Enhanced EDCF for VOIP Applications in IEEE 802.11 Based Wireless LAN Networks

M.Sarada[1] , Prof Avula Damodaram[2]

[1]Assistant Professor, Dept. of Computer Science and Engineering , Medha Institute of Science and Technology for Women, Khammam , Telangana, India

[2] Dept. of Computer Science and Engineering, JNT University , Hyderabad , Telangana, India

---***---

Abstract: IEEE 802.11 is the standard MAC layer protocol being used in various wireless networks, WLAN is the major deployment of this protocol. The rapid increase of multimedia applications like VoIP, live video streaming and internet based games it has become crucial to provide quality of service (QoS). This paper provides the basic overview of existing QoS enhancements of IEEE 802.11 networks. Analysis of previous work is carried and specified various techniques to be implemented to achieve the QoS. We propose a new mechanism based on contention window modification (for VoIP and video traffic). Simulation study confirms positive of proposed scheme.

Keywords: IEEE 802.11, QoS, VoIP, EDCF, DCF, PCF, Contention Window.

1.INTRODUCTION

The IEEE 802.11 based wireless local area networks (WLAN) are most deployed wireless networks in the world. The rapid growth of multimedia applications like VoIP, live video streaming and internet based games lead to development of new QoS enhancements. Wireless local area networks (WLANs) can operate in two mode infrastructure mode and Ad hoc mode, multimedia applications over these two modes need more guaranteed performance.

QoS is the major issue for real time applications like video-conferencing, VoIP over WLAN. Due to the error prone nature of wireless medium and ad hoc characteristic like lack of central authority, less power and more mobility QoS provisioning became challenging. Datagram routing over unreliable wireless medium made QoS provisioning more challenging.

In this paper we provide the basic QoS requirements like resource allocation which offer two services like IntServ and DiffServ, service differentiation like Distributed Coordination Function (DCF) and Point Coordination Function (PCF), admission control, congestion control, scheduling and traffic shaping and engineering. Some QoS features at MAC layer like priority queuing, differentiated service, QoS scheduling are discussed. An overview of IEEE 802.11 e based QoS features like EDCF and HCF controlled access channel access were analyzed and new contention window modification mechanism is proposed as an enhancement for EDCF for VoIP and video traffic. Paper concludes with comparison of existing and proposed approaches, identifies new areas for applying enhancements.

2. QOS REQIREMENTS

Communication networks are of two types wired and wireless, both require QoS. A lot of research has been carried to provide QoS in wired networks, some of the techniques can be adapted to wireless networks but due to error prone nature of wireless medium new techniques to be developed. Compared to traditional internet application like E-Mail and FTP based on packet data delivery the latest HTTP multimedia applications based on datagram delivery need more QoS provisioning. Different techniques have been adopted to facilitate QoS Provisioning including a) resource Allocation b) service differentiation c) admission control d) congestion control e) Traffic shaping and engineering.

The rest of this section discuss about a brief overview of the problems in resource allocation, admission control, classification of service differentiation, congestion control, scheduling and traffic shaping and engineering.

2.1 **Resource Allocation**

The major reason for QoS issue is resource allocation, as we know the computer network is a collection of resources like communication links with varying bandwidth and routers with different buffer sizes. Packet losses and delays are common if the network doesn't meet the requirements. A strong network must meet resource allocation challenges. There are many architectural frameworks to support resource allocation [2] but two popular architectures are a) Integrated Services (IntServ) and b) Differentiated Services (DiffServ) discussed.

IntServ: It works on the principle of per-flow resource reservation for service differentiation. A flow of service is provided where a flow contains a stream of packets with common source, destination addresses and port number is maintained. IntServ maintains a packet scheduler to enforce resource allocation, it also supports prioritization. Delay bounds may be statistical or deterministic and maintained by IntServ scheduler [3]. Two types of IntServ abstractions are provided, Standard Resources and Reserved Resources respectively. The standard resource abstraction maintains router buffers and capacity of links. In Reserved resource abstraction, session based buffer capacities are maintained by routers. [4][5][6] [7].

DiffServ: It works on the principle of per-class resource reservation for service differentiation, and provides services such as multiple forwarding classes, edge policing, and prioritization to classify different traffic classes. Two types of router are used, core routers used for simple operations and edge routers are used for complex computations in the network. PHB (per Hop Behaviour) packet handling rule is used in DiffServ. This is intended to decide whether a packet needs to be forwarded or dropped based on QoS parameters. This framework is limited to homogeneous networks and cannot be applied to heterogeneous networks. [8] [9] [10]. DiffServ has been used for implementing QoS in various IEEE 802.11-based wireless networks such as [11] [12].

2.2 **Admission Control**

QoS is achieved in wireless networks through admission control – if sufficient resources are available for existing session then only the new sessions are allowed onto network. [13]. To ensure QoS by preventing the congestion occurred due to incoming traffic on network has made the admission control a challenging area. In homogeneous networks such as public switched telephone networks (PSTNs) techniques such as Call Admission Control (CAC) have been employed for traffic management [14]. However in present heterogeneous networks CAC scheme implementation is challenging. Extensive research work is going on algorithms and policies for admission control and scheduling. Hou et al. [15] have presented a theoretical QoS enhancement to improve the delivery ratio, delay and channel reliability.

2.3 Service Differentiation

Service differentiation is used to support multiple services with diverse requirements—such as interactive delay-sensitive services along with elastic delay-tolerant file transfer services[16]. The overprovisioning of network resources is not always possible in radio networks, thus making service differentiation an integral component of most QoS-baased solutions. In service differentiation, several parameters (e.g., packet deadline) can be modified to define how a flow should access the wireless medium. A variety of services can be provided by the use of simple network parameters deployed in network nodes, and these services can be classified according to a large number of characteristics [17]. Service requirements are often application-specific. For example, certain applications are delay-sensitive (e.g., voice conferencing which is sensitive to round-trip delay), while others are concerned more with average transmission rate (e.g., bulk file transfer). Service requirements are often expressed using metrics (i) bandwidth, (ii) delay, (iii) jitter, and (iv) loss rate.

2.4 *Scheduling*

Scheduling is the key to share network resources fairly among users in a network, and it provides service guarantees to time-critical applications. The scheduler first decides the order of requests to be served, and then it manages the queues of these awaiting requests. The scheduling scheme is important for the networks because there are two types of applications. One is insensitive to the performance that users receive from the network, and the other has a strict bound on the performance. The scheduling can provide different services to the flows using parameters such as different bandwidths—by serving only a single flow at a particular interval; different mean delays—according to the level of priority defined for the flow; and different loss rates—by assigning more or fewer buffers to the flows [18].

2.5 *Congestion control*

Congestion control in the modern Internet is typically performed using the TCP protocol [19]. Congestion in a network may occur if the number of packets sent to the network is greater than the number of packets a network can handle. Congestion control refers to the techniques to control the congestion level and keep the load below the capacity. In the QoS-integrated services, the congestion control mechanism should be different for different kinds of sources: e.g., file transfer/ email is different from real-time voice/video applications [20]. The QoS enabled routers provide services to certain flows based on their requirements. Congestion control helps to provide priority differentiation of flows by servicing queues in different manners (e.g., the order in which the flows are serviced).

2.6 *Traffic Shaping and engineering*

Scale [21]. In order to achieve QoS guarantees, decisions on buffering and forwarding must be performed quickly. Traffic engineering is the process that maximizes network utilization through careful distribution of network resources [22]. Most of the Internet backbones currently rely on label switching by adopting 'multi-protocol label switching' (MPLS) technology. The purpose of label switching is to enhance the scope of traffic engineering, QoS provisioning and overlay networks [23].

3. MAC LAYER QOS FEATURES

3.1 *Priority Queuing*

Queues with different priorities are used to segregate the flow of data packets. Eight different queues with each unique priority are maintained and packets can be transmitted based on based on this priority value. The highest priority packet is transmitted when the station has access to channel. The classification of priorities is shown in table 1.

Priority Queue Based Upon Different Application Types

User priority	Access category	Description
1 (Lowest)	AC-BK	Background traffic
2	AC-BK	Background traffic
0	AC-BE	Best effort
3	AC-BE	Best effort
4	AC_VI	Video
5	AC_VI	Video
6	AC_VO	Video
7 (Highest)	AC_VO	Video, network mngt

The working of queue is based upon priorities shown in above table. Eight different levels of priorities are maintained for different applications. The most critical application like network management and video traffic are assigned highest priority and background data is assigned with lowest priority. The delay-sensitive video and audio traffic are enabled medium traffic. [24]

3.2 ***Differentiated services***

Differentiated services are classified in two forms DCF based and PCF based and a broad classification these techniques are represented below.

QOS Enhancements	Queue-based	PCF-based	• HCCA 802.11 e • HCF
		DCF-based	• ECDF 802.11 e
		Priority based	• Priority Queuing
	Station-based	DCF-based	• DFS • Different Maximum Frame Length • • Varying DIFS • Blackburst
		PCF-based	• Priority-based PCF • Distributed TDM

Table 1. Classification of MAC layer QoS enhancements for IEEE 802.11 e based Wireless networks.

There are four main techniques for deploying differentiated services using DCF and they are as below

DCF based

Distributed Fair Scheduling

For good performance of a system, it is not a fair practice to restrict the services of low-priority traffic and to provide better services to high priority traffic. One way is to assign more bandwidth to the high priority traffic in comparison to the low priority traffic. Distributed fair scheduling (DFS) is a technique used in this respect. In this technique, each flow is assigned some weight depending on its priority and the bandwidth it gets is then proportional to this weight. The DFS scheme uses the backoff mechanism of IEEE 802.11 to decide the transmission order of each station. When the transmission starts, each station chooses a random backoff time. This backoff interval is a function of packet length and the priority of the flow. The stations with low priority flows have longer backoff intervals than the stations with high priority flows. Using packet size in the backoff calculation ensures fairness amongst the stations, resulting in smaller packets being sent more often. In the case of a station experiencing a collision, the new backoff interval is generated using the same algorithm.

Varying DIFS

Another solution is to vary the distributed inter-frame spacing (DIFS) duration for differentiation among flows [17]. For example, we know that the ACK packet in the IEEE 802.11 standard gets higher priority than RTS packets, due to the fact that ACK packet waits short inter-frame spacing (SIFS) amount of time, while RTS packet waits DIFS amount of time, which is much longer. The same idea can be taken to the data frames; in which each flow's priority is set with a different DIFS duration. To avoid collisions, a backoff time is maintained similarly in these packets as well. Such technique is much beneficial in real-time applications, where delays have a greater significance compared to packet loss [25].

Differentiated Maximum Frame Length

In this approach, service differentiation is achieved in a way that different stations can transmit frames with different maximum frame sizes. The stations with high priority flows can transmit a larger frame than the one with the lower priority flows. To ensure this, there are two mechanisms: either the packets that exceed the maximum frame size are discarded or an upper bound on the size of packetsis maintained in each station [26]. In some cases, when the packet size is greater than the maximum limit, the packets are fragmented. These fragments are sent without any RTS in between, waiting just for the reception of corresponding ACKs. These mechanisms provide us with the same data rates as those without fragmentation [25].

Black burst

The black burst scheme imposes certain constraints on high priority flows rather than the low priority flows which