as packet based flow and the upper layer such as queuing algorithms and traffic shaping. However, most of the algorithms proposed are designed specifically for wired networks. Since the method on medium accessing for wired and wireless network are completely different, the proposed algorithm or technique may not be suitable to be implemented directly on the wireless medium.

Highly congested network are demanding for better enhancement to support Quality of Service (QoS) that requires fast yet reliable transmission, where one of the attribute of an ideal QoS property is a stable throughput [11] which is the main focus of this research. Stable throughput sustains the throughput at a certain consistent level. Most multimedia applications such as video streaming and voice over internet protocol (VoIP) require stable throughput to avoid variation in data packet arrival which will lead to jittery video and sound.

The remainder of this paper is organized as follows. Firstly, this paper will discuss on the IEEE 802.11 channel coordination function before focusing on the Distributed Coordination Function (DCF) channel access method. Then, related works and techniques from previous research are presented, before

outlining the author's proposed techniques. Finally, a brief description of simulation scenarios and findings are given.

2. IEEE 802.11 Channel Coordination Function

In wireless networks, radio frequency (RF) is scarce where only one node can use it at a time. Therefore, there are turns for the nodes to oblige before successfully gaining the channel to transmit data. The technique where the nodes take turns is called the Channel Coordination Function.

There are two types of Channel Coordination Function, which are the Point Coordination Function (PCF) and Distributed Coordination Function (DCF) [7]. As the name suggests, applying PCF needs an intermediate controller that manages the nodes. PCF is used in the centralized, contention-free accesses while DCF is used for asynchronous contention based distributed accesses to the channel. Since this paper focuses on DCF, the following subsection will discuss more on DCF access method.

Distributed Coordination Function (DCF)

In DCF, the technique is distributed to each of the nodes. The nodes themselves determined whether they have the opportunity to transmit data. It is a contention-based method where nodes have to compete with each other to use the RF. In the contention basis, any client nodes can attempt to transmit data at any time it wanted to. However, the problem occurs when two computers start to transmit data at the same time, where a collision will definitely happen. In order to avoid collision, DCF implements a mechanism called Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) which is primarily adopted by wired LAN's Carrier Sense Multiple Access with Collision Detection (CSMA/CD) to avoid collision. Fig. 1 below illustrates on how DCF mechanism avoids collision.

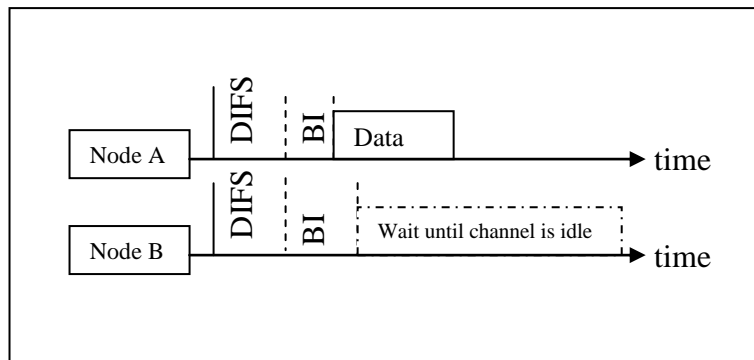


Fig. 1. DCF operation Function

From the above figure, there are two nodes, Node A and Node B where both nodes are in the position to transmit data. In order to avoid collision, CSMA/CA has all the clients to wait for a random amount of time, T_{wait} , which consists of DCF Interframe Space (DIFS), and backoff interval (BI) which is also known as the Contention Window (CW), before attempting to do transmission, as shown in (1). BI is a uniform random value, sampled exponentially from $[0, CW_{max}]$.

$$T_{wait} = DIFS + BI \quad (1)$$

Although the value of DIFS is the same for each station, the BI value is taken randomly to avoid collision. On the other hand, DIFS is derived from an equation as in (2) below:

$$DIFS = 2 (\text{Slot time}) + SIFS \quad (2)$$

It is known that all of the stations will have the same value of DIFS because SlotTime and SIFS are both constant value of $9 \mu s$ and $10 \mu s$ respectively (IEEE Std. 802.11g, 2003), while the BI value is the

parameter which finally determines which node will use the channel first. It is essential to know where the DIFS is derived from, as this involves on providing QoS which will be discussed later in this paper.

