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AN ADMISSION CONTROL METHOD FOR IEEE 802.11e CONTENTION ACCESS MECHANISM

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Abstract. IEEE 802.11 Wireless Local Area Network (WLAN) is a shared medium communication network that transmits information over wireless links for all 802.11 stations in its transmission range to receive. The support of audio, video, real-time voice over IP (VoIP), and other multimedia applications over 802.11 WLAN with Quality of Service (QoS) requirements is the key for 802.11 WLAN to be successful in multimedia home networking and future wireless communications. Recently, the IEEE 802.11 task group E specified a distributed access approach, called Enhanced Distributed Coordination Access (EDCA), which supports service differentiation in the Medium Access Control (MAC) layer. However, no assurance can be given to higher priority traffic in terms of throughput and delay performance. The problem is especially apparent when the wireless channel is overloaded causing the bandwidth share of each flow to diminish. In this research, a simple measurement based admission control method is proposed to enhance the QoS of EDCA network when it is heavily loaded. The proposed method is implemented in Network Simulator ns-2. The results have shown that the proposed method can protect the QoS of high priority applications but sacrifice the QoS of low priority flow at a moderate level.

Keywords: WLAN, Quality of Service, EDCA, admission control

Abstrak. Rangkaian Setempat Tanpa Wayar (WLAN) IEEE 802.11 merupakan rangkaian komunikasi dengan perkongsian medium yang menghantar maklumat melalui laluan tanpa wayar di antara semua stesen IEEE 802.11 yang berada dalam jarak penghantaran dan penerimaan. Keupayaan untuk menyokong aplikasi audio, video, suara melalui IP (VoIP), dan aplikasi multimedia lain yang memerlukan jaminan kualiti perkhidmatan (QoS) ialah kriteria penting untuk mempopularkan WLAN. Kumpulan Tugas E di bawah IEEE 802.11 sedang menyediakan piawaian baru untuk meningkatkan QoS dalam WLAN. Satu kaedah yang diperkenalkan dalam piawaian baru ini ialah Saluran Capaian Teragih (EDCA) yang mampu menyokong pengkelasan aplikasi di lapisan Kawalan Capaian Media (MAC). Namun tiada kepastian mutlak yang dapat dijanjikan kepada aplikasi berkepentingan tinggi dalam pencapaian daya pemprosesan dan lengah masa. Kualiti perkhidmatan akan menurun apabila tahap beban dalam medium tanpa wayar sudah melebihi kapasiti yang boleh ditampung. Dalam penyelidikan ini, satu kaedah 'kawalan kemasukan' yang menggunakan pengukuran tahap beban dicadangkan untuk meningkatkan QoS dalam rangkaian EDCA bila ia berada dalam tahap trafik tinggi. Kaedah yang dicadangkan diimplementasikan menggunakan ns-2. Keputusan penyelidikan menunjukkan kaedah yang dicadangkan dapat mengawal QoS aplikasi perkhidmatan berkepentingan tinggi dan hanya mengorbankan sedikit QoS aplikasi perkhidmatan berkepentingan rendah.

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Kata kunci: WLAN, jaminan kualiti perkhidmatan (QoS), EDCA, kawalan kemasukan

1.0 INTRODUCTION

With the provisioning of high-speed Wireless LAN (WLAN) environments, it is possible to offer high-speed data services to the users. Hence, traffic classes (e.g., VoIP or Video Conference) with different QoS requirements will be provided in future WLANs. The support of audio, video, real-time voice over IP and other multimedia applications with QoS requirements is the key for IEEE 802.11 [1] WLAN to be successful in multimedia home networking and future wireless communications.

Since these traffic classes require distinct specific features, such as delay sensitivity or guaranteed bandwidth requirement, it is desirable to provide a service differentiation mechanism in the IEEE 802.11 Standard. The existing standard of IEEE 802.11 does not support service differentiation because it was initially created for the data communications. Many researches [2 - 10] have been carried out to propose a suitable and robust service differentiation mechanism for WLAN. Recently, the IEEE 802.11 task group E [11] has specified a distributed access approach, called Enhanced Distributed Channel Access (EDCA), which supports service differentiation in the MAC layer. It ensures the packets sent by each mobile station can be differentiated by assigning different access parameters. However, supporting service differentiation in the MAC protocol does not guarantee that the QoS requirement of each traffic class to be fully satisfied. Since each mobile station may transmit packets egotistically in a distributed environment, network load might be led to an unacceptable level. An admission control strategy could mitigate the effect of egotistic transmission. It could ensure that the acceptance of a new traffic stream will not cause the QoS of any ongoing sessions below an unacceptable level.

This paper is focused on presenting an admission control method to be used in IEEE 802.11e EDCA MAC layer. The structure of this paper is as follows: Section 2 gives an overview of the existing admission control methods proposed by many researches; Section 3 illustrates the proposed admission control method, Section 4 discusses its implementation in network simulator-2 (ns-2), and Section 5 demonstrates the performance of the proposed method using simulation. Finally, conclusions are drawn in Section 6.

2.0 BACKGROUND

Admission control is an important tool to control the number of flows in network to maintain the QoS experienced by end users. With the increasing demand on high priority applications like voice over IP and video conference in WLAN, it is necessary to make sure the QoS of these applications do not degrade severely when the network is heavily loaded. Up to now, most of the researches on QoS in WLAN concentrate on resource allocation. Not many researches have been focused on admission control especially for IEEE 802.11e WLAN. Sachin and Kappes [12] proposed an admission control method for Voice over IP traffic in IEEE 802.11 WLAN. However, the method was only tested in ordinary IEEE 802.11 DCF access mechanism. Figure 1 shows the previous contributed works on admission control in IEEE 802.11e EDCA access mechanism.

