Enhanced Layer 3 Service Differentiation for WLAN

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Abstract: - The existing wireless networks are dominated by IEEE802.11a/b/g that only provides the best effort services to the wireless end users. All the wireless users and services are traded equally without any Quality of Service (QoS) feature embedded in the existing wireless system. The IEEE802.11e Medium Access Control (MAC) is introduced to provide QoS to the Local Area Network (WLAN) users, but it involves significant investment in money and time to migrate the existing systems to the new IEEE802.11e systems. We proposed an Enhanced Layer 3 Service Differentiation (EL3SD) scheme for the existing WLAN systems to provide QoS to the WLAN end users. The EL3SD is a software approach that operates above the IEEE802.11 MAC to maintain the existing wireless network architectures and devices. A queuing mechanism is added in a gateway between the wired and wireless WLAN. Simulations have been carried out with IEEE802.11b and IEEE802.11e systems. Four queuing mechanisms are selected in the simulation; the Class based Queuing (CBQ), Deficit Round Robin (DRR), Fair Queuing (FQ) and Stochastic Fair Queuing (SFQ). The FQ and CBQ are capable to provide flows differentiation under heavy downlink scenario, but the CBQ is programmable to provide users differentiation to the end users. This is something extra that is not available in the IEEE802.11e and the network administrator controls the WLAN bandwidth distribution through the CBQ.

Key-Words: - WLAN, Queuing Analysis, Bandwidth Allocation

1 Introduction

The success of IEEE 802.11 Wireless Local Area Network (WLAN) technology is largely due to its simplicity, scalability, and robustness against failures. However, the existing WLAN IEEE802.11a, b or g [1-3] standards only support best effort services and are not designed to support the real-time multimedia services e.g. voice and video. The IEEE 802.11e [4] standard provides the QoS solutions through two access mechanisms, the enhanced distributed channel access (EDCA) and hybrid coordination function controlled channel access (HCCA). The EDCA defines four access categories (ACs) for different types of packets. However, bandwidth, jitter or latency are still not guaranteed [1-4]. Specific enhancements on the Medium Access Control (MAC) layer have been implemented such as differentiating the initial window size (CW_{min}), the window-increasing factor, the maximum backoff stage or the inter-frame space (IFS) in order to achieve the QoS differentiation specified in IEEE802.11e [4]. This is a hardware-intensive approach that requires major hardware upgrade and hence significant cost.

We propose an alternative direct software solution to provide QoS to IEEE802.11 systems. A two level queuing mechanism is proposed to offer priority treatment and bandwidth distribution to the WLAN end users. The remaining of this paper is organized as follows: Section 2 provides a summary of the related work in WLAN QoS provisioning. The proposed scheme and the implementation details are described in section 3. Simulation analyses are discussed in section 4. Finally, a conclusion is presented in Section 5.

2 Related Works

Many researches have been carried out to provide QoS in the IEEE802.11 WLAN. The researches can be categorized to few different categories that include the physical, MAC, network, transport layer approaches. The physical and MAC layer solutions need hardware upgrading that require significant cost and time. The literature reviews are targeted in MAC, network and transport layer approaches. The related research works that had been carried out are discussed as follow.

2.1 MAC Layer Approaches

For the MAC approaches, QoS schemes are implemented by differentiating the initial window size, window-increasing factor, maximum backoff stage or the inter-frame space (IFS) [5, 6]. New or enhanced version of the MAC have been proposed to support QoS [8, 9, 10]. The IEEE802.11e was introduced to enhance the QoS capability for the real time applications [4] since the preceding standards have no QoS support. The 802.11e Enhanced Distributed Coordination Function (EDCF) is based on IFS and Contention Window (CW) differential adjustment to provide eight different types of service classes. Each service class has different IFS and CW to distinguish between each other. The HCF is an extension of the PCF mode. The Hybrid Coordinator (HC) controls the channel access and ensures QoS guarantee for prioritized flows by granting explicit access during the Contention Period (CP). The IEEE802.11e provides the QoS based on the types of services. The MAC enhancement is an approach that requires hardware upgrade and thus involving significant cost.

Service class mapping between the 802.11 and IntServ is proposed in [5] to preserve traffic differentiation at the link layer. It selectively provides service differentiation between the guaranteed services and the best effort services. It reduces the packet loss but the hidden terminal problem is not included.

An investigation is carried out in [6] to study the ability of the IEEE802.11b MAC to support simultaneously voice and data traffic. The backoff control and priority queuing are implemented at the AP. The scheme distinguishes delay-sensitive packets and provides them the priority treatment by improving their queue positions and allowing them to use a zero backoff value during contention period.

The researches on MAC layer are mainly targeting to provide service differentiation between different types of services where the real time services have higher priority compare to the best effort services.