3. Related Works in WLAN QoS

WLAN has been a major issue in the wireless network field. This is proved by the number of research done. In providing service differentiation, the network traffic is divided into two categories, which are the low priority and the high priority traffic. Service differentiation is then made based on the two priority categories. Focusing on DCF, several approaches had been made by past researchers to support QoS. In this section, several ideas to provide QoS in IEEE 802.11 are described, which involves Interframe Space based, Contention Window (CW) separation based, and persistence factor based, discussed in the subsection below.

Contention Window Based

Deng [6] proposed a scheme based on separation of CW. Originally, the random Backoff Interval (BI) is uniformly distributed between $[0, 2^{2+i} - 1]$, in which i is the number of times the station attempted transmission of the same packet. In his scheme, the high and low priorities have random BI values uniformly distributed in intervals $[0, 2^{2+i}/2 - 1]$ and $[2^{2+i}/2, 2^{2+i} - 1]$. This approach is then combined with the IFS approach, discussed earlier. Simulation results reveal some improvement only in delay and jitter for high priority traffic (voice and video).

On the other hand, Xiaohui [14] suggests the Modified DCF (M-DCF) scheme, which uses different values of CW_{min} and CW_{max} for service differentiation. Simulations of ad-hoc wireless LAN with 10 data stations and between 10 and 35 voice stations were performed. Voice service had CW_{min} of 7 and CW_{max} of 127 while data service had CW_{min} of 15 and CW_{max} of 255. The outcome illustrates that M-DCF decreases the total packet dropping probability and the dropping probability of voice packets as well as reduces the contention delay of both voice and data packets compared with DCF.

Another work done by Barry [3] and Veres [13] recommend using different values of CW_{min} and CW_{max} for different priorities, in which higher priority has lower CW_{min} and CW_{max} values than those of lower priority. Simulations of high priority traffic with CW_{min} between $[8, 32]$ and $CW_{max} = 64$, and low priority traffic with CW_{min} between $[32, 128]$ and $CW_{max} = 1024$ were performed. The outcomes show that the high priority and low priority traffic undergo different delay.

Meanwhile, Aad [2] introduces a differentiation mechanism based on CW_{min} separation, in which higher priority traffic has lower CW_{min} value. Simulations of a wireless LAN consisting of an access point (AP) and three stations with CW_{min} values of 31, 35, 50 and 65 were conducted with both TCP and UDP flows. The results reveal that for the same set of CW_{min} values, the differentiation effect is more significant on UDP flows than on TCP flows. The per-flow differentiation is introduced, in which the AP sends back Acknowledge (ACK) packets with priorities proportional to priorities of the destinations. In other words, the AP waits for a period of time which is proportional to delay from a destination before transmitting an ACK packet to the destination.

Interframe Space (IFS) Based

In the same paper on CW separation, Deng [6] rejects reservation schemes as it leads to a major drawback, which is when the source is reserved but unused, it is simply wasted. He proposed a method to support two priorities, high priority and low priority stations. Higher priority stations will wait for a duration of PCF Interframe Space (PIFS), while lower priority stations will wait for a duration of DIFS before attempting data transmission. This is because PIFS has a shorter waiting time compared to DIFS. Several assumptions are made where there is no hidden node, no stations operates on power-saving mode and no interference from nearby Basic Service Sets (BSS). Simscript simulation of video, voice and data traffic with priorities of 3,2 and 0 with the ratio of 1:1:2 is performed. Results (IFS based, combined with CW separation) showed that there are performance improvements for high priority traffic in heavy load conditions where video traffic uses most of the bandwidth (55%) and lower priorities use the remaining bandwidth. In low load condition, lower priority traffic has the required bandwidth. Although it is illustrated that video and voice traffic has lower access delay and lower

packet loss probability than in DCF, data traffic suffers access delay and higher packet loss than in DCF.