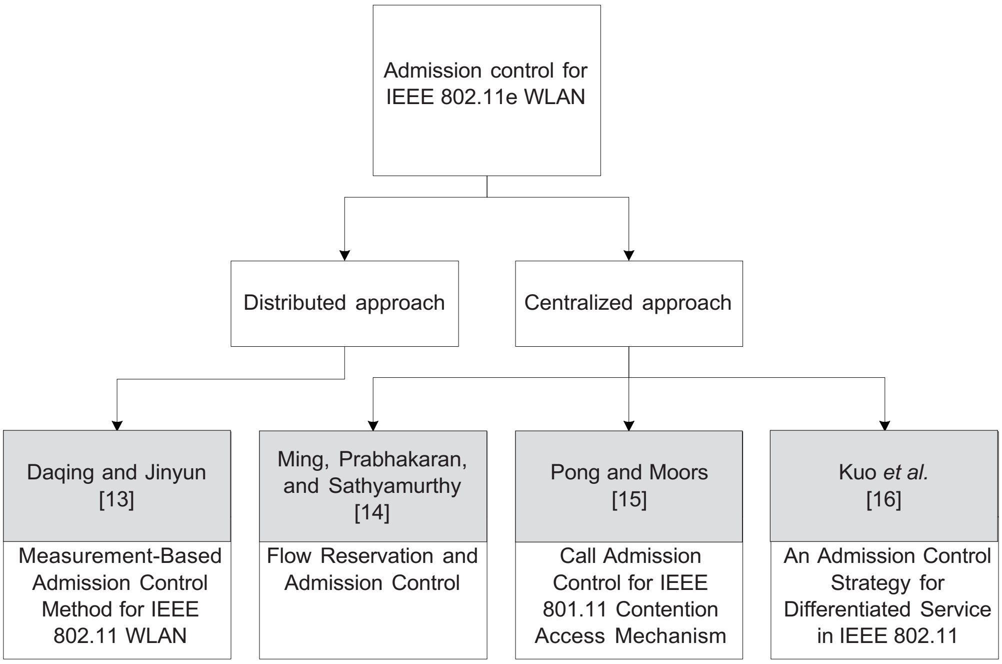


Figure 1 Previous admission control methods in IEEE 802.11e

Daqing and Jinyun [13] proposed two measurement based admission control methods in their paper. The first method, known as Relative Occupied Bandwidth Method, uses a time window to measure the amount of time used for transmission during a fixed sampling period, T. The amount of time used for data transmission is the time when the wireless medium is busy, no matter if the transmission is successful or not. The second method, which is Ming *et al.* [14], proposed flow reservation and admission control. The method deploys the flow reservation for real time flows with First Come First Serve (FCFS) basis. It introduces a Wireless Bandwidth Manager (WBM) for admission control and flow reservation. Each high priority mobile stations, before data transmission, must send their QoS requirements to WBM, which will accept or reject the requests according to the availability of the bandwidth in the WLAN. Pong and Moors [15] and [17] proposed the centralized admission control method. The algorithm estimates the throughput that flows would achieve if a new flow with certain parameters was admitted, and so indicates whether such new flow can be admitted while preserving the QoS of existing flows. Besides, the algorithm deals with EDCA parameters of minimum contention window size and transmission opportunity duration, and indicates what values should be used for different flows. Kuo *et al*. [16] introduces an analytical model for EDCA to evaluate the expected bandwidth and the expected packet delay of each traffic class. The admission control strategy uses the performance measures derived from the analytical model to decide if a new traffic stream is permitted into the system or not. The simulations by the authors have shown that the QoS of the high priority flows can be maintained using the proposed method.

3.0 THE PROPOSED METHOD

Admission control is a critical element for supporting QoS in networks. The admission control function deals with the question of whether or not to accept a new connection, depending on the status of the network resources and the level of service called for by the new request. The purpose of any admission control is to ensure that admittance of a new data flow into a resource-limited network does not degrade QoS committed by the network to the admitted data flows while optimizing the network resource usage. In the proposed scheme, a service set (SS) that includes a number of IEEE 802.11e wireless stations is considered. Since the proposed scheme works only in infrastructure mode, the assumed service set is a basic service set (infrastructure mode). A SS is a terminology used in 802.11 standard that is equivalent to the cell in cellular communications. If it is a basic service set, the AP (Access Point) will be considered as a wireless station that is identical to the other wireless stations. The proposed method requires the AP in the SS to measure the traffic condition (traffic load) in the wireless link. When the traffic load on wireless medium is greater than a threshold, this means that the 802.11 wireless network is experiencing overload, long medium access delay, and possibly degradation of throughput. The AP will reject the new connection to ensure that the high priority data flows continue to receive their requested QoS as much as possible. When the traffic load on wireless medium is smaller than a given threshold, this means that the 802.11 wireless network is insufficiently used. The AP will accept new data flows to increase the network efficiency.

In this research, the proposed admission control method is based on the method in [12] with a minor change in the equation. The change is necessary because the researcher in [12] proposed the method to be used in the IEEE 802.11b with original IEEE 802.11 MAC layer. From the literature review, it is mentioned that service differentiation is needed in the IEEE 802.11 MAC in order to provide QoS for demanding applications such as Voice over IP (VoIP) and video conference. Hence, the research will propose an admission control method to be used in the IEEE 802.11e WLAN.

In this method, modified Network Utilization Characteristic (mNUC) of a flow will be used as the deciding criteria in the admission control. mNUC of a flow is defined as the fraction of time per time unit needed to transmit the flow over the network. For a situation in 802.11b wireless infrastructure based network with a single client, the mNUC can be obtained using Equation (1).

$$\text{mNUC} = n * (s * 20\mu s + 192\mu s + b*8/\text{Ravg} + 10\mu s + 192\mu s + 14*8/\text{Ravg} + \text{AIFS}) \quad (1)$$

where n is the number of frames transmitted per minute;
s is the number of slots to wait before transmission;
b is the size of data payload in bytes;
Ravg is the average channel transmission rate;
AIFS is the amount of time to defer in 802.11e MAC.

The Admission Controller which is implemented in the Access Point (AP) will get the size of the payload of every frame to be transmitted or received (for existing admitted flows) and sum up the NUC of them as shown in Equation (2), where k is the number of flows available at that time. The interval of every calculation will be 1 second. NUC_i is actually the mNUC for flow i. The NUC_i in Equation (2) can be defined as the summation of NUC_unit shown in Equation (3). n is the number of packets transmitted in that particular interval. Equation (4) shows the equation for NUC_unit which is actually the mNUC without n in front of it. In the admission control method, the NUC_unit of every successful incoming packet is accumulated by the admission controller to obtain the NUC_i value. Then, the NUC_i is accumulated to form mNUC_total.

$$\text{NUC\_total} = \sum_{i=1}^{k} \text{NUC}_i \quad (2)$$

$$\text{NUC}_i = \sum_{n=0}^{n} \text{NUC\_unit} \quad (3)$$

$$\text{NUC\_unit} = s \times 20\mu s + 192\mu s + b \times 8 \div \text{Ravg} + 10\mu s + 192\mu s + 14 \times 8 \div \text{Ravg} + \text{AIFS} \quad (4)$$

where,
s is the number of slots to wait before transmission;
b is the size of data payload in bytes;
Ravg is the average channel transmission rate;
AIFS is the amount of time to defer in 802.11e MAC.

