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Service Differentiation Evaluation on Quality of Service in IEEE 802.11E Enhanced Distributed Channel Access (EDCA)

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A B S T R A C T

Quality of service is an important feature of networks, whether wired or wireless. As far as the user is concerned, a physical feature should not compromise service delivery. The IEEE 802.11e Medium Access Control (MAC) is asupplement to the IEEE 802.11 Wireless Local Area Network (WLAN) standard that supports Quality-of-Service (QoS) requirements for both data and real-time applications. The IEEE802.11e MAC is based on both centrally-controlled and contention-based channel accesses. One of the most important functions in this MAC is the contention-based channel access mechanism known as enhanced distributed coordination function (EDCF), which provides a priority scheme by differentiating the arbitration inter-frame spacing (AIFS), transmission opportunity (TXOP), and contention window parameters (CW_{min} and CW_{max}), for each access category. This paper evaluates the EDCA priority scheme to ascertain the effect of differentiating frames with different priorities on QoS using a MATLAB computer simulation model. This model was used to compute the optimal performance, maximum sustainable throughput, loss rate and service delay distribution for each priority class under saturation load. Information obtained from the analysis shows that changing the values for the arbitration inter-frame space number (AIFSN) and varying the contention window sizes (CW) resulted in the acquisition of the radio channel by the higher priority traffic than the lower priority traffic, causing the packets in the lower priority queue to be starved. From the performance of different access parameters, arbitration inter-frame space number (AIFSN) has more influence on the QoS performance of IEEE 802.11e EDCA Protocol, than the contention window (CW) size. It was also observed that small CW values generate higher packet drops and collision rate probability. Best practice is to use small values of AIFS to avoid starving the lower priority traffics while CW size has to be tuned in response to varying load. Finally, larger CW size is advised to reduce the chances of collision.

Keywords: *Arbitration inter-frame space number, Contention window, Enhanced distributed coordination function, Service differentiation*

1. Introduction

The IEEE 802.11 wireless LAN (WLAN) is a wireless technology used globally for connecting several devices and users. The main features of the IEEE802.11 WLAN technologies are its flexibility, ease of operation and cost effectiveness. This wireless technology provides people with unfettered access to wireless communication and computing environment in offices, institutions, homes, factories, hospitals, airports, etc (Ni et al., 2004).The use of multimedia applications has increased exponentially as users now require high-speed video, audio, voice and Web services regardless of whether they are stationary or mobile.

Wireless Local Area Network is set up in such a way that stations are connected wirelessly to a common access point (AP) that makes use of distributed multiplexing algorithm for sharing an access channel referred to as Media Access Control. This type of networking requires a media accesscontrol protocol to coordinate access to the wireless ink. In view of this, a number of network protocols have been devised to handle access to a wireless shared link; this includes distributed coordination function (DCF), point coordination function (PCF), enhanced distributed coordination function (EDCF) and hybrid coordination control function (HCCF).

The DCF protocol is the fundamental channel access mechanism based on Carrier Sense Multiple Access with Collision avoidance (CSMA/CA). It provides fair access to the channel for all devices or stations with no room for prioritization (Shah Ahsanuzzaman Md et al., 2010). The second protocol; PCF, is an optional capability that can be used to provide contention free services by allowing poll station to transmit without contending for the channel. These two protocols do not guarantee quality of service (QoS) requirements for real-time services. This is because all data traffic passes through the same queuing and transmission processes. As a result of the limitation of DCF and PCF protocols in providing guaranteed QoS for multimedia applications, EDCF and HCCF media access techniques were introduced in 2007 by IEEE 802.11e task group. These two protocols are hybrid coordination functions (HCF) and an enhancement of DCF and PCF protocols respectively.

Multimedia applications requiring some QoS support such as guaranteed bandwidth, delay, and jitter and error rate. Multimedia is a huge part of our wireless connection to the internet in recent times, especially with the advent of social media and people sharing so much information through multimedia platforms. The goal of this paper is to evaluate the effect of service differentiation on QoS of a simulated wireless network using IEEE 802.11e Enhanced Distributed Channel Access.

2. Literature Review

Wireless LANs based on the IEEE 802.11 Distributed Coordination Function (DCF) have been widely used in recent years due to their being easier in deployment and low cost (Crow et al., 1997). Since the current DCF can only support best effort traffic, the IEEE 802.11 Task Group E recently proposed a new contention-based channel access method called Enhanced Distributed Channel Access (EDCA) in the IEEE 802.11e standard (Choi et al., 2003). It supports standard QoS by providing differentiated classes of service in the MAC layer to deliver time-critical multimedia traffic, in addition to traditional data packets. Despite providing prioritized services, the EDCA still cannot efficiently support real-time applications like voice and video. The creation of the EDCA is due to extensive research works that were aimed at supporting prioritized service over the IEEE 802.11 DCF (Xiao et al., 2004). Recently, there have been some researchers conducted on EDCF with some results. Most of the researches were on improving the performance of the network (Tao et al., 2006).

Varying the medium access priority level has a tremendous improvement on QoS (Abbas, 2010). In other cases, analysis results for this standard were compared with the legacy IEEE 802.11 standard. Simulation results show that IEEE 802.11e out performs legacy IEEE 802.11 in terms of improved QoS parameters due to its flow differentiated channel allocation and better queue management architecture. Scaling of the contention window and using different inter frame spacing or maximum frame length for services of different priorities have also been proposed (Ada and Castelluccia, 2001). Two mechanisms; virtual MAC and virtual source, were proposed to enable each node provide differentiated services for voice, video, and data (Veres et al., 2001).

Meanwhile, some previous investigations into protocol performance have been considered for the distributed coordination function (DCF), the basic MAC access mechanism for IEEE 802.11 WLANs. Priority scheme has proven to be effective by differentiating the backoff window. The higher priority class uses the window $[0, 2i+1 -1]$ and the lower priority class uses the window $[2i+1, 2i+2 -1]$, where i is the backoff stage (Deng et al., 1999). Simulation was conducted to analyze the proposed scheme. The results show that DCF is able to carry the prioritized traffic with the proposed scheme.

Generally, based on the reviewed literature, a number of modifications of the IEEE 802.11 WLAN EDCA protocols have recently been proposed. These proposals have the major drawback of not x-raying the characteristics of the medium access parameters of IEEE 802.11e EDCA protocol and how its settings influence network traffics. In the current paradigm, this paper is intended to model the IEEE 802.11e contention based EDCA protocol and the IEEE 802.11b network bearer using the recommended network QoS parameters. The rest of this paper will therefore present EDCA protocol model simulation and simulation results using MATLAB Simevent which will identify the effect of service differentiation on network QoS parameters used to overcome the aforementioned limitations of the standard.