2.2 Network and Transport Layer Approaches

Yongho Seok and Jaewoo proposed and simulated a queue management algorithm for multi-rate WLAN using network simulator (NS) in 2003 [7]. Three different applications, video, audio and data traffics are considered in the study. Three different queues, drop tail, Tx time based priority, and Tx time priority dequeue + enqueue are used in the simulation. The algorithm proposed achieves higher throughput and resource utilization compared to the original configuration.

Dong Liu proposed the distributed adaptive bandwidth allocation scheme and the interactive signaling mechanism between the centralized manager and the distributed agents to provide QoS support for the real time applications in the uplink channels [8]. The testbed includes an access point (AP) and 2 mobile hosts with 1 mobile host as the video server streaming video to a wireless client through the AP. The proposed scheme can dynamically performs reallocation of resources.

HK Yip and YK Kwok investigated the efficiency of a software based interference coordination approach in 2004 [9]. Four algorithms are used in the study, the First in First out (FIFO) queue, the Hierarchical Token Bucket and Stochastic Fair Queue (HTB+SFQ), Priority Queuing and Token Bucket Filter (PRIO+TBF), and SFQ. The PRIO+TBF provides the best performance in the aggregate bandwidth achieved by the Bluetooth and IEEE802.11b compared to the others in this study.

Yuxiao Jia proposed an adaptive resource allocation approach using the dynamic class based queuing (CBQ) to reallocate the resources based on the prediction of the future demand in 2003 [10]. The QoS requirement can be satisfied through the prediction.

The wireless HTB is used as the scheduling algorithm to be integrated in AP [11] and compared with other standard scheduling algorithm, which do not take into account information on channel quality. The results showed that WHTB provides higher goodput compared to CBQ, HTB and deficit round robin (DRR) when one of the mobile station changes among the position with good, medium, bad, very bad links and out of range from AP.

The combination of IEEE802.11 with HTB traffic shaper is proposed in [12] to provide QoS for IEEE802.11b. The hosts have been configured to send their packets at different fixed rates. It achieves a plain and sustained throughput with low standard deviation to stations.

Traffic-shaping algorithm is proposed to avoid the users with different distances from AP that supports different throughputs in [13]. The study is targeted to FTP and video traffics. The algorithm reduces the effect of one bad link on other users in the same BSS, by limiting the packets addressed to the users that suffer from a poor link. The degradation in the downlink quality of one user affects the performance of others under the same AP.

The weighted fair queuing is proposed in [14] to achieve the desired bandwidth allocation on a wired link through simulation. The distributed weighted fair queuing provides a flow with an average bandwidth proportional to its weight, but does not provide guarantee for individual packets. The scheme reduces the throughput of each station when higher number of stations is connected to the system.

2.3 Justification

From the reviews that we have carried out, it is clear that most of the researches are targeted to provide QoS for different types of services. The service differentiations are focus on two different categories, the protected services and the best effort services. The protected services are the real time traffics such as VoIP and video streaming have higher priority to access the wireless medium. Most of the researches improved the chances of the real time traffic to access the wireless medium, but none of the researches targeted on users differentiation.

The IEEE802.11e provides the service differentiation to the WLAN end users, which is not available in the existing IEEE802.11b/a/g systems. The network administrator is not authorising to control the IEEE802.11e, since all the bandwidth allocation is controlled by the IEEE802.11e MAC.

We proposed a QoS provisioning scheme that implemented in a gateway that located between the wired and wireless networks to handle the wireless bandwidth distribution. A queuing mechanism such as Class Based Queue (CBQ), Deficit Round Robin (DRR), Fair Queuing (FQ) or Stochastic Fair Queue (SFQ) is configured in the network gateway to handle the bandwidth distribution. Simulation is carried out to compare the performances of the proposed scheme by applying various queuing mechanisms with the original IEEE802.11b/e system.

3 Proposed EL3SD Scheme

To overcome the limitation of the IEEE802.11b without QoS capability, the extra queuing mechanism is added in a network gateway between the WLAN and wired system to control the bandwidth distribution. Various queuing technologies as mentioned are implemented in the two-level queuing scheme. The proposed scheme is shown in Fig. 1. The proposed scheme is a software approach that implemented in a Linux based network gateway that located between the wired backbone and the IEEE802.11b/a/g AP. The old computer is sufficient to install the Linux operating system and the Linux operating system is a free open source operating system. WLAN is the bottleneck of a network system and the majority are downlink traffics that send from wired to wireless end users. The proposed scheme is a software approach that requires minimum hardware modification and thus minimum cost expenses.