Another IFS-based research, done by Aad [1] uses almost the same scheme as Deng [6]. Higher priority stations, labeled as $j+1$ and low priority stations, j have different Interframe space (IFS) values, denoted as $DIFS_{j+1}$ and $DIFS_j$, where the value of $DIFS_{j+1}$ is lower than $DIFS_j$. The maximum random range of priority $j+1$, (RR_{j+1}) is defined as the maximum Backoff Interval (BI) of that priority. If the strict condition $RR_{j+1} < DIFS_j - DIFS_{j+1}$ is satisfied, then all packets of priority $j+1$ have been transmitted before any packet of priority j is transmitted. In lower load condition, $RR_{j+1} > DIFS_j - DIFS_{j+1}$, a packet which could not access the medium the first time may have its priority decreased in the subsequent attempts. Simulations were carried out and the results show that the method does not change the system efficiency, with data sums remains the same [12]. The method works well for both Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) flows with more significant effect on UDP flows compared to TCP flows. It also works in noisy environment and keeps the same stability of the system.

Meanwhile, the use of Urgency Arbitration Time (UAT) to differentiate service by Benveniste [4] gives another perspective on providing QoS. UAT is the time a station has to wait before a transmission attempt following a period when the medium is busy. He also introduces Arbitration Interframe Space (AIFS) and Backoff Counter Update Time (BCUT) but both are actually DIFS and SlotTime respectively. Higher priority traffic is assigned shorter AIFS and BCUT values compared to the low priorities. The AIFS value for high priority is the same as PCF Interframe Space (PIFS) and a minimum backoff time of 1 in order to prevent conflict with medium access by centralized protocol PCF. A simulation was carried out where $AIFS(\text{high_prio}) = PIFS$, $AIFS(\text{low_prio}) = DIFS$, $CW(\text{high_prio}) = [1, 32]$ and $CW(\text{low_prio}) = [0, 31]$. Results showed that the delay and jitter of high-priority traffic are decreased and under moderate load condition, the performance of low priority traffic is also improved compared to DCF.

4. Proposed Scheme

Service differentiation between traffic classes (priorities) is based on differentiation of the time the traffic has to wait before transmission. Two main parameters that decide the waiting time of traffic are Interframe Space (IFS) and Contention Window (CW) (Pham et. Al, 2004). The proposed scheme adopts contention parameters, which are the DIFS period and the back off interval period to bias performance in favor of high priority traffic. Besides that, another parameter being tuned is the maximum packet size.

Smaller Contention Window Separation

In Deng's [6] experiment, the CW is divided into two parts equally, which are the range of $[0, 2^{2+i} / 2 - 1]$ and $[2^{2+i} / 2, 2^{2+i} - 1]$. However, in this research, the experiment of Deng will be further enhanced where different value of CW will be tested. Instead of the CW is divided to two similar values of $CW/2$, the CW in this research is divided to two parts which is more biased to high priority traffic flow. The CW for high priority is ranged from 0 to 128 while the rest of the CW is ranged from 128 to 1023. This gives the opportunity to the high priority traffic flow to gain even better chance to be treated with smaller CW.

Shorter DIFS

DIFS is the duration for a mobile node that wants to transmit data has to wait after sensing the channel is idle. The technique proposed in this experiment is that the high priority nodes are assigned shorter DIFS. This means high priority nodes have a shorter waiting time, which allows the higher priority node to transmit ahead of the lower priority nodes [9]. While high priority nodes will always have a shorter waiting time, it means high priority nodes are most likely to have the opportunity to always being first to transmit data after the channel is sensed idle compared to the low priority nodes.

Smaller Packet Size

In the original IEEE 802.11, there are no differences of packet size between a high priority and low priority traffic. No differentiation means the packets for the different priorities are treated the same. In this experiment, a high priority flow is assigned smaller frame size compared to low priority traffic.

With smaller frame size, a high priority node will be able to transmit more more frequent and avoid a surge of packet data arrival at the receiver's end. If packets are received at a very quick time, the buffer at the receiver's end will fill up quickly while there is no time for the receiver to process the data. This will lead to buffer overflow that will result to packets being dropped. Dropped packets will be retransmitted by the sender which consumes more time for a the same data to arrive at the receiver.