3. System Design

Wireless LAN architecture in Fig. 1 was adopted in this paper and the model was based on the unique topology. The AP in the architecture uses the EDCA protocol to control access to the medium. The network comprises of four QSTA, transmitting background, data, video and voice traffics, and wirelessly linked to a central server interface system that is considered as the WLAN AP. The central server system connects the WLAN QSTA to a second layer Ethernet distribution systems (Switch) interfaced to the VSAT terminal through a third layer device (router). Each station transmits packets when it senses that the AP is idle. The AP is such that only one QSTA can transmit packets when the medium is idle. If a station is transmitting, other stations that have packets to transmit will wait for the medium to be idle before contending to use the medium. Arrival pattern of the packets from the QSTA is typically that of on-off. Packet generation was based on different distribution while arrival pattern is distributed following exponential distribution law. The inter-arrival time and service time patterns follow the exponential service distribution. Each QSTA intending to transmit, decrements its binary exponential counter to zero before sending packets in bursts, after sensing the WLAN AP to be idle. This is for the station to gain access into the network with standard QoS parameters.

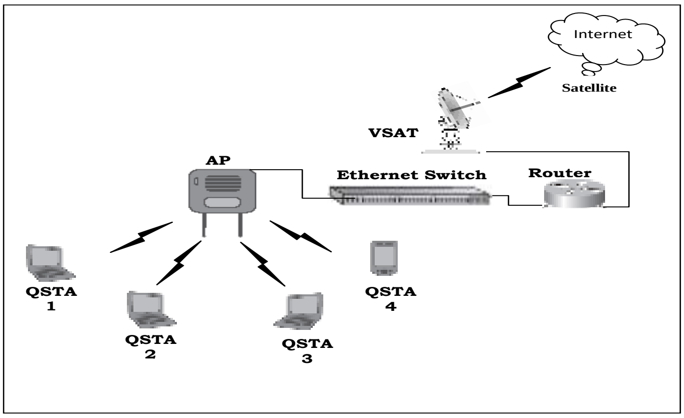


Fig. 1 - WLAN scenarios

The rate of arrivals is higher than the service rate and the number of active stations is varied so that at a particular interval of time the QoS parameters such as throughput, delay, and loss rate are individually investigated. This work is based on the activities that take place at the WLAN QSTA and AP, therefore the model is based on WLAN AP which operates on the principles of CSMA/CA.

3.1 Model development in MATLAB

The model development in Fig. 2 was implemented in MATLAB SimEvent environment. The simulation model consists of sources, access point and sink. The sources are made up of generators that generate packets based on different processes (see chapter four). It has parameters such as arrival rate and packet length. The sources also contain, set attribute blocks, FIFO queue blocks of different capacity, output switch that manages arrivals and departures of packets, entity sink for dropped packets, timing mechanism that implements AIFS and binary exponential back-off counter with retransmission (m) loop for packets yet to attain retransmission limit and probes. These blocks are replicated into four places with each representing a different AC as shown in Fig. 3 and 4.

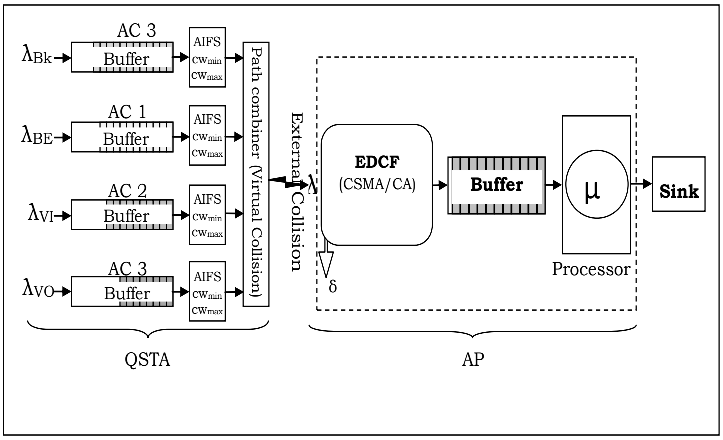


Fig. 2 - Implementation of WLAN EDCA model

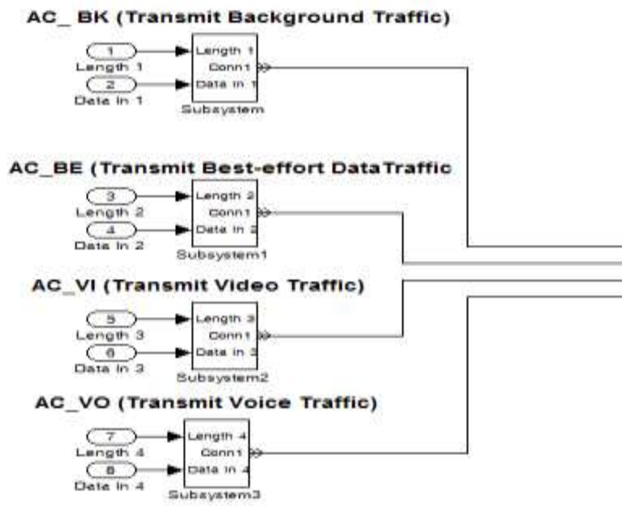


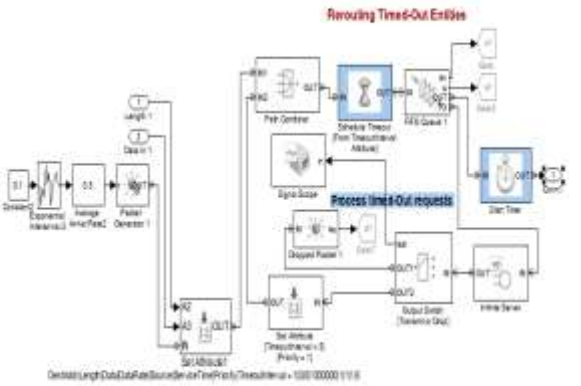
Fig. 3 – MATLAB simevent Model of four traffic Sources

$$\lambda >> \mu, \lambda = \sum_{n=1}^{n} (\lambda_{VO} + \lambda_{VI} + \lambda_{BE} + \lambda_{BK}) \quad (1)$$

*where*VI= Video Traffic, VO= Voice Traffic, D = Data Traffic, λ = arrival rate, δ=Packet loss rate due to collision and Acknowledgement timeout of packets, μ = service rate, AC=Access Category, and n = Number of nodes generating a particular traffic.

Fig. 2 represents the network model of IEEE 802.11e contention-based protocol. The model consists of a QSTA with four AC's that represent a virtual station, EDCA MAC controller which uses the fundamental CSMA/CA protocol and a destination sink. Each of the traffic types uses the parameters of the AC which is periodically advertised by AP to access the channel.

Every station maintains four transmit queues one for each AC as shown in Fig. 2. The EDCA protocol implements an independent back-off entity for each AC. Each queue works as an independent DCF station and uses its own parameter set (AIFS, CWmin, CWmax and TXOP limit). Similarly, to an 802.11 DCF node, each of the 4 ACs with packet to transmit waits for a period of AIFS before accessing the medium. If at the end of AIFS and the medium is still busy, the station initiates back-off algorithm. It calculates its exponential value of the back-off counter and keeps decreasing the value of its back-off counter after the air medium is sensed to be idle, but freezes when the medium is sensed busy again. When backoff timer becomes zero, the AC transmits. The number of packets transmitted from its queue is a function of TXOP limit.