When a new flow is to be transmitted, the admission controller will compare the mNUC_total with the mNUC_threshold. If the mNUC_total is smaller than the mNUC_threshold (refer to inequality (5)), the new flow is admitted. Else, it is rejected. Ideally, the mNUC_threshold should be 1. However, after taking into consideration the collision and loss event, it will take a value lower than this. The optimum value of the mNUC_threshold will be obtained from simulation tests.

$$\text{mNUC\_total} \leq \text{mNUC\_threshold} \quad (5)$$

As mentioned before, the approach used in the admission control method is centralized based. This means the Equation (1) explained above is proposed to be implemented in the Access Point (AP) of the WLAN. In the EDCA of the IEEE 802.11e, there are four Access Categories (AC) from AC0 (lowest priority) to AC3 (highest priority). Voice and video traffic are classified as AC3 and AC2 in the traffic classification. In the proposed approach, AC0 and AC1 are defined as "low priority" traffic while AC2 and AC3 are defined as "high priority" traffic. The admission control approach needs "high priority" traffic to request for admission before the beginning of the flow while "low priority" traffic can access the network as long as the NUC_total of the network is less than the NUC_threshold. However, "low priority" flows may be stopped at any time when the NUC_threshold is exceeded.

Before the detail explanation of the operation of the admission control method is given, it is important to have a better look at the new feature introduced in the method. For the "high priority" flows, to request for admission, a newly proposed Frame Access Request (FAR) will be sent by the sender to the AP. The content of the FAR packet is the priority of the new high priority flow. Besides, the combinations of the source address, destination address, and flow priority can be used to form the unique flow id of the flow. Other type of flow id can be used as long as each flow can be differentiated. The admission controller will decide whether the request to be accepted or not based on the policy of the admission control method. If it is accepted, another newly proposed packet named Frame Access Granted (FAG) will be sent back to the sender. Figure 2 depicts the flow chart of the Admission Control Method (ACM) in the AP. It can be seen that there are three vertical parts for four cases which are uplink new flows, uplink existing flows, downlink new flows and finally, downlink existing flows.

4.0 ACM IMPLEMENTATION IN NS-2

Ns-2 is a powerful open source network simulator that is widely used in the networking research nowadays. There are a few contributed modules regarding EDCA implemented in ns-2 [18]. In this research, the EDCA module contributed by Sven Wietholter and Christian Hoene from Technical University Berlin Telecommunication Networks Group is used. The main reason this contributed module is used is because its implementation is well documented and verification has been made by the researchers to verify the correctness of their implementation [19].

Basically, the process involving ns-2 in this research can be seen from the chart shown in Figure 3. The process starts with the installation of ns-allinone-2.26. Ns-2 version 2.26 is chosen because the EDCA module was implemented in that version. Details regarding the installation process can be found easily from the ns-2 official

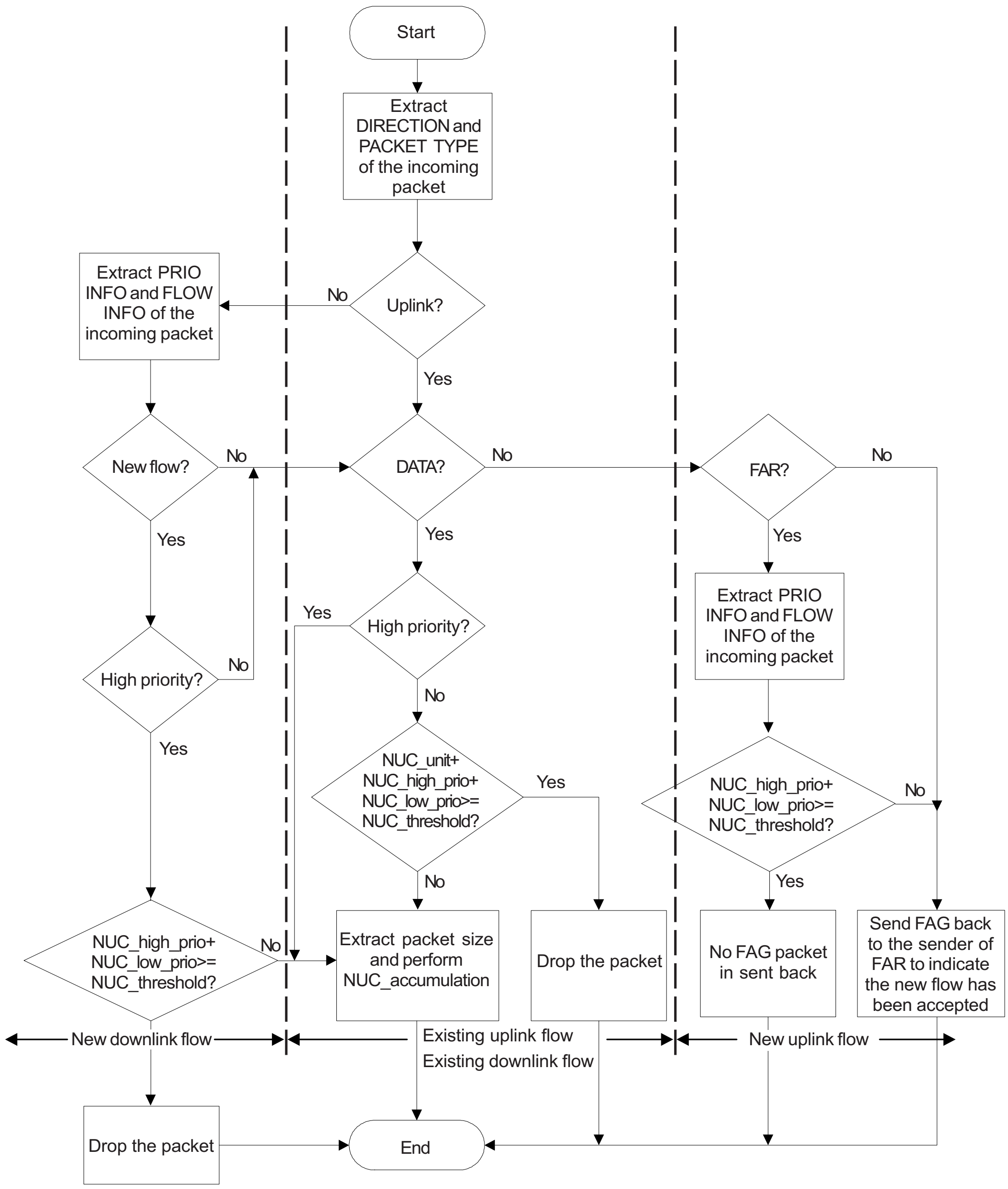


Figure 2 Flow chart of ACM at AP

website [18] and thus will not be covered in this paper. After installing ns-allinone-2.26, the contributed EDCA is added in the ns-2. This is followed by the addition of a contributed module named Non Ad Hoc (NOAH). The module allows the process of running the simulation for infrastructure network. After the first three steps, the implementation of the ACM is ready to be carried out.