5. Simulation Scenario

All simulation setup are configured using the TCL language in the TCL script of NS-2 [10]. In the simulation setup, the environment is set to radio links where channel type is configured as wireless channel.

Radio propagation models are used to predict the received signal power of each packet. Since IEEE 802.11 considers both the direct path and a ground reflection, the propagation model used in this simulation is the Two-Ray Ground Reflection Model.

This experiment is done as a per-based mobile communication. This means that each node only transmit one type of data, that is whether a high priority data, or a low priority data. 16 nodes, named N0 to N15 are used where eight nodes acts as the data source and the other eight nodes as the destination. As a result, there are eight pairs of nodes, which is assigned identifiers of flow id (fid) 1 to fid 8. Only one pair (fid 1) will simulate the high priority data flow and the rest simulates the low priority data flow. Low priority flow will use the default configurations of the IEEE 802.11g standard while high priority flow will use the proposed scheme parameter. All of the QoS parameter readings are taken at the destination nodes. The topology of the network can further be depicted as in Fig. 2 below. Each of the station are in each other's range. Therefore, no hidden-node case arises.

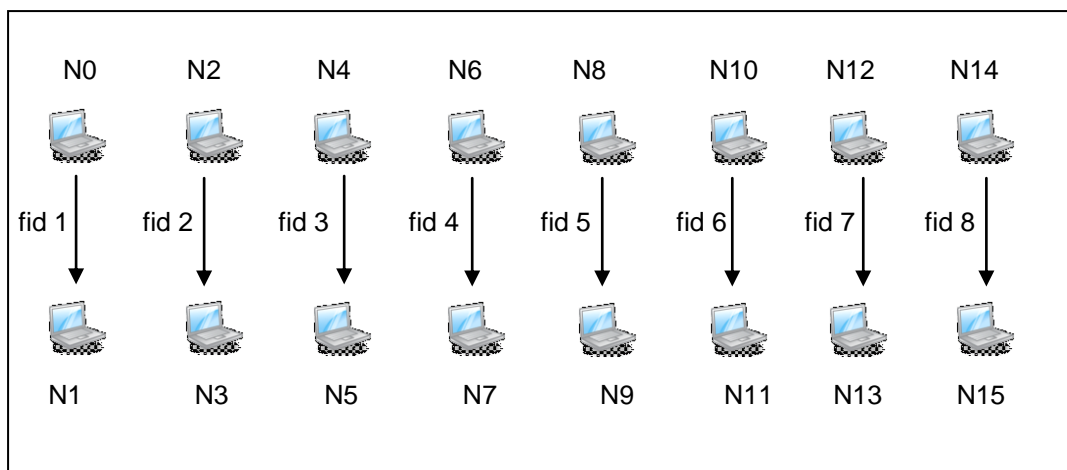


Fig. 2. Network Topology of Simulation

In order to simulate the real wireless network, the traffic involved includes Constant Bit Rate (CBR) and File Transfer Protocol (FTP).

The performance of the network is measured based on the output of the dependent parameter, which is the throughput. The output of the proposed scheme scenario will be compared to the original scheme, namely the Null scenario in order to determine any improvements or effects of the proposed scheme itself.

Table 1. Configurations of flow id 1 in both original IEEE 802.11g and the proposed scheme

Fid 1	Experiment		
	CW	DIFS	Packet Size
Proposed Scheme	[0, 256]	16	600
Null (Original IEEE 802.11g specifications)	[0, 1023]	28	1024

In a predetermined duration, the simulation time used is 100 seconds. At time, $t = 20s$, the high priority traffic of fid 1 as started, followed by fid 2 and so on at the interval of 5 seconds. Fid 1 is then stopped at time, $t = 120s$, followed by the other flow id, also with the interval of 5 seconds. The start and stop time of each flow id can be represented as in Table 2 below.

Table 2. Simulation start, stop and duration time of each flow id.

Flow id	Start time	Stop time	Duration
1	20	120	100
2	25	125	100
3	30	130	100
4	35	135	100
5	40	140	100
6	45	145	100
7	50	150	100
8	55	155	100

In the next section, in depth results of the simulation will be discussed.