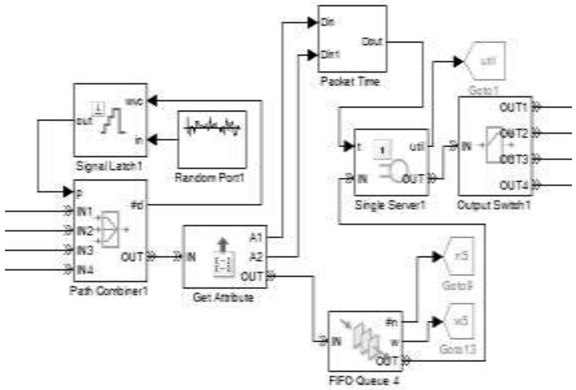


Fig. 4 - MATLAB simevent Model of one traffic Source

Fig. 5 – MATLAB simevent Access Point model

The access point as shown in Fig. 5 consists of a single path combiner which combines the sources' based on CSMA/CA mechanism, signallingblockset, get attribute block, FIFO queue, single server, output switching system and probes. The destination stations (sink) consist of get attribute blocks, packet timer blocks, output switch and probs as shown in Fig. 6.

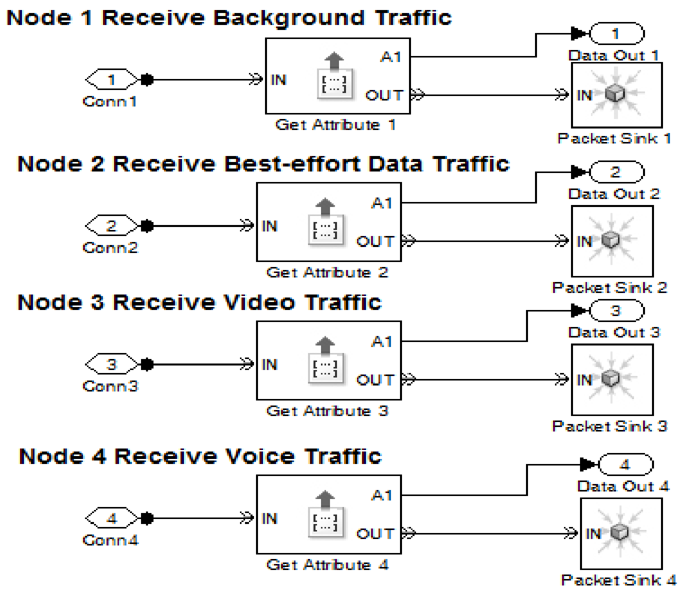


Fig. 6 - MATLAB simevent of the Sink

The packets transmitted from each AC to the WLAN AP follows exponential distribution. The sources transmit packets in burst when the server is idle. The WLAN server was modelled based on the principle of CSMA. It serves packets for a period through the out port on a sequence of first-in-first-out. The service pattern follows exponential distribution process. In this model, collision occurs when two sources send data at the same time as described in figure 3.4. The traffic intensity and the traffic trends of the WLAN were probed during and after simulation time.

The traffics transmitted from the source stations are received at the sink via the single server. A stop time is attached to the sinks to ascertain the delay or time taken to transmit the packets or traffic from the source to the sink. The QoS parameters such as throughput, delay and loss rate are also probed and displayed graphically. Note that the mean QoS are computed and displayed at the end of the 3600s simulation run time. The transmission rate of background, data, video and voice were varied while other parameters were kept constant for different arrival rates, different attempts, and different service rates respectively.

3.2 Performance Metrics

At the end of the simulation time, the mean value of busty traffic transmitted by the sources to the WLAN-AP, the mean value of traffic served by the WLAN-AP and the mean value of traffic loss as a result of collision and difference between the generated traffic time and the served traffic time were computed. Below are the performance metrics used for verification and evaluation.

- Throughput

Throughput (S_c) is the fraction of time the network transmits the packet payload bits of priority-c successfully [6]. It is a measure of how fast we can actually send data through a network. In essence, it is the amount of data transferred in a given amount of time, usually expressed in bits per second (bps). However, multimedia applications such as video and audio are required to have sufficient throughput to meet the QoS standards (Yang and Li, 2004):

$$\gamma = \frac{1}{C}\sum_{i=1}^{c}\left(\left(\frac{1}{T_{end}-T_{start}}\right)(\text{NS8bits})\right) \tag{2}$$

where, γ = Throughput in Mbps, T_{start} = Transmission start time in seconds, T_{end} = Transmission end time in seconds, C = Total number of flows in the network., N = Number of packets received successfully, and S = successfully delivered packet size.

- Average End-to-End delay

The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is generated from the source. It can be said that latency is made of four components: propagation time, transmission time, queuing time and processing delay (Forouzan et al., 2007). On the other hand, medium access delay means the time from the moment a packet is ready to be transmitted to the moment the packet starts its successful transmission (Zhang et al., 2007). Packet delay is also seen as the duration from when the packet arrived at the front (of queue) of the sender to the time it is successfully received at the receiver (Zhang et al., 2007). Frame Transmission from source nodes to destination nodes (sinks) via the MAC EDCA controller was monitored for intervals, M and the mean delay taken for the traffic computed. The average end-to-end delay is calculated using the following equation:

$$Average\text{ end-to-end delay} = \frac{1}{N}\sum_{i=1}^{n}(r_i + n_i) \tag{3}$$

where, N = Number of successfully received packets, i = Unique packet identifier, r_i = Time at which a packet with unique identifier is received, and N_i=Time at which a packet with unique identifier *i*.

- Packet Loss

A packet is lost due to queue overflow (at the sender side), i.e., by the time the packet arrives at the MAC layer, the corresponding AC transmit queue is already full. The packet loss rate is directly proportional to the throughput/bandwidth. The higher the throughput, the faster the packets are transmitted and the lower the chances of packet losses.

$$\text{Mean loss} = \frac{Total\ loss}{N} = \frac{\sum_{i=1}^{n} Loss_i}{N} \tag{4}$$

where $Loss_i$ = Total offered traffics – Total served traffics – Total traffics pending = Total traffic that collided + Total unacknowledged traffic transmitted.

$$\text{Mean packet loss rate} = \frac{\sum_{i=1}^{n} Loss_i}{Total\ traffic\ for\ transmission} \tag{5}$$

During an observation Time = N* dt

3.3 Simulation parameters.

Simulation model is applied in this research to verify access parameters as it affects some QoS parameters in IEEE 802.11 Wireless LAN EDCA protocol. The IEEE 802.11e simulation parameters used are shown in Table1.