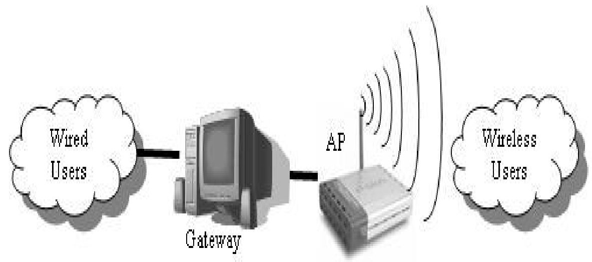

Fig. 1: Proposed scheme network architecture

Network Simulator is used for the simulation analysis. Four types of queuing mechanisms that selected for the simulation are the CBQ, DRR, FQ and SFQ. CBQ is a traffic management algorithm developed by the Lawrence Berkeley National Laboratory Network Research Group as an alternative to the router. CBQ operates at the IP layer and divides the traffic into a hierarchical of classes/queues. The root queue defines the total bandwidth available and the child queues are created under the root queue. The bandwidth distribution of the child queues with different priorities is fully controlled by the CBQ. The packets are divided to the child queues according to the source address, destination address, port number, protocol or the combination of the parameters. The queues can be configured to borrow bandwidth from the parent queue if it is under utilized. The borrowed bandwidth is granted to the higher-priority classes before the lower-priority classes. The higher priority queues are serviced first within the limits of their bandwidth allocation, and the delay of the priority queues is reduced. A complete hardware implementation analysis of the CBQ router is done in [15] and the operational issues are discussed in this journal.

DRR or deficit weighted round robin (DWRR) which is a modified weighted round robin scheduling discipline. It handles packets of variable sizes without knowing their mean sizes. A maximum packet number is subtracted from the packet length. Packets that exceed the number from the subtraction are held back until the next visit of the scheduler. It serves packets at the head of every nonempty queue which deficit counter is greater than the size of the packet. The deficit counter is increased if the value is lower.

Fair queuing is a technique that allows each flow that passed through a network device to have a fair share of network resources. FQ is used in computer network and statistical multiplexing to allow several packet flows to fairly share the link capacity. The advantage of FQ over the conventional first in first out (FIFO) queuing, is the ill-behaved flow which consists of unfairly large data packets, will only punish itself and not other flows. FQ allocating bandwidth fairly to users, achieving promptness and allocating buffer space properly. FQ is used in routers, switches or multiplexers that forward packets from a buffer. FQ estimates a virtual finishing time of all candidate packets based on the arrival time of the packets, packet sizes and the number of queues. The FQ compares the virtual finishing time and selects the minimum one.

SFQ is a simple implementation of the fair queuing algorithms family. It is less accurate than others, but it also requires less calculations. Traffic is divided into a large number of FIFO queues, one for each flow. Traffic is sent in a round robin fashion. Multiple sessions might end up in the same bucket because of hash, which would halve each session in chance of sending a packet, thus halving the effective speed available. SFQ changes its hashing algorithm frequently so that any two colliding sessions will only do so for a small number of seconds. It schedules the transmission of packets based on flows and does not shape the traffic. It ensures fairness so that each flow is able to send data in turn, thus preventing any single flow from drowning out the rest.

4 Simulation Analyses

The simulations are carried out to identify the most suitable queuing mechanism for the proposed scheme. IEEE802.11b and IEEE802.11e are used in the simulation, and the parameter values used in the simulation are shown in Table 1 and 2. The new IEEE802.11e is simulated to investigate the compatibility of the proposed scheme.

The simulations are carried out under two conditions; 1) heavy downlink and 2) heavy uplink traffics condition. The performance analysis is carried out by comparing the performance in terms of throughput, jitter and delay. The average values are compared between the original and the systems with extra queuing mechanism. The performance analysis is targeted on flows differentiation, since the IEEE802.11e provides the same QoS services. All the wireless end users had 5 flows, with 4 downlink flows (audio, video, background traffic – bg_down and ftp) and an uplink flow (background traffic – bg_up) under heavy downlink traffics scenario. The heavy uplink traffics scenario had 5 flows, with 4 uplink flows (audio, video, background traffic and ftp) and a downlink flow (background traffic). The traffics setting are shown in Table 3. All the simulations contained 10 wired users and 10 wireless users that connected by a network gateway and an AP.

Table 1: IEEE802.11b parameters vales used in the simulation

Attributes	Values
Slot Time	20us
SIFS	10us
Preamble	72 bits
PLCP Header Length	48 bits
PLCP Data Rate	1Mbps
Basic Rate	1Mbps
Data Rate	11Mbps
RTS Threshold	3000 bytes

Table 2: IEEE802.11e parameters values used in the simulation

Attributes	Prio0	Prio1	Prio2	Prio3
Persistent Factor (PF)	2	2	2	2
Arbitrary Interframe Space (AIFS), us	2	2	3	7
Minimum Contention Window (CW_MIN)	7	15	31	31
Maximum Contention Window (CW_MAX)	15	31	1023	1023
Transmission Opportunity Limit (TXOPLimit)	0.003008	0.006016	0	0

Table 3: Traffics setting of the simulation analysis

Flows	Rate	UDP/TCP	Priority
Audio	128Kb	UDP/CBR	0
Video	650Kb	UDP/CBR	1
Background (uplink / downlink)	200Kb	UDP/CBR	2
FTP	Produce 50000	TCP	3