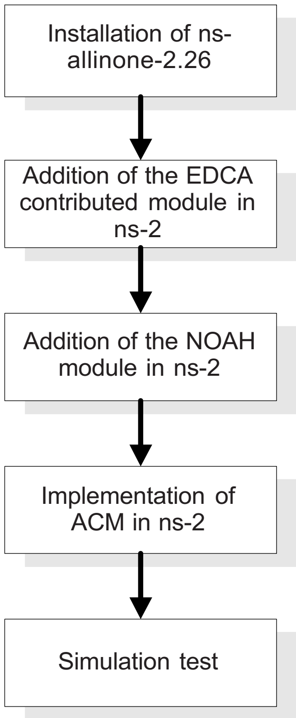


Figure 3 Implementation steps

Figure 4 gives a brief view of the class hierarchy in ns-2. There are many classes in ns-2. However, here, only some important classes involved in this research are shown. From the diagram, it can be seen that NsObject class inherits from two base classes which are TclObject base class and Handler base class. Besides, the shaded boxes show the added classes in ns-2 in order to implement the ACM. UpdateTimer_802_11e is added to perform the counter to accumulate the NUC_total every second. Mac802_11e_acm is added to the AP of the WLAN to perform the admission control function. Initially, in ns-2, AP uses the same MAC function with all other mobile nodes.

Figure 5 illustrates the name of the files which are added or edited in the ns-2. The grey colour boxes on the right hand side of the chart shows the added files in ns-2 which are mac-802_11e.{h,cc} and mac-timers_802_11e.{h,cc}. Previously, in ns-2, the mobile nodes and the AP (in ns-2, known as base station) use the same mac-802_11e files.

However, in the proposed implementation, the MAC function of the mobile nodes and AP is separated by introducing another MAC in the AP. The functions of the MAC in the AP are basically the same with the mobile node's functions except for the added admission controller functions in the AP's MAC. Meanwhile, the edited files of the ns-2 are shown in the grey colour boxes in the figure.