Table 1 - Simulation parameters (Szymon Szott, 2011

Parameters	Value
Basic Channel rate	1Mbps
Maximum Channel rate	11Mbps
Packet size (bytes) [VO, VI, BE, BK]	160, 1280, 1500, 660
Packet interval (ms) [VO, VI, BE, BK]	20, 10, 12.5, 12.5
Data rate (kbps) [VO, VI, BE, BK]	64, 1024, 960, 1000
Retry limit	5
Slot Time	20µs
SIFS	1 x 20µs=20µs
PIFS	20µs + 1 x 20µs=40µs
DIFS (DCF)	20µs + 2 x 20µs=60µs
AIFS[3] (AC_VO)	20µs + 2 x 20µs=60µs
AIFS[2] (AC_VI)	20µs + 2 x 20µs=60µs
AIFS[1] (AC_BE)	20µs + 3 x 20µs=80µs
AIFS[0] (AC_BK)	20µs + 7 x 20µs=160µs
CWmin, CWmax (DCF)	31, 1023
CWmin[3], CWmax[3] (AC_VO)	7, 15
CWmin[2], CWmax[2] (AC_VI)	15, 31

CWmin[1], CWmax[1] (AC_BE)	31, 1023
CWmin[0], CWmax[0] (AC_BK)	31, 1023
TXOP Limit	3000µs
simulation run time	3600s

4. Simulation Results

Simulation analysis was carried out in terms of service differentiation effect. This involves examining the arbitration inter frame space number (AIFSN) and the contention window (CW) size of the default settings to identify its impacts on QoS parameters and to gain more understanding about the differentiation effects. The scenario considered two traffic types; voice and best effort data. Voice traffic was selected due to its sensitivity to delay and throughput, and the delay tolerability of the best effort data traffic. The aim in this scenario is to show the effect of the AIFSN and CW sizes on the performance of higher priority traffic compared to the lower priority traffic. In this simulation, each traffic type includes one station, i.e. one voice AC and one best effort data AC. The data rate of the voice station and that of the best effort data station is 1Mbps.

The contention window size of both traffic (Voice and Best effort Data) is fixed at $CWmin_{1,3} = 31$ and $CWmax_{1,3} = 1023$ respectively while their arbitration inter-frame space number is varied ($AIFSN_1 = 3$ and $AIFSN_3 = 2$). At the same $CWmin_{1,3}$ and $CWmax_{1,3}$, $AIFSN_{1,3}$ was varied as 5 and 2 to see how this impact on the output of voice and best effort data traffics. Then $CWmin_{1,3}$ and $CWmax_{1,3}$ of the best effort data and voice were varied as (31, 7) and (1023, 15) while $AIFSN_{1,3} = 2$ (best effort data and voice traffics). This is to study the effect of varied CW size on the QoS of higher and lower priority traffics. The network load was increased from 0 to 1000kbps during the simulation run time of 3600s. Apart from parameters highlighted in this scenario, the simulations were run at the same traffic characteristics like the other scenarios. At the end of each simulation, result was collated for the analysis. The throughput, delay and loss rate of voice and best effort data were obtained under all conditions.

4.1 Throughput analysis

- Impact of AIFS Number on Throughput

Figure 7 shows the mean throughput of two traffic classes at varied AIFN and the same CW sizes

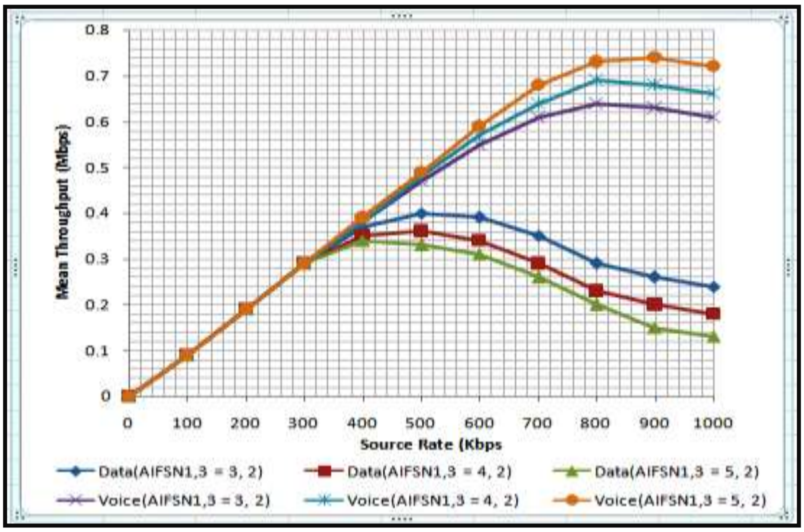


Fig. 1 - Mean throughput of two traffic classesat varied AIFSN and the same CW sizeversus source rate

The first case shows the result of voice and best-effort data traffics with different arbitration inter-frame space number ($AIFN_{1,3} = 3, 2$) and the same Contention window size ($CWmin_{1,3} = 15$ and $CWmax_{1,3} = 1023$). As observed from the graph, voice traffic constitutes approximately 61% of the aggregate throughput while best-effort data traffic makes the remaining 39%. It is clear that voice traffic grabbed most of the bandwidth. The lower priority traffics starts dropping as source rate increased to 500kbps. At the same rate higher priority traffics maintained a positive throughput and began to decrease from source rate of 800kbps. The optimum performance of the medium was observed at a source rate of 700kbps

The second case shows the aggregate throughput of voice and data traffic versus source rate for $AIFSN_{1,3} = 4, 2$ at fixed CW size. It is observed that voice traffic achieved saturation throughput of 0.69Mbps at 800kbps source rate and began to fall afterwards. The throughput of best-effort data traffic decreased to 0.36Mbps at 500kbps source rate. As source rate increased, the throughput begins to depreciate. The voice traffic therefore contributes 65% of the aggregate throughput against 35% of best-effort data at an optimum performance of 700kbps source rate.

In the third case, channel access parameters were finally set to; $AIFSN_{1,3}$ = 5, 2, $CWmin_{1,3}$ = 31 and $CWmax_{1,3}$ = 1023. The result shows that the throughput of voice traffic is recorded its maximum performance at 900kbps while that of best-effort data traffic reduced to 400kbps as source rate varied from 0kbps to 1000kpbs. The reduction in best-effort data throughput introduced a little increase in the throughput of voice traffic to 68% while the throughput of best-effort data traffic was negative as it reduced to 33% against higher values for the previous figures. The optimum performance was also observed to be stable at 700kbps source rate.

In comparison, the combined effect of the result of these three different cases enables us to examine closely the contribution of each of the arbitration values to service differentiation. As identified, voice traffic throughput achieved 61% while best-effort data recorded 39% of the aggregate throughput. However, the effect of an increase in AIFSN for best-effort data traffic from 3 in the first case to 4 in the second case decreased the throughput result of data traffic by 4% and introduced a little increase in voice throughput by the same percentage. In the third case ($AIFSN_{1,3}$ = 5, 2 at the same CW size) we observed that, voice traffic throughput further increased by 3% while best-effort data traffic throughput decreased by the same percentage. This result however, shows that high AIFSN for best-effort data traffic improves the throughput of voice traffic and vice versa. It also shows that these changes have a negligible effect on the optimum performance of the system as it remained stable at 700kbps source rate.