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4.1 Heavy Downlink Traffics Scenario

The maximum average throughput of the IEEE802.11b protocol is below 5.12Mbps [16]. The wireless bandwidth is shaped to 7Mbps by the network gateway to limit the traffic between the LAN and AP for all the simulations. The bandwidth is distributed to four child queues with Queue1 with the highest priority, followed by Queue2, 3 and 4. Queue1 is allocated 2.1Mbps, Queue2 2.1Mbps, Queue3 2.1Mbps and Queue4 0.7Mbps. Queue1 and Queue2 are reserved for the real time applications, the audio and video. Queue3 and Queue4 are allocated for the best effort services, the background traffics and FTP. The simulation period is 30s. The simulation is targeted on the IEEE802.11b and IEEE802.11e protocols with the CBQ (cbq-11b, cbq-11e), DRR (drr-11b, drr-11e), FQ (fq-11b, fq-11e), SFQ (sfq-11b, sfq-11e) and the original architectures (11b, 11e).

The total average throughput of the IEEE802.11b system increased 1.52% after the SFQ added as shown in Table 4 and Fig. 2, and the sfq-11b gives the highest total throughput among the others. The total average throughputs of the IEEE802.11e systems are much lower compared to the IEEE802.11b systems. The sfq-11e also gives the highest total average throughput among the other IEEE802.11e systems. The average audio throughput increased 226% in cbq-11b and 30.89% in fq-11b, but the average video throughput reduced after the extra queuing mechanism is added to the IEEE802.11b system. No significant improvement of the average throughput in IEEE802.11e after the proposed two-level queuing is implemented for the real time applications. The downlink background traffic (bg_down) is increased more than 154% after the extra queuing mechanisms added to the IEEE802.11b as shown in Fig. 2. The FQ provides the best performance compared to the other queuing mechanisms in IEEE802.11b and no significant improvement in IEEE802.11e system after the proposed scheme is implemented. The FQ increased the average throughput of the IEEE802.11b applications except the video flow is 43% reduced as shown in Fig. 2.

The average packets jitter of the IEEE802.11b applications are reduced more than 23% for the cbq-11b and fq-11b as shown in Fig. 3, except the video flow. The CBQ reduced 69.36% of the IEEE802.11b audio average packets jitter. No significant improvement in average packets jitters of the IEEE802.11e after the extra queuing mechanism is added as shown in Fig. 3.

The average audio packets end-to-end delay of IEEE802.11b is reduced 10.86% after the CBQ added as shown in Fig. 4. The average delay of the FTP is reduced 34.57% in IEEE802.11e after the CBQ added. The end-to-end delays of the majority IEEE802.11b/e systems are increased, since the extra queuing mechanism contributes extra delay. The audio and video end-to-end delays are less than 0.142s and 0.423s respectively after the extra queuing mechanism added to the IEEE802.11b/e systems.

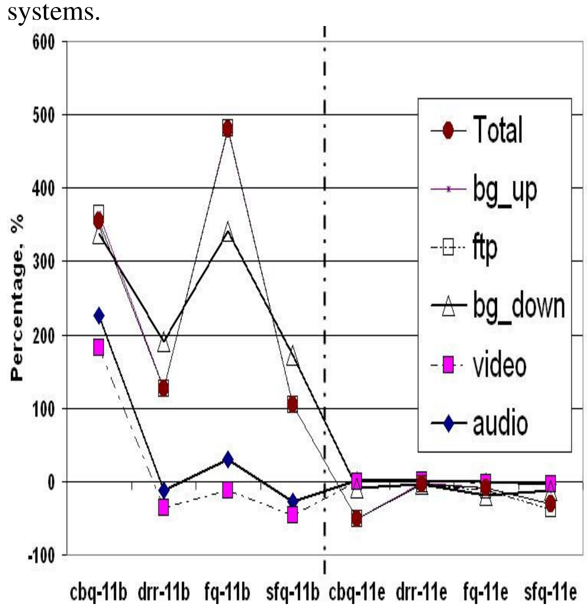

Fig. 2: Percentage different of the flows throughput for IEEE802.11b and IEEE802.11e with extra queuing added comparing the original architectures

The CBQ and FQ are suitable for IEEE802.11b system to provide the service differentiation. The performance of the FQ is better compared to CBQ in providing the service differentiation. Both queuing mechanisms provide higher throughput to all the services compared to the original IEEE802.11b system, except the video flow. This is caused by the video flow that demanded large bandwidth and some of the video packets are dropped to reserve bandwidth for the other services. The CBQ and FQ provide significant lower packets jitter, but with higher end-to-end delay. The performance of the IEEE802.11e is slightly degraded after the extra queuing added.