6. Result

Recapping back the objective of the proposed scheme in Section 1, it is expected that the new scheme will provide better dependent variable results in terms of stability which is essential towards multimedia networks. In this section, only the effects of the CW, DIFS and packet size towards throughput stability will be discussed. Effects of the CW, DIFS and packet size towards delay and jitter is still in progress by the author.

In this experiment, the high priority network flow, fid 1 will be given focus as this network flows constitutes the result of the proposed scheme.

The analysis of the result is computed using SPSS. The average variance value of the throughput is examined to determine the stability of the throughput. This is because variance will show the degree of the value that deviates from the mean value of the throughput which reflects the throughput stability.

In Experiment CW, results showed that there is a significant improvement towards throughput stability in fid 1 shown in Fig. 3.

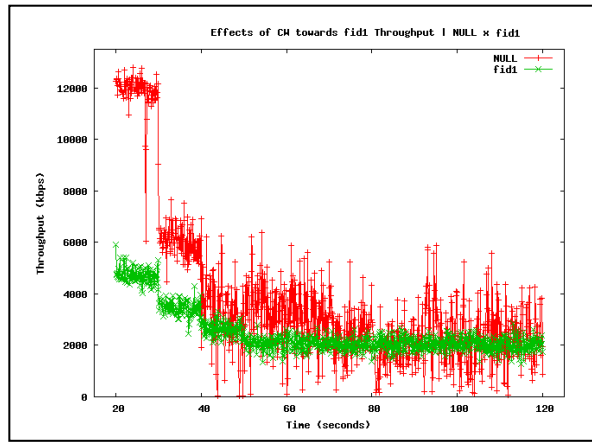


Fig. 3. Effects of CW=[0, 256] towards throughput stability in fid 1

After the fid 1 is configured to use the proposed scheme, the throughput can be seen to become more stable compared to the default configurations of the IEEE 802.11g. The effects of CW are further analyzed using SPSS, shown in Table 3 below.

Table 3. Effects of CW=[0, 256] towards throughput stability

Flow id 1 (fid 1)		
Experiment	Variance	Improvements
Null	9853278.176	-
Proposed Scheme (CW)	797388.494	91.907%

After computing the results in SPSS, the variance value of the throughput in the proposed scheme had been decreased by 9055889.68 which represent an improvement of 91.907% thus improving the throughput stability of the flow id 1.

Table 4 below describes the difference of throughput of Null and the proposed scheme in using different value of DIFS.

Table 4. Effects of DIFS = 16 μ s towards throughput stability

Flow id 1 (fid 1)		
Experiment	Variance	Improvements
Null	1273794.210	-
Proposed Scheme (DIFS)	1253284.326	1.610%

Results also showed that the throughput stability had increased when the DIFS period is shorter compared to Null. Null marked the variance at 1273794.210 while the proposed scheme recorded the variance with a decrease of variance of 20509.884 at 1253284.326. It is an improvement of 1.610%.

Table 5 below describes the difference of throughput of Null and the proposed scheme in using different value of DIFS.

Table 5. Effects of different packet size towards throughput stability

Flow id 1 (fid 1)		
Experiment	Variance	Improvements
Null	1273794.210	-
Proposed Scheme (DIFS)	549719.681	131.71%

Results computed from SPSS showed that using smaller packet size for high priority traffic flow will lead to smaller variance. From the table above, using 600 bytes of packet size instead of the default packet size of 1000 bytes results on smaller value on variance. This reflects more stability in terms of throughput of the high priority traffic of fid 1.

7. Conclusion

The primary contribution of this paper focuses on detailed investigation on many of the DCF based access method of the wireless LAN by past researchers, focusing on the deploying method of the Contention Window, DIFS and packet size. From the literature, most of them only consider throughput guarantee but not jitter requirements, which is essential to determine throughput stability of the wireless network. These aspects of QoS are very important for video streaming and interactive video applications.

The simulation model proposed in this paper is derived from the literature which includes tuning the Contention Window, DIFS and packet size to differentiate services between high priority and low priority traffic. From the findings and result of the experiments, it is viable that the author's approach to provide QoS in terms of throughput stability in wireless LAN is valid and applicable, thus improving the IEEE 802.11 to support Quality of Service.

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