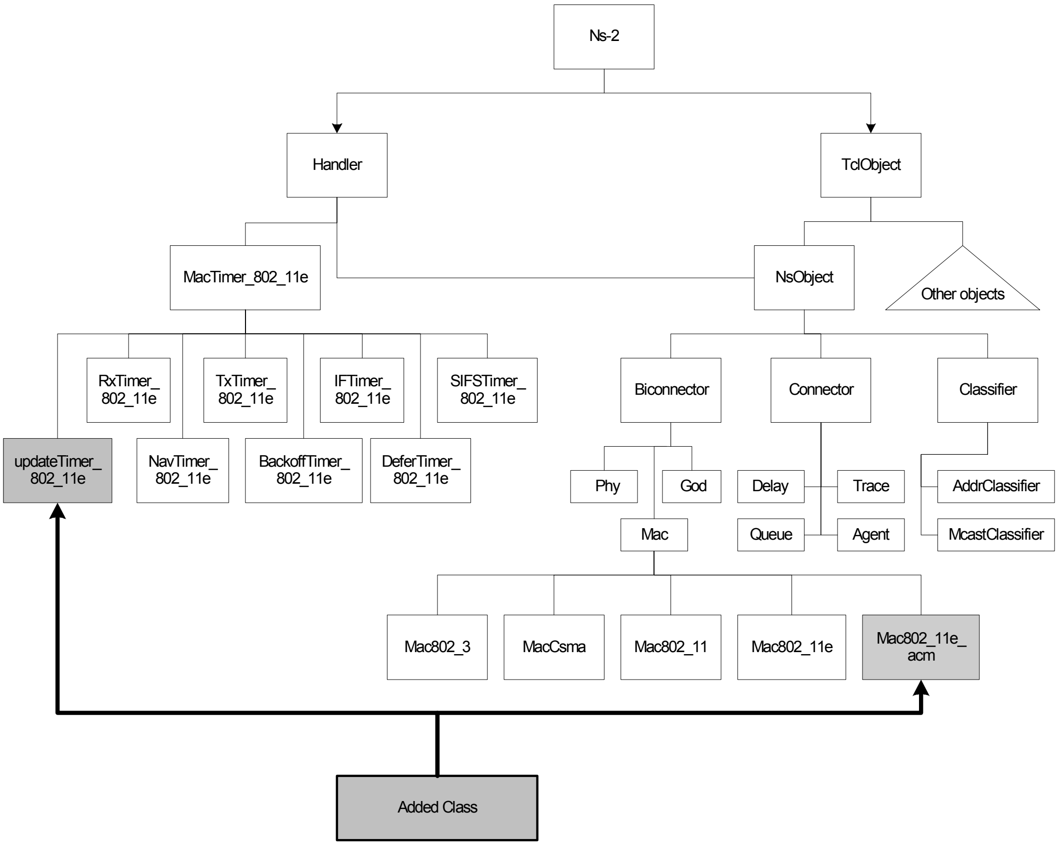


Figure 4 Class hierarchy in ns-2

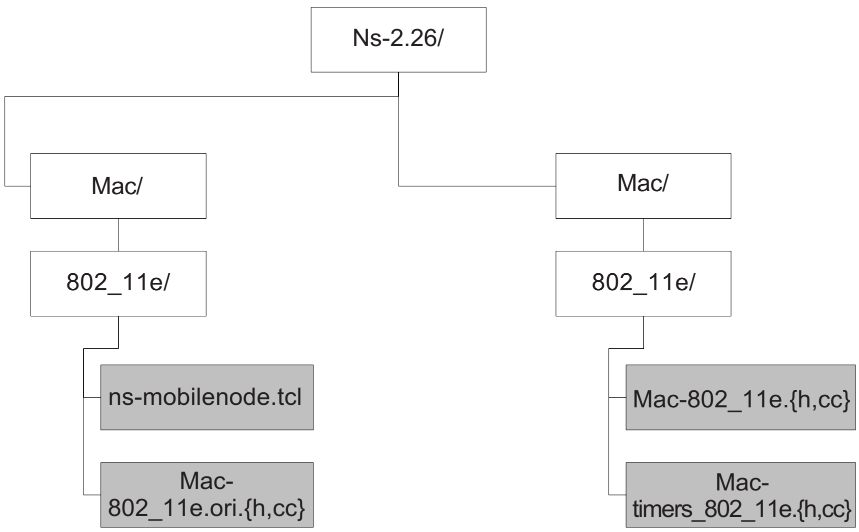


Figure 5 The files in ns-2 framework that are edited and added

5.0 SIMULATIONS AND RESULTS ANALYSIS

In order to evaluate the performance of the admission control method (ACM) described, simulation studies were conducted comprehensively using ns-2 network simulator. The simulations consider four types of traffic sources: web traffic, VoIP, video, and FTP. Table 1 lists the details of the traffic in the simulations.

Table 1 Simulation traffic

Type	Inter-arrival time (Avg. in sec)	Frame size (bytes)	Data rate (Mbps)	Burst time (s)	Idle time (s)	Shape
Voice	CBR (0.02)	160	0.064	-	-	-
Video	CBR (0.025)	1000	0.32	-	-	-
Web traffic	Pareto distribution	1000	0.25	0.5	0.1	1.5
FTP	-	1500	-	-	-	-

Nowadays, heavy-tailed distribution is most suitable for internet traffic data and it can be represented as Pareto distribution ON and OFF periods [20]. The interarrival of the web traffic is modeled according to Pareto distribution with the shape parameter equals to 1.5. The voice source model generates 160 bytes payload with an interval of 20 ms resulting in the bit rate of 64 kbps, a suitable model for G.711 [21] voice coder. The video traffic is generated constantly with the interval of 0.025 seconds. The transport layer for voice and video is UDP. The FTP is transmitted continuously as long as there is bandwidth available. The transport layer for web traffic and FTP is TCP.

Table 2 lists the four defaults Access Category (AC) specified in IEEE 802.11e. AC2 and AC3 are defined as high priority category while AC0 and AC1 are defined as low priority category. In this paper, the term high priority flow means flow from AC2 or AC3 while low priority flow means flow from AC0 and AC1.

The most relevant parameters in IEEE 802.11 EDCA MAC and ACM are listed in Table 3. The physical layer simulated is IEEE 802.11b which can reach the 11Mbps maximum data rate.

Table 2 The four default ACs specified in IEEE 802.11e

AC	AIFSD(AIFS)	CWmin	Cwmax
AC0	50 µs (2)	31	1023
AC1	30 µs (1)	31	1023
AC2	30 µs (1)	15	31
AC3	30 µs (1)	7	15

Table 3 Simulation parameter values

Parameter	**Value**
Time slot	20 μs
SIFS	10 μs
RTSThreshold	3000 bytes
PLCP preamble and header length	192 bits
PLCP preamble and header bit rate	1 Mbps
PSDU bit rate	11 Mbps (maximum for 802.11b)
Flow Admission Request (FAR) size	23 bytes
Flow Admission Granted (FAG) size	14 bytes
NUC_Threshold	0.8
Simulation time	100 s

Figure 6 shows the IEEE 802.11 infrastructure network topology consisting of several Mobile Stations (MS) communicating with corresponding wired nodes via an Access Point (AP) co-located with the Access Router (AR). In the simulation, the number of downlink video flows is 4; the number of downlink web traffic and FTP is 2 for each

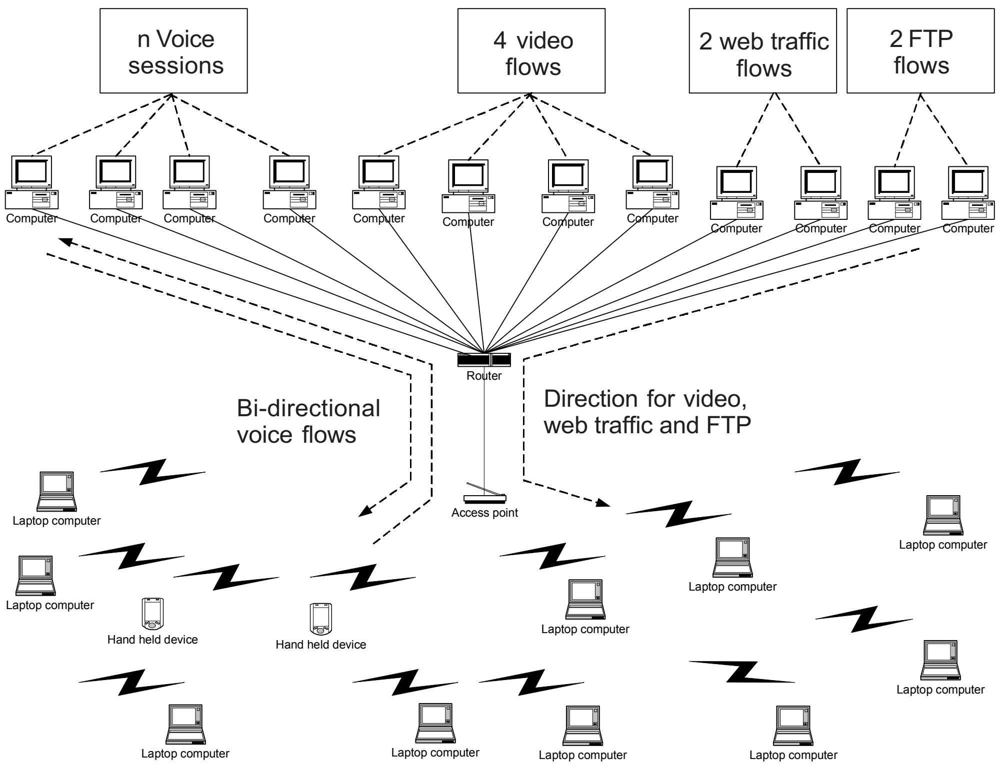


Figure 6 Simulation topology

respectively. The voice traffic is bi-directional. Each MS will only involve one type of traffic.

In the simulation, waiting time and throughput performance are investigated. Waiting time is the metric measures of the total time from the time a packet enters MAC of the sender until it is received by the MAC of the receiver. It is actually the summation of transmission delay and queuing delay. The term waiting time is used because it is too common to use the term "delay" to represent the summation of transmission delay and queuing delay. The unit for the waiting time is second (s). According to ITU-T G.114 specification, the one way end-to-end delay for voice communication should not exceed 150 ms to achieve an acceptable QoS. Truong and Vannuccini [22] have used 20 ms as the acceptable delay in their simulation. In the simulation, 20 ms was defined as the acceptable delay performance for voice communication in the wireless portion, considering the fact that other amount of delay might occur in the wired part of the network. Meanwhile, throughput is the amount of traffic successfully transmitted over a specific period of time. The unit for throughput in this research is kilobytes per second (kB/s).

In the simulation, no hidden stations was present and the channel was assumed to be error free. All mobile stations are located such that every station is able to detect a transmission from any other station, and there is no mobility in the system. No handover is considered in all simulations because the ACM will only be tested in one cell for simplicity.

A. QoS issue in downlink voice flows

In this simulation, the waiting time performance of EDCA for voice flows is compared when the number of voice sessions in network is 6 and 7. The value of 6 and 7 is chosen because preliminary results have shown that the QoS of the downlink voice starts to degrade when the number of voice session turns to 7. A mixed traffic with a number of voice sessions, four video flows, two web traffic flows, and two FTP flows is considered. It should be noted that a voice session consists of two flows which are uplink and downlink. Here, uplink is defined as the flow direction from mobile stations to access point while downlink is the flow direction from the opposite direction. The simulation is conducted using different numbers of voice flows while number of flows by other traffic remains fixed. At time t=20 s, web traffic and FTP start transmission. Voice sessions start at time t=30 s while video transmission starts at time t=52 s. Figure 7 shows the average waiting time comparison for downlink voice flows when there are six and seven voice sessions. It can be seen that the waiting time for downlink voice with 7 voice sessions exceeds the acceptable delay according to the specification of ITU-T G.114. This is because every downlink voice packet will share the same queue in the AP while uplink voice packet will use different queue for each flow. Grilo and Nunes [23] have highlighted this issue before in their research.

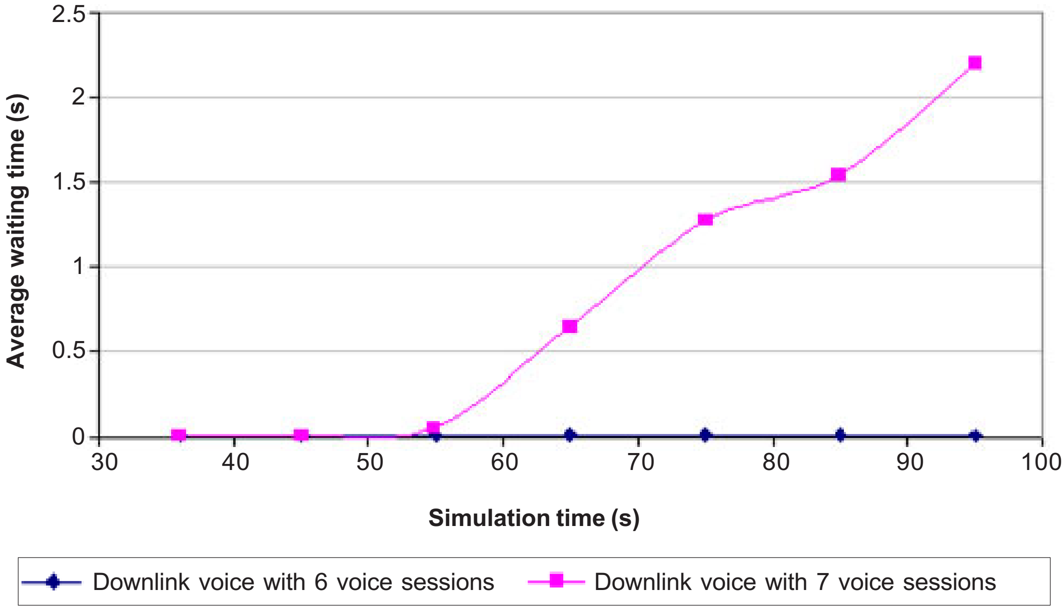


Figure 7 Average waiting time for uplink and downlink voice

B. Average throughput comparison with increasing number of voice sessions

Figure 8 shows the overall throughput comparison for all types of traffic in the simulation which consist of voice over IP sessions, video streaming flows, web traffic and finally, FTP flows. It can be seen that voice and video have a nearly guaranteed average throughput in all the cases. An interesting point to be noted in the video traffic is when the number of voice sessions reaches 9, where all the video flows fail to get into the wireless medium due to the NUC_threshold has been exceeded. This is to preserve the QoS of other high priority flows. For the case of web traffic and FTP, as expected, the average throughput drops as the number of voice sessions increase. The degree of decrease in EDCA MAC with ACM is more than the EDCA MAC without ACM. This is because the low priority flows have to sacrifice its throughput level to maintain the acceptable QoS experienced by high priority flows. Figure 9(a), (b), (c) and (d) gives a close-up look at Figure 8. Figure 9(a) shows that the average throughput for downlink voice without ACM drops when the number of voice sessions increase from 7 to 9. The decrease is undesirable because voice demands guaranteed throughput.

C. Average waiting time comparison with increasing number of voice sessions

Figure 10 shows the overall average waiting time comparison for all traffic when the number of voice session increases. It is noted that the average waiting time for downlink voice without ACM becomes unacceptable after the number of voice session exceeded 6. Figure 11(a) shows the close-up view of the average waiting time for voice. The

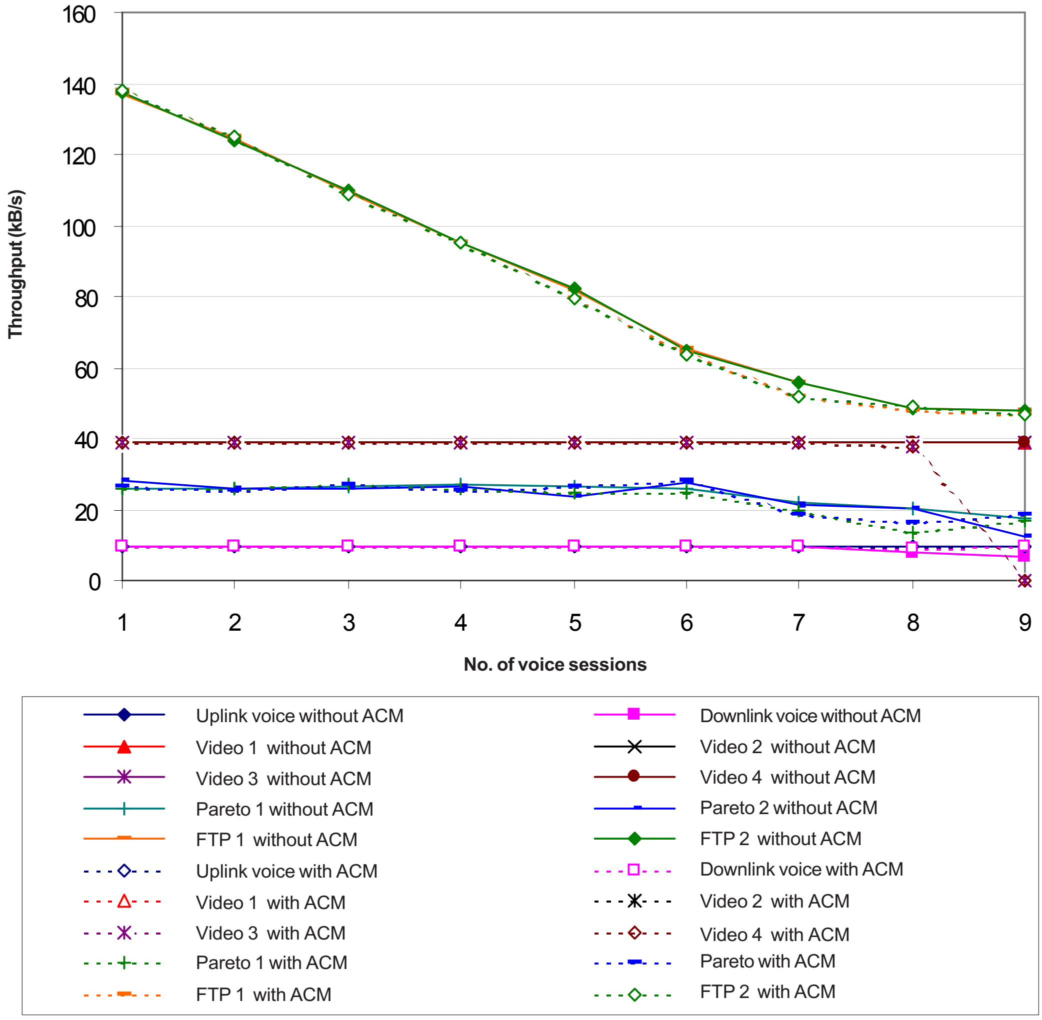
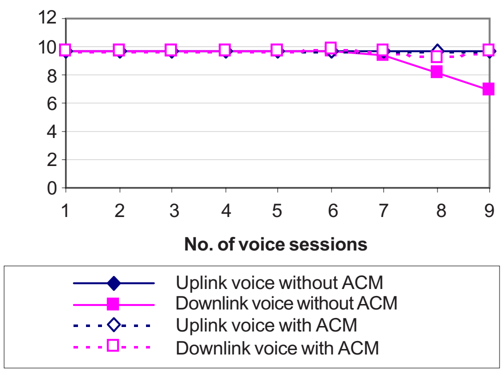
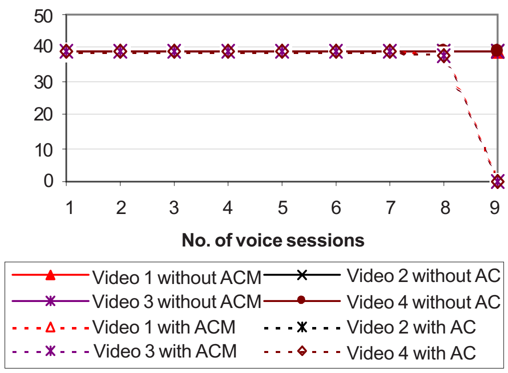


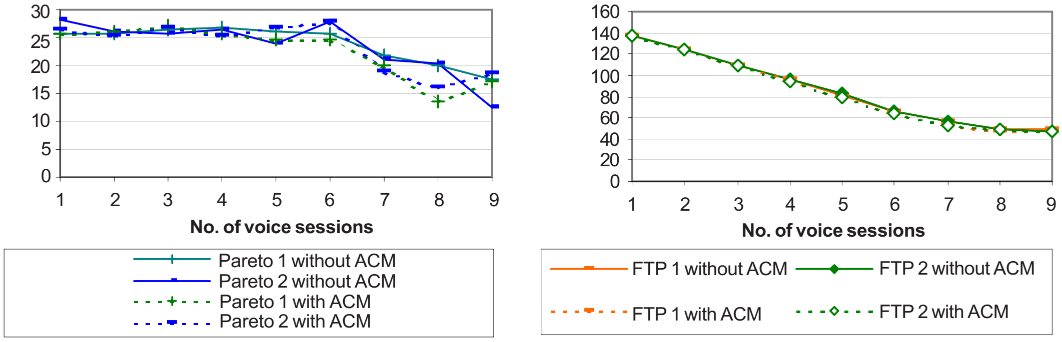
Figure 8 Average throughput comparison when the number of voice flow increases



(a) Voice



(b) Video



(c) Web traffic (d) FTP

Figure 9 Average throughput comparison

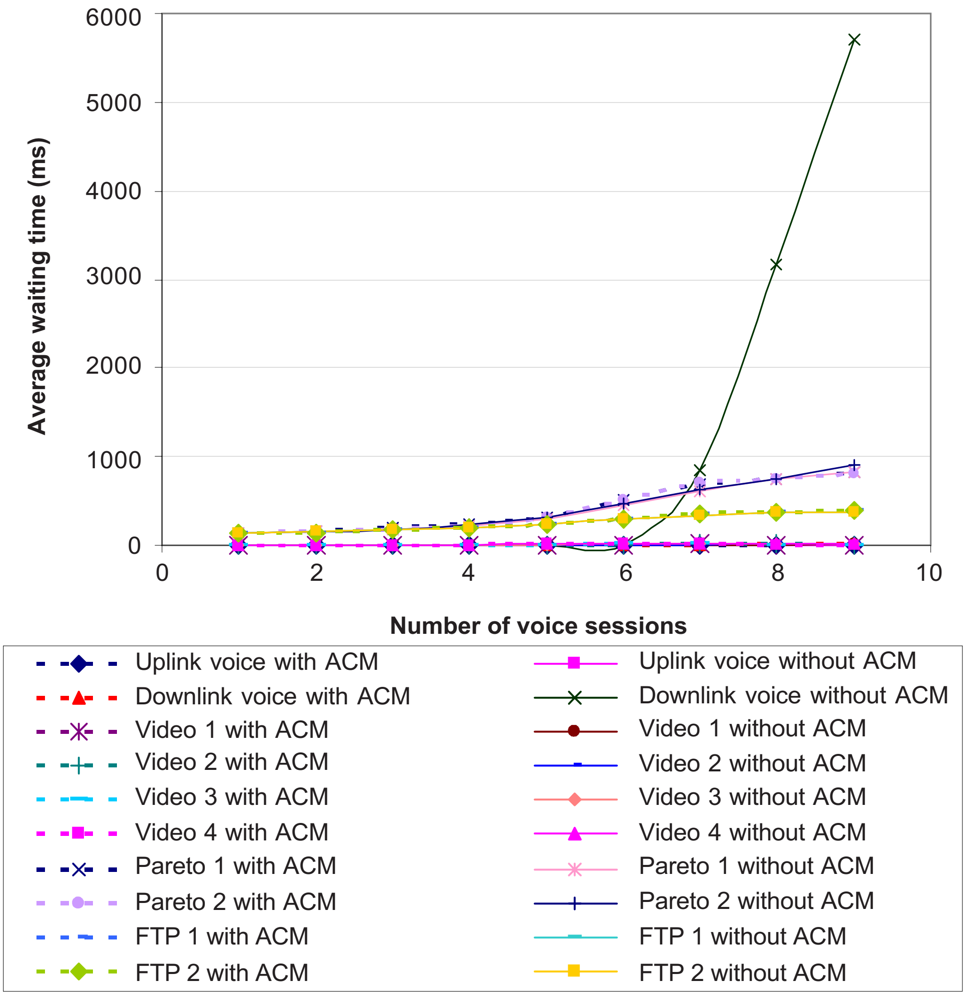


Figure 10 Average waiting time comparison for all traffic with and without ACM when the number of voice session increases

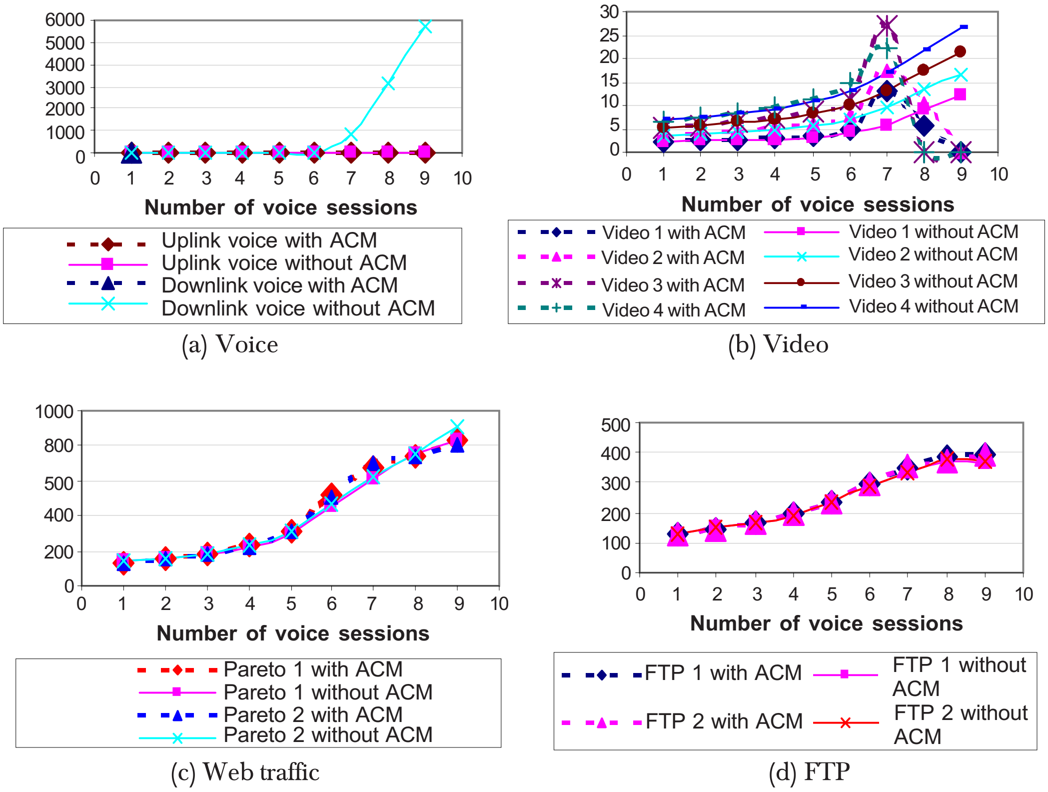


Figure 11 Average waiting time comparison

blocked from entering the network when the number of voice session is 9. This is to preserve QoS experienced by voice traffic in the network. As for average waiting time for web traffic and FTP in Figure 11(c) and (d), the average waiting time increases when the number of voice session increases.

6.0 CONCLUSION

The simulation results show that the high priority flows can be maintained after the implementation of the ACM. The delay of the high priority flows can be maintained within the acceptable delay specified by ITU-T G.114. Besides, the throughput of the high priority flows is also achieved. However, the throughput of the low priority flows with ACM implemented performs worst than the case without ACM. This is acceptable because low priority applications do not require stringent delay. Moreover, the ACM only starve the low priority flow's throughput at a moderate level. There is still a portion of the bandwidth dedicated to low priority flows when the network is heavily loaded. Another point to be noted is the setting of the NUC_threshold value. It should not be set too high because the ACM does not take into consideration the time wasted due to the uplink transmission collisions. In addition, setting a very high NUC_threshold will starve the throughput of low priority flows severely. In this research, the NUC_threshold value was set as 0.8 after a couple of simulation tests.

In conclusion, the proposed ACM is modeled successfully in ns-2 simulator. The performance evaluation of the ACM has shown that the QoS of high priority flows can be protected during the medium is heavily loaded. At the same time, the ACM does not starve the throughput of the low priority flows seriously even with the implementation of the ACM.

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