- Impact of CW Size on Throughput

Figure 8 is the simulation curve for the Mean throughput of two traffic classesat varied CW size and the same AIFSNversus source rate.

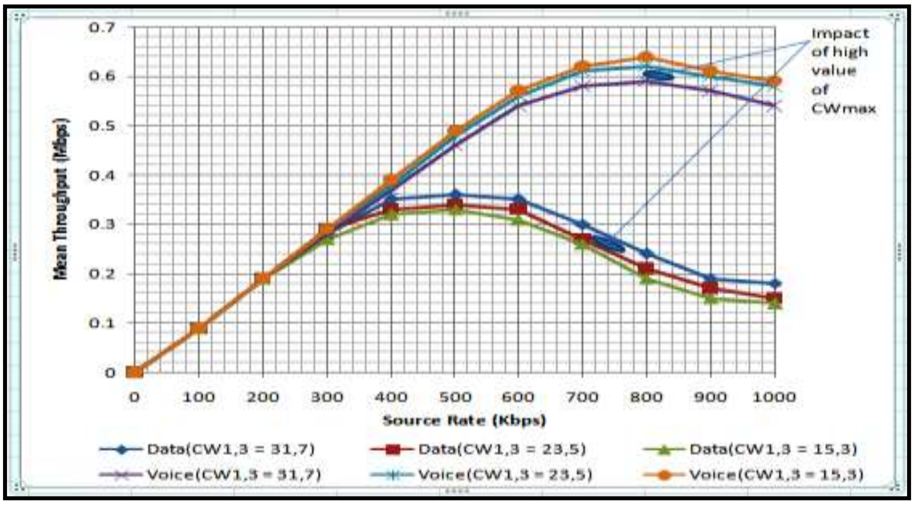


Fig. 8 - Mean throughput of two traffic classesat varied CW size and the same AIFSNversus source rate

In this case, the entire ACs have the same AIFSN value but different CW size was also examined. The traffic priority differentiation is thus only realized through differentiating the contention window size of voice and best-effort data traffics. In Fig. 8, the result of three different cases used in the analysis of the impact of CW size on throughput is shown.The entire cases were simulated at a varied source rate of 0 to 1000kbps.

The first case is the result of voice and best-effort data traffics with the same $AIFSN_{1,3}$ = 2, and different Contention window size ($CWmin_{1,3}$ = 31, 7 and $CWmax_{1,3}$ = 1023, 15) at $M_{1,3}$ = 2. The aggregated saturation throughput as the source rate was symmetrically increased in each AC from 0kbps to 1000kbps, favours voice traffic. This is as expected and proves the service differentiation ability of contention window size. The voice traffic contributes 62.5% of the aggregate throughput. As source rate varied from 0 to 100kbps, voice recorded an increasing throughput. The throughput was highest at 800kbps, above which it began to drop. Data traffic on the other hand recorded 37.5% throughput and a maximum throughput attained at a source rate of 500kbps, beyond which it decreases symmetrically as collision increased. However, an optimum performance of the medium is observed at 600kbps source rate. The second case shows the aggregated saturation throughputs performance when symmetrically decrease the size of CW size ($CWmin_{1,3}$ = 23,5 and $CWmax_{1,3}$ = 364,11) in each AC while maintaining a fixed AIFS number for all AC's. The result shows that voice trafficis65% of the aggregate throughput while best-effort data traffic contributed the remaining 35% of the aggregate throughput. The optimum throughput value of the medium remained stable at 600kbps.

In the third case, contention window size of each AC was further decreased ($CWmin_{1,3}$ = 15,3 and $CWmax_{1,3}$ = 64,7) while the AIFSN remained fixed. This is to further examine the effectiveness of CW size in differentiating voice and best-effort data services. The voice traffic contributed 67% to the total throughput while best-effort data traffic recorded approximately 33%. The optimum throughput performance at this point was also noted to be the same with the other cases.

The aggregated throughputs for the three CW variations from simulation are compared. As observed, there is good agreement between the different CW size variations. The aggregate saturation throughput decreased with increasing number of source rates due to increased collision and backoff in the network. The result shows that voice traffic at $CWmin_{1,3}$ = 15,3 and $CWmax_{1,3}$ = 63,7 recorded the highest throughput, followed by$CWmin_{1,3}$ = 23,5 and $CWmax_{1,3}$ = 363,11, and lowest at $CWmin_{1,3}$ = 31,7 and $CWmax_{1,3}$ = 1023,15. On the other hand, throughput of best-effort data traffic was lowest at the first case and highest at the last case. In other words, an increase in CW size decreases voice traffic throughput and favours best-effort data traffic due to reduced collision and backoff in the network.

It was also observed that, as the CW size of the first case was increase, the throughput showed just 2% reduction for Voice traffic and the same percentage increase for best-effort data traffic. When the CW size of the second case increased to $CWmin_{1,3}$ = 31,7 and $CWmax_{1,3}$ = 1023,15, a significant increase in throughput values of best-effort data traffic and decrease in voice traffic was observed respectively. This result is the effect of significant change in CWmax of best- effort data traffic from 363 to 1023.

Generally, Fig. 7 and 8 however revealed the relationship between AIFSN and CW size. A comparison shows that AIFS has a more dramatic effect on traffic differentiation. However, increasing AC2's AIFS by one has almost the equivalent effect of doubling its CWminvalue. But setting AIFS difference to too large a value may lead to traffic starvation for low priority traffics. More also, AIFS value in the case of Fig. 7 has more effect on optimal throughput performance of the medium than CW size in the case of Fig. 8 as it was stable at 700kbps source rate against 600kbps source rate recorded in the later parameter.

4.2 Delay analysis

- Impact of AIFSN on Delay

The mean delay of two traffic classes at varied AIFSN and the same CW size against source rate is shown in Fig. 9.

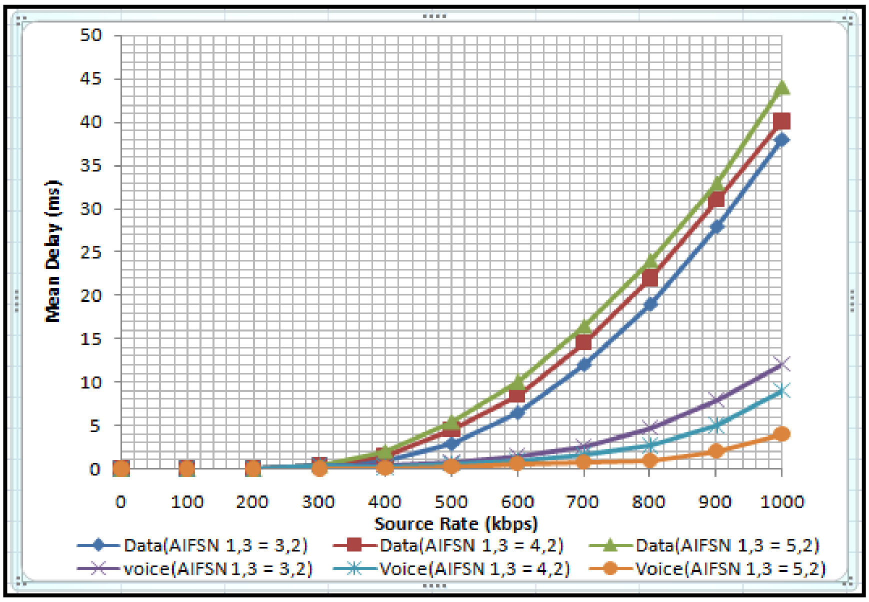


Fig. 9 - Mean delay of two traffic classesat varied AIFSN and the same CW size versus source rate

Another QoS performance metrics considered in the third simulation scenario is medium access delay. Figure 9 shows the result of the three different cases used to analyze the impact of AIFS number on delay. In this scenario, network load was varied in steps of 100kbps from 0kbps to 1000kbps, for voice and best-effort data traffic while maintaining the same model simulation parameters. The first case shows the effect of setting the AIFSN $_{1,3}$ = 3, 2 while fixing the $CWmin_{1,3}$=31 and $CWmax_{1,3}$ = 1023 on the medium access delay of voice and best effort data traffics. As observed, voice traffic records 22% of the overall access delay against 78% of best-effort data. In light load of 0kbps to 500kbps, the lower priority traffic had the bandwidth it needs to transmit with a very little delay. This is because there are still fairly enough network resources for the entire traffic. Under heavy load of 500kbps to 1000kbps, lower priority traffic was heavily delayed as higher priority traffic grabbed most of the bandwidth, witnessing a very little delay from 700kbps to 1000kbps. At this point, voice and best-effort data traffics became clearly differentiated. This result reaffirms the findings in the first case of Fig. 7 which also demonstrates the differentiating ability of AIFS as it provides higher priority to voice traffic.

The second case illustrates the effect of changing the AIFSN $_{1,3}$ = 4, 2 while fixing the CW size to 31 and 1023 on the mean delay of the voice and best-effort data traffics at a varying source rate. It is observed that best-effort data recorded 86% of the overall delay at maximum of 40ms while voice traffic has only 14% of the total delay at a maximum of 9ms. The third case examines the effect of setting AIFSN $_{1,3}$ = 5, 2 while fixing the CW size to 31 and 1023 on the mean delay of the voice and best effort data flows at a varying source rate. Voice traffic records a maximum of 4ms delay at 1000kbps source rate against 44ms delay recorded by best effort data. Voice traffic as well contributed to 6% of the aggregate delay in the simulation whereas best effort data witnessed 94% of the aggregate delay.

The aggregate delays of each traffic type are also compared in Fig. 9. It was observed that first, as the source rate increases, for either of the AIFS number variation results, the delays for both traffic classes increase. The reason is as follows. In the unsaturated case, the collision is not severe with the collision probability less than 0.1, and the queue does not build up. As a result, the queuing delay is small and the MAC layer service time dominates the delay.

When the number of competing traffics increases, the collision increases and so does the MAC layer service time. Secondly, the delay for the voice traffic is much smaller than that for the best-effort data traffic, which is consistent with the fact that the voice traffic has a higher priority than the best-effort data traffic in terms of channel access. Thirdly, when the value of the AIFSN in AC1 changed from 3 to 4 and AC3 fixed at 2, the total delay of voice traffic decreased by 10ms approximately 9% while that of best effort data increased by 14.5ms which is 9% increment. At the same AC3 parameters, AC1 AIFSN was ones again changed from 4 to 5. The mean delay of the best effort data traffic increased by 13ms (8%) while Voice traffic delay reduced by 11.8ms which also amount to 8% increase. Finally, it is important to point out that when we keep the network working in the unsaturated case, the delays for both traffic classes are sufficiently small to satisfy their QoS requirements, where the one-way transmission delay for interactive communications like VoIP and videoconferencing should be preferably less than 150ms, and must be less than 400ms.

- Impact of CW Size on Delay

The simulation curves for the mean delay of two traffic classes at varied CW size and the same AIFSN against source rate is shown in Fig. 10.

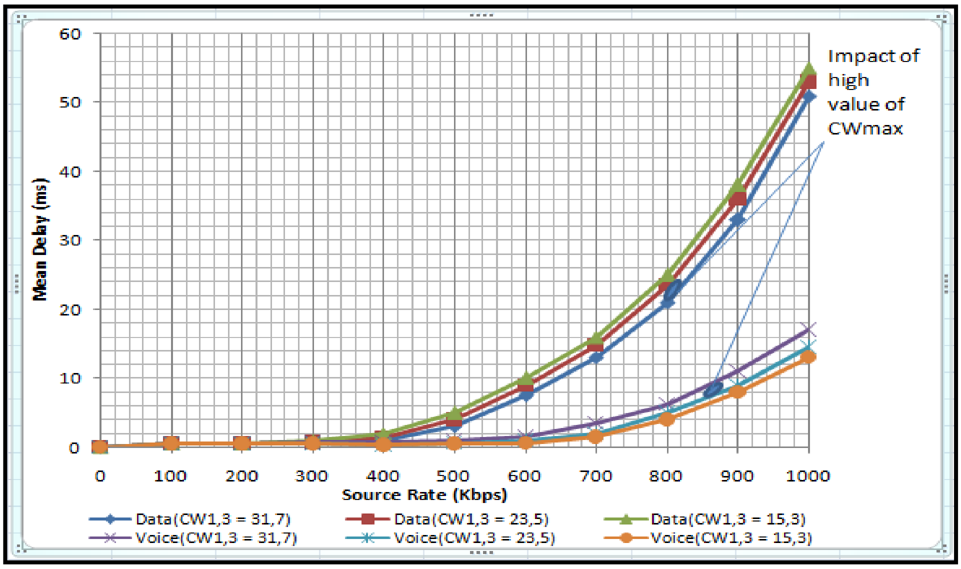


Fig. 10 - Mean delay of two traffic classesat varied CW size and the same AIFSNversus source rate

The forgone simulation only considers the effects of the AIFSN on the delay differentiation of voice and best-effort data. The IEEE 802.11e standard also defines traffic differentiation by utilizing different CW size. In Fig. 10, the result of three different cases used in the analysis of the impact of CW size on delay is shown. The entire cases were simulated at a varied source rate of 0 to 1000kbps.

The first case examines average delay effect of setting $CWmin_{1,3}$= 31, 7 $CWmax_{1,3}$ = 1023,15 while fixing the AIFSN $_{1,3}$ = 2 on the mean delay of the voice and best-effort data traffic. The graph reaffirms the mean throughput performance result of the first case of Fig. 8. However, minimal delay was recorded from 0 to 400kbps network load. As the network load increases beyond this load, best-effort data packet began to witness collision while voice traffic started dropping at a source rate of 700kbps. The best effort data contributed 75% to the aggregate delay while voice traffic added the remaining 25% to the mean delay.

On the other hand, the second case shows how setting $CWmin_{1,3}$= 23, 5 and $CWmax_{1,3}$ = 364,11 affect delay of both traffics while fixing the AIFSN $_{1,3}$ = 2. This result verifies the throughput result of Fig. 8 second case. As observed, the best effort data changed to 81% whereas voice traffic delay reduced to 19% of the total delay. Finally, we changed the access parameter setting to $CWmin_{1,3}$= 15, 3, $CWmax_{1,3}$ = 64,7 and fixed the AIFSN $_{1,3}$ = 2 in the third case. Best effort traffic once more increased to an aggregate of 153ms which is 84% of the overall delay against 16% of the total delay recorded by voice traffic.

In comparison, it is observed that as CW size of the first case was decreased to $CWmin_{1,3}$ = 23, 5 and $CWmax_{1,3}$ = 364,11, the best-effort data delay increased by 6% while voice traffic delay decreased by the same percentage. The best-effort delay further increased by 3% and voice traffic decreased by the same value, when decreased the CW size parameter of the second case to $CWmin_{1,3}$ = 15,3 and $CWmax_{1,3}$ = 64,7.

Generally, this result shows that high CW size especially under saturation condition improves the performance of lower priority traffics as it decreases the chances of collision and backoff in the network. At low CW size voice traffic experienced the least delay due to the collision effect. We also noted the 3% impact introduced by high reduction of CWmax of best-effort data traffic from 1023 in the second case to 64 in the third case. This impact is advantageous to higher priority traffic and against the lower priority traffic. A comparison of the graphs shown in Fig. 9 and Fig. 10 however, reveals the relationship between the impacts of AIFS number and CW Size on mean delay.

4.3 Packet loss rate analysis

Packet drop and loss rate is the third important factor that has a great effect on the IEEE 802.11e WLAN performance for QoS support. We subtract the number of packets successfully received by the receiver (QoS access point in our case) from the total number of packets sent by the sender (each ACs) in order to calculate the number of packets dropped or lost in the transmission medium. In this case, network load was varied in steps of 100kbps from 0kbps to 1000kbps, for voice and best-effort data traffic while maintaining the same simulation parameters.

- Impact of AIFSN on Loss Rate

Figure 11 shows the result of three different cases used in the analysis of the Impact of AIFS number on loss rate.

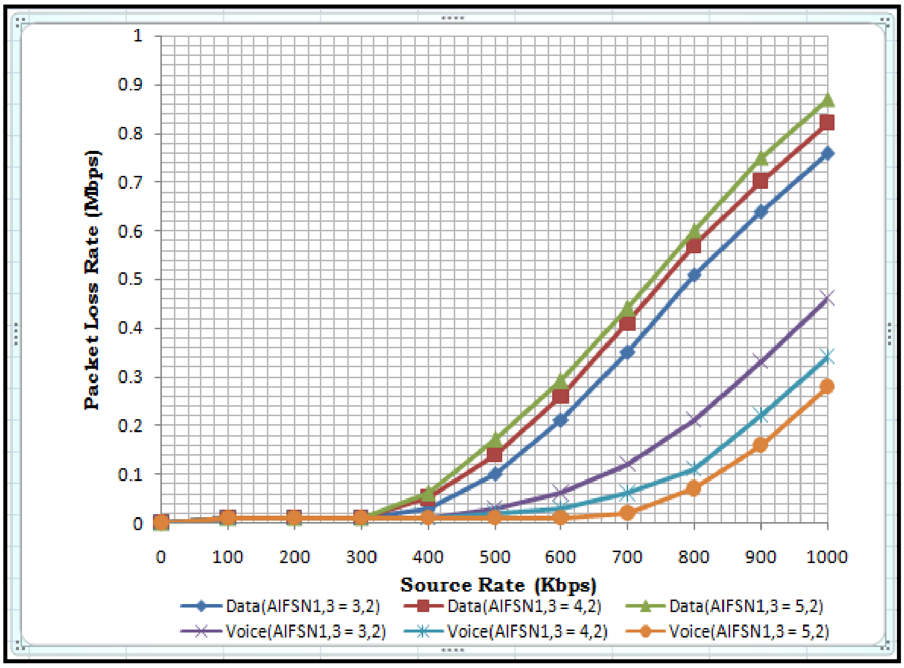


Fig. 11 - Packet Loss rate of two traffic classesat varied AIFSN and the sameCW sizeversus source rate

The first case examines the effect of setting the AIFSN $_{1,3}$ = 3, 2 while fixing CWmin, max to 31,1023 on the mean loss rate of the voice and best-effort data flows. It is clearly observed that service differentiation between the two traffics, is according to the priority levels offered by AIFSN. This difference appears more when the channel is heavily loaded. The data packet drop starts when the source rate is 400kbps, due to the fact that best-effort data has the lowest priority. On the other hand, as the voice traffic is considered, the packet drop starts when the source rate increases to 700kbps. This reflects the fact that voice traffic has the highest priority on the channels when it is heavily loaded. The percentage of the packet drop reaches up to 68% for the maximum channel load considering the best-effort data traffic, while it reaches up to 32% for the voice.

In the second case, the AIFSN for best-effort data in the first case was increased to 4 while fixing CWmin, max to 31, 1023. As observed, the best-effort data traffic records 78% of the overall packet loss whereas voice traffic contributed only 22%. The third case shows the effect of setting the AIFSN $_{1,3}$ = 5, 2 while fixing CWmin, max to 31,1023 on the mean Loss rate of the voice and best-effort data flows. The loss rate of best-effort data traffic increased to 84% while that of Voice traffic reduced to 16% of total Packet loss rate.

In comparison, the graph above identifies the service differentiation impact of AIFSN on Packet loss rate. As the AIFSN of best-effort data increased to 4, its overall loss rate increased by 350Kbps, which is approximately 10% increase of best effort traffic in the first case. On the other hand, voice traffic decreased by 430Kbps. When the AIFS value of was further set to AIFSN $_{1,3}$ = 5, 2, the overall best-effort data loss rate increased by 230Kbps while voice traffic reduces by the same percentage.

- Impact of CW Size on Loss Rate

Figure 12 shows the result of three different cases with respect to the effect of varied CW size and fixed AIFSN on packet loss rate.

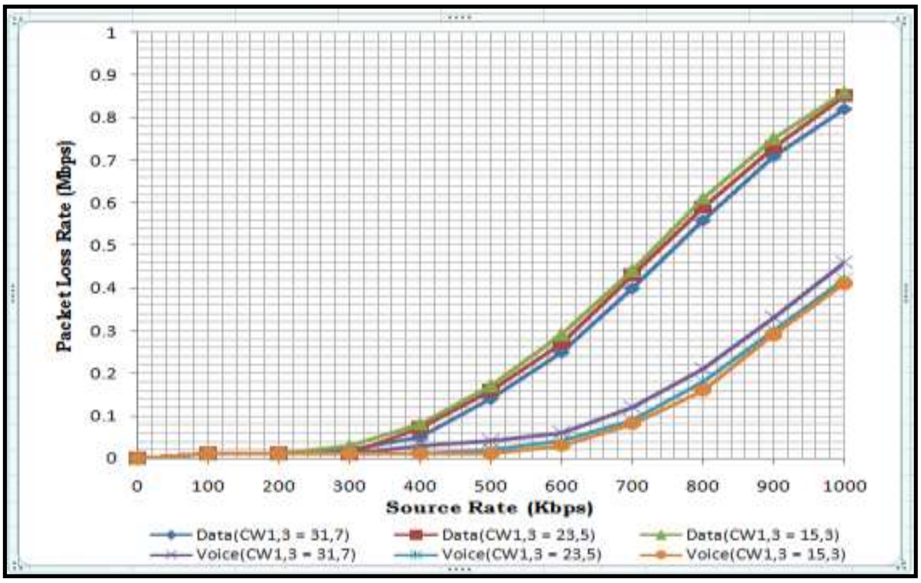


Fig. 12 - Packet Loss rate of two traffic classes at varied CW size and the same AIFSNversus source rate

The first instance shows the effect of setting the $CWmin_{1,3}$ = 31, 7 and$CWmax_{1,3}$ = 1023,15 at a fixed $AIFSN_{1,3}$ = 2 on the mean loss rate of the voice and best-effort data traffic. The graph affirms the service differentiation ability of CW size. For the best-effort data traffic, the packet began to drop when the source rate increased to 300kbps. On the other hand, as the voice flow is considered, the packet drop starts when the source rate increases to 600kbps. The percentage of the packet drop and loss rate reaches up to 70% for the maximum channel load considering the best effort data flow, while it reaches up to 30% for the voice traffic.

The second case describes Packet loss rate versus source rate when the CW parameter of best-effort data and voice is changed to $CWmin_{1,3}$ = 23,5 and $CWmax_{1,3}$= 364,11. As observed, the best-effort data traffic recorded 74% of aggregate loss rate while the remaining percentage is attributed to loss rate due to voice traffic.

In the third case, the CW parameter of best-effort data and voice was further changed to$CWmin_{1,3}$ = 15,3 and $CWmax_{1,3}$ = 64,7 at a fixed$AIFSN_{1,3}$ = 2. Best-effort data traffic loss rate was observed to be minimal at 300kbps as the overall loss rate attained 76% of the aggregate result. On the other hand, voice traffic contributed 14% to the overall packet loss rate. In fact, the system throughput is inversely proportional to the number of dropped and lost packets. In addition, packet drop has great effect on the network average end-to-end delay. Relatively, delay is directly proportional to the number of dropped packets.

Comparing the three different cases in Fig. 12, it is observed that at first setting, the best effort data packet loss rate was 70% and 30 % for voice traffic. This result increased by 4% and decreased by the same percentage in the second setting. In the third setting ($CWmin_{1,3}$ = 15,3, $CWmax_{1,3}$ = 64,7 and $AIFSN_{1,3}$ fixed at 2) the result of the best effort data traffic result of the second case further increased by 2% while it decreased by the same percentage for voice traffic.

Conclusively, enhanced Distributed Channel access and coordination Function (EDCF) in IEEE802.11e provide adequate throughput, minimal delay and high reliability for multimedia data such as VoIP and video streaming. From the analysis carried out in chapter four, the result of the proposed model as validated shows that EDCA protocol provides mechanism for service differentiation. This improvement is a result of the trade off in decrease in quality of the lower priority traffic almost up to the point of starvation. The standard is not considered efficient when used for applications that involve data and background traffic in the transmission, but mainly voice and video. The acquisition of the radio channel by the higher priority traffic is a lot more aggressive than for the lower priority. Higher priority traffic gained immensely, while lower priority traffic suffered.

The model studied analytically the impact of CW size and AIFS number in EDCA and how to apply it to IEEE 802.11 Wireless LAN. The result of the study shows that AIFSN has more effect on the QoS performance of IEEE 802.11e “EDCF Protocol”. It was also seen that small contention window values generate higher packet drops and collision rate probability.

This implies that wireless networks that place emphasis on background data or best effort traffic are not suitable for the application of this protocol. If a network relies primarily on voice and video traffic, then it is ideally suitable.

References

Abbas, A. (2010). Fairness and quality of service issues and analysis of IEEE 802.11e Wireless LAN. *International Journal of Information and Communication Engineering, 6*(3).

Ada & Castelluccia, C. (2001). Differentiation mechanisms for IEEE 802.11. in Proceeding of IEEE INFOCOM’01, Anchorage, Alaska, April 2001.

Choi, S., Prado, J., Mangold, S., & Shankar, S. (2003). IEEE 802.11e contention-based channel access (EDCF) performance evaluation," in Proceeding of IEEE ICC'03, May 2003.

Crow, P. et al (1997). IEEE 802.11 wireless local area networks. *IEEE Communication Magazine, 35,* 116–126.

Deng, D.J. et al. (1999). A priority Scheme for IEEE 802.11 DCF Access Method. IEICE Transaction on Communications., E82-B(1), 96-102.

Forouzan, B. A. (2007).Data Communication and Networking. Fourth Edition, McGraw-Hill, a New York, NY 10020.

Ni, I. Q. et al. (2004) .A survey of QoS enhancements for IEEE 802.11 Wireless LAN. *Journal of Wireless Communications and Mobile Computing*, 4(5), 547-566

Shah Ahsanuzzaman Md et al. (2010). Performance Analysis of Wireless Ad-Hoc Network Based on EDCA IEEE802.11e. *World Academy of Science, Engineering and Technology,* 69, 2010

Szymon Szott, (2011). Assuring QoS in IEEE 802.11 EDCA Multi-hop Ad-hoc Networks in the Presence of Misbehaving Node. PhD Thesis, AGH University of Science and Technology, Faculty of Electrical Engineering, Automatics, Computer Science and Electronics, Poland.

Tao, Z. et al. (2006). Throughput and Delay Analysis for the IEEE 802.11e Enhanced Distributed Channel Access. IEEE Transactions on Communications, 54(4), 2006.

Veres, A. T. Campbell, M. Barry, &. Sun, L.-H. (2001). Supporting service differentiation in wireless packet networks using distributed control. *IEEE Journal of Selected Area in Communication, 19*(10), 2081–2093.

Xiao, Y., Li, H., & Choi,S. (2004). Protection and guarantee for voice and video traffic in IEEE 802.11e Wireless LANs," in Proc. IEEEINFOCOM'04, Hong Kong, China, March 2004.

Yang X. and Li H., (2004). Voice and Video Transmissions with Global Data Parameter Control for the IEEE 802.11e Enhance Distributed Channel Access. *Computer Journal of Parallel and Distributed Systems IEEE Transactions, 15*(11),1041-1053.

Zhang, Q., Liu, W., Cheng, B., & Cheng, W. (2007). Improve IEEE 802.11 MAC Performance with Collision Sequential Resolution Algorithm" WCNC 2007 proceedings 334.