Table 4: Average flow throughputs (Mbps) for WLAN with different queuing mechanisms

Flows	11b	cbq-11b	drr-11b	fq-11b	sfq-11b	11e	cbq-11e	drr-11e	fq-11e	sfq-11e
Audio	0.12	0.38	0.10	0.15	0.09	0.83	0.84	0.84	0.83	0.80
Video	2.84	1.61	2.16	1.61	2.29	1.30	1.29	1.30	1.29	1.29
Downlink background	0.31	0.78	1.01	1.40	0.98	0.24	0.22	0.20	0.20	0.22
ftp	0.01	0.02	0.00	0.03	0.00	0.01	0.01	0.01	0.01	0.01
Uplink background	2.04	2.04	2.04	2.04	2.04	1.27	1.28	1.30	1.31	1.35
Total	5.32	4.84	5.32	5.23	5.40	3.66	3.63	3.64	3.64	3.68

Table 5: Average flow packets jitter (ms) for WLAN with different queuing mechanisms

Flows	11b	cbq-11b	drr-11b	fq-11b	sfq-11b	11e	cbq-11e	drr-11e	fq-11e	sfq-11e
Audio	14.4	4.4	16.4	11.0	19.6	2.0	2.0	2.0	2.0	2.1
Video	2.8	5.0	3.7	5.0	3.5	6.2	6.2	6.2	6.2	6.2
Downlink background	26.0	10.2	7.9	5.7	8.2	33.5	36.9	40.0	40.2	36.3
ftp	599.7	440.2	1666.6	249.3	1795.5	622.4	1106.7	1426.9	569.8	821.9
Uplink background	4.0	4.0	4.0	4.0	4.0	6.4	6.4	6.3	6.2	6.0

Table 6: Average flow packet end-to-end delay (s) for WLAN with different queuing mechanisms

Flows	11b	cbq-11b	drr-11b	fq-11b	sfq-11b	11e	cbq-11e	drr-11e	fq-11e	sfq-11e
Audio	0.120	0.107	0.142	0.122	0.139	0.105	0.111	0.113	0.105	0.079
Video	0.120	0.243	0.144	0.222	0.141	0.322	0.423	0.319	0.416	0.320
Downlink background	0.116	0.371	0.146	0.135	0.143	1.733	2.276	1.750	1.753	1.882
ftp	0.122	0.114	0.144	0.121	0.149	25.685	16.806	7.042	28.378	0.000
Uplink background	0.016	0.024	0.032	0.024	0.024	2.512	2.554	2.686	2.443	2.318

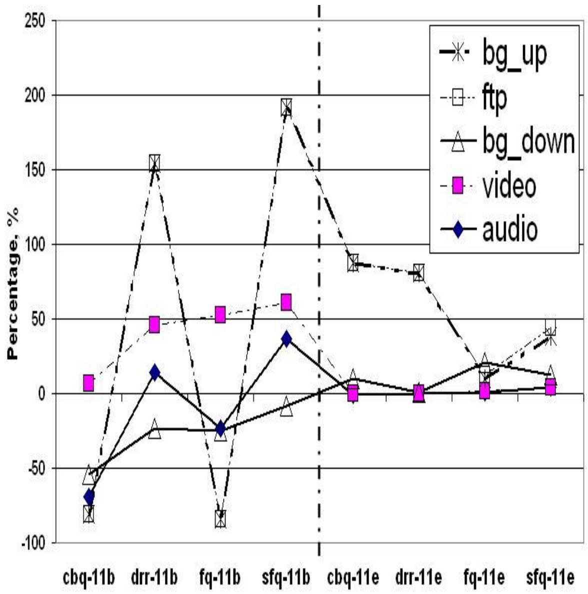

Fig. 3: Percentage different of the flows jitter for IEEE802.11b and IEEE802.11e with extra queuing added comparing the original architectures

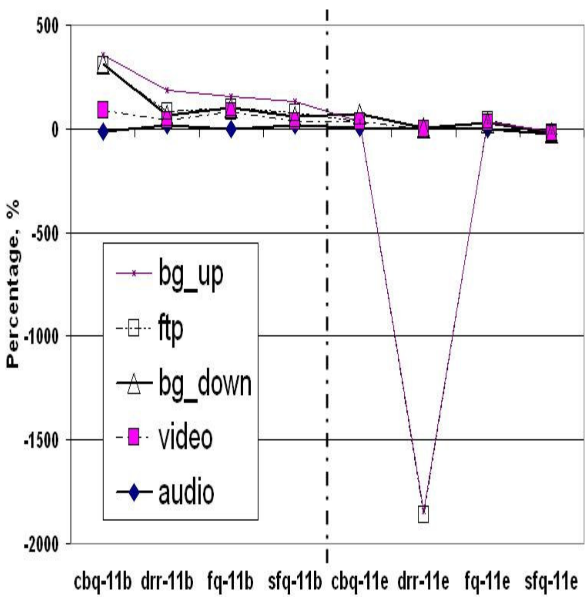

Fig. 4: Percentage different of the flows end-to-end delay for IEEE802.11b and IEEE802.11e with extra queuing added comparing the original architectures

4.2 Heavy Uplink Traffics Scenario

The total average throughput of the IEEE802.11b maintained at 4.5Mbps and 1.8Mbps for IEEE802.11e under heavy uplink scenario as shown in Table 7. The total average throughput of the IEEE802.11b is 60% higher than IEEE802.11e. The throughput of the FTP is 33% lower after an extra queuing added in IEEE802.11b as shown in Fig. 5. The total throughputs maintained after the extra queuing added in IEEE802.11e system. The audio flow throughputs are higher in IEEE802.11e, but the other flows throughputs are much lower in IEEE802.11e compared the IEEE802.11b system.

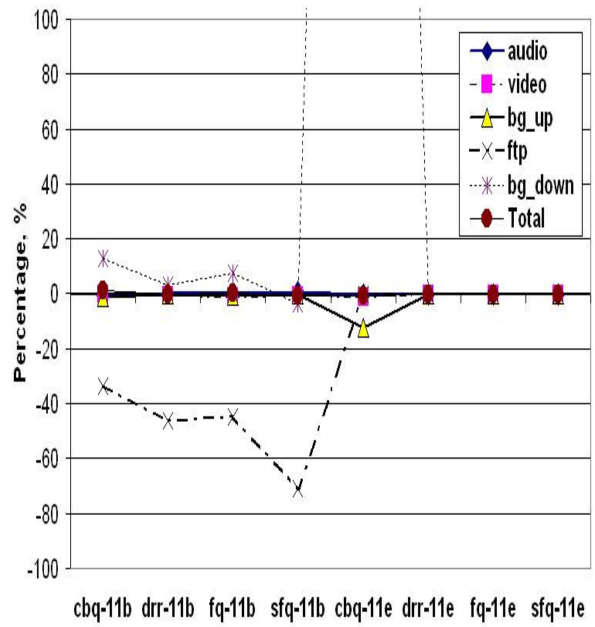

Fig. 5: Percentage different of the flows throughput for IEEE802.11b and IEEE802.11e with extra queuing added comparing the original architectures

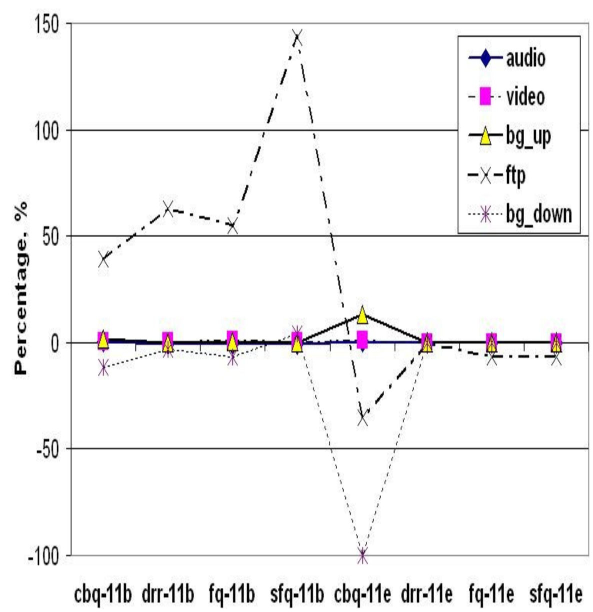

Fig. 6: Percentage different of the flows jitter for IEEE802.11b and IEEE802.11e with extra queuing added comparing the original architectures

Table 7: Average Flow throughput (Mbps) for WLAN with different queuing mechanisms

Flows	11b	cbq-11b	drr-11b	fq-11b	sfq-11b	11e	cbq-11e	drr-11e	fq-11e	sfq-11e
Audio	0.5677	0.5646	0.5700	0.5701	0.5721	0.6709	0.6692	0.6709	0.6709	0.6709
Video	2.6697	2.6626	2.6483	2.6378	2.6562	1.1752	1.1628	1.1751	1.1751	1.1751
Uplink background	0.7649	0.7538	0.7629	0.7608	0.7633	0.0111	0.0097	0.0111	0.0111	0.0111
ftp	0.0121	0.0080	0.0065	0.0067	0.0035	0.0002	0.0002	0.0002	0.0002	0.0002
Downlink background	0.5439	0.6150	0.5612	0.5850	0.5230	0.0005	0.0048	0.0005	0.0005	0.0005
Total	4.5583	4.6041	4.5489	4.5604	4.5181	1.8578	1.8467	1.8578	1.8578	1.8578

Table 8: Average flow packets jitter (ms) for WLAN with different queuing mechanisms

Flows	11b	cbq-11b	drr-11b	fq-11b	sfq-11b	11e	cbq-11e	drr-11e	fq-11e	sfq-11e
Audio	3.2	3.3	3.2	3.2	3.2	2.7	2.7	2.7	2.7	2.7
Video	3.1	3.1	3.1	3.1	3.1	6.9	7.0	6.9	6.9	6.9
Uplink background	10.7	10.8	10.7	10.7	10.7	734.9	830.6	734.9	734.9	734.9
ftp	563.4	786.0	916.9	871.9	1369.9	2.2	1.4	2.0	2.0	2.0
Downlink background	14.7	13.0	14.2	13.7	15.3	1489.5	2.2	1489.2	1489.2	1489.2

Table 9: Average flow packet end-to-end delay (s) for WLAN with different queuing mechanisms

Flows	11b	cbq-11b	drr-11b	fq-11b	sfq-11b	11e	cbq-11e	drr-11e	fq-11e	sfq-11e
Audio	0.669	0.683	0.689	0.680	0.676	1.201	1.211	1.202	1.202	1.202
Video	0.671	0.682	0.688	0.682	0.676	2.972	2.990	2.973	2.973	2.973
Uplink background	0.668	0.684	0.687	0.683	0.675	18.758	17.703	18.759	18.759	18.759
ftp	0.516	0.578	0.596	0.691	0.667	-	-	-	-	-
Downlink background	0.705	0.919	0.699	0.661	0.705	-	0.372	-	-	-

Table 10: Performance comparison between WLAN with and without CBQ

		11b	cbq-11b	11e	cbq-11e
Average Throughput, Mbps		5.113	5.125	4.759	4.832
Total Number of Packet Received	User1	6672	8238	9202	9204
	User2	6581	8078	9201	9204
	User3	5109	7882	6627	9204
	User4	4524	4922	5806	4876
Average Packet Jitter, ms	User1	14.59	12.53	11.43	11.43
	User2	15.75	12.77	11.43	11.43
	User3	49.17	13.44	29.94	11.43
Average packet end to end delay, ms	User1	73.46	69.15	20.54	16.17
	User2	71.88	68.91	20.56	17.35
	User3	80.09	73.62	26.37	19.66

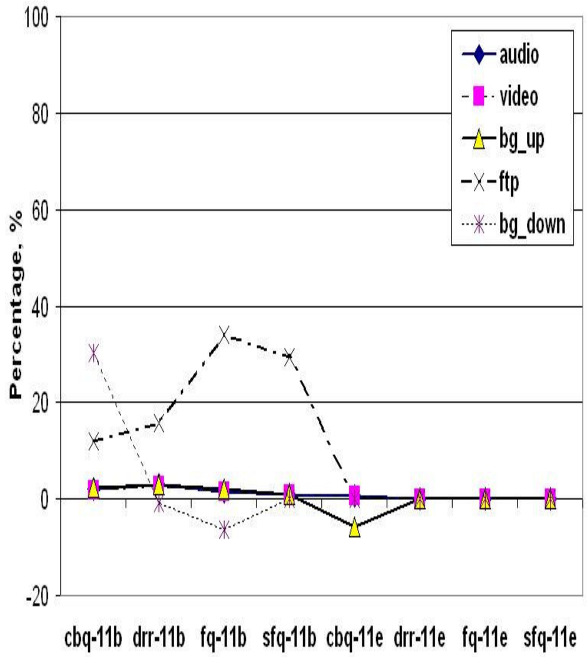

Fig. 7: Percentage different of the flows end-to-end delay for IEEE802.11b and IEEE802.11e with extra queuing added comparing the original architectures

Fig. 6 and Fig. 7 show the percentage different of the flows average packets jitter and end-to-end delay after the extra queuing scheme added to the WLAN compared to the original system without extra queuing added to it. The systems with extra queuing added obtain slightly lower or almost equal average packets jitter as shown in Fig 6. Since the queuing mechanisms manage the bandwidth distribution and the greedy best effort FTP application is sacrificed with higher average jitter especially in IEEE802.11b system as shown in Fig. 6 to support others real-time applications (audio and video).

The average end-to-end delay of the real-time applications are slightly higher in IEEE802.11b systems but almost equal in the IEEE802.11e systems after the extra queuing added as shown in Fig.7. The real time applications have higher priorities to access the WLAN compared the best effort applications in IEEE802.11e system and extra priority queuing is added in the IEEE802.11e MAC. The average end-to-end delay of the best effort applications are much higher in IEEE802.11b system after the extra queuing added, but performance of FTP is not constrained with higher end-to-end delay introduced to it.

4.3 Simulation Analysis for the CBQ User Protection Scheme

The simulation contains 24-wired users sending a Constant Bit Rate (CBR) traffic 700kbps each, with packet size 1000 bytes to 24 WLAN users through a network gateway and an AP. The User1 has the highest priority, follow by User2 with second priority, and User3 with third priority and the others are the best effort users. The CBQ divides the bandwidth equally to 4 different queues, the first, second, third and fourth priority queues. The first, second and third queues with priority 1 (highest), 2 and 3 are allocated to the protected User1, User2 and User3. The last queue is reserved for all the best effort users. The simulation results are summarized in Table 10.

The total average throughput increased after the CBQ added. The protected users received higher throughput after the CBQ added, compared with the best effort User4. Table 10 shows the Class Based Queue (cbq-11b and cbq-11e) provides lower average packet end-to-end delay and jitter to the users with higher priority compared to the original WLAN systems.

5 Conclusion

The Two-level Queuing QoS provisioning scheme is a simple, easy and low cost approach to provide partial QoS to the wireless clients. The proposed scheme is a software approach that implemented in a network gateway. It maintains the current IEEE802.11b/a/g systems and is compatible with the IEEE802.11e system. The FQ/CBQ provides the flows differentiation to the IEEE802.11b system and the CBQ provides the user differentiation to the WLAN systems. The network administrator can controls the WLAN bandwidth distribution through the CBQ. The proposed scheme provides higher throughput, lower packets jitter and end-to-end delay to the protected users under users differentiation scheme. The proposed scheme is realizable in the real wireless network and the network gateway can be implemented in a free Linux based server.

References:

[1] IEEE 802.11a WG, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specification: High-speed Physical Layer in the 5GHz Band, Sep. 1999.

[2] IEEE 802.11b WG, Part 11: Wireless LAN Medium Access Control (MAC) and Physical

Layer (PHY) specification: High-speed Physical Layer Extension in the 2.4 GHz Band, IEEE, Sep. 1999.

[3] IEEE Std 802.11g/D1.1, Part11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher-Speed Physical Layer Extension in the 2.4 GHz Band, 2001.

[4] IEEE Std 802.11e^{TM}-2005, Part 11: Wireless LAN Medium Access Control (MAC) and physical layer (PHY) specifications: Medium Access Control (MAC) Quality of Service Enhancements, November 2005.

[5] Bryan Ng, SW Lee, "Wireless LAN architecture supporting service differentiation in an IntServ context", MUSIC 2004, Jun 2004.

[6] Anjum, F.; Elaoud, M.; Famolari D.; **"**Voice performance in WLAN networks - an experimental study", Global Telecommunications Conference, 2003. GLOBECOM '03. IEEE Volume 6, pp. 3504-3508, 1-5 Dec. 2003.

[7] Yongho Seok, Jaewoo Park, Yanghee Choi, "Queue management algorithm for multirate wireless local area networks," Personal, Indoor and Mobile Radio Communications, 2003. 14th IEEE Proceedings on Volume 3, pp2003-2008 7-10 Sept. 2003.

[8] Liu, D.; Makrakis, D.; Groza, V.; "A channel condition dependent QoS enabling scheme for IEEE802.11 Wireless LAN and its Linux based implementation," Electrical and Computer Engineering, 2003. IEEE CCECE 2003. Canadian Conference on Volume 3, pp 1907-1810, 4-7 May 2003

[9] Hoi Kit Yip; Yu-Kwong Kwok, "A performance study of packet scheduling algorithms for coordinating colocated Bluetooth and IEEE 802.11b in a Linux machine," Parallel Architectures, Algorithms and Networks, 2004. Proceedings. 7th International Symposium, pp 533-538, 10-12 May 2004.

[10] Jia, Y.; Guerrero, M.L.; Kabranov, O.; Makrakis, D.; Barbosa, L.O., **"**Design and testbed implementation of adaptive MPLS-DiffServ enabled virtual private networks," Electrical and Computer Engineering, 2003. IEEE CCECE 2003. Canadian Conference on Volume 2, pp 965-968, 4-7 May 2003.

[11] R.G. Garroppo, S. Giordano, S. Lucetti and E. Valori, "The wireless hierachical token bucket: a channel aware scheduler for 802.11 networks", Proceedings of the Sixth IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks, 2005.

[12] J.L. Valenzuela, A. Monleon, I. San Esteban, M. Portoles, "A hierachical token bucket algorithm to enhance QoS in IEEE 802.11: Proposal, Implementation and Evaluation", IEEE 2004.

[13] Portoles, M.; Zhun Zhong; Sunghyun Choi, **"**IEEE 802.11 downlink traffic shaping scheme for multi-user service enhancement"**,** Personal, Indoor and Mobile Radio Communications, 2003. PIMRC 2003. 14th IEEE Proceedings on Volume 2, pp. 1712-1716, 7-10 Sept 2003.

[14] Banchs, A.; Perez, X.; "Distributed weighted fair queuing in 802.11 wireless LAN", Communications, 2002. ICC 2002. IEEE International Conference on Volume 5, pp. 3121-3127, May 2002.

[15] F. Risso, Panas Gerros, "Operational and Performance Issues of a CBQ Router", ACM Computer Communication Review, Vol. 29, Number 5, pp. 47-58, Oct 1999.

[16] G. Anastasi, E. Borgia, M. Conti, E. Gregori, "IEEE802.11b Ad Hoc Networks: Performance Measurements", Cluster Computing, Vol. 8, N. 2-3, pp. 135-145, July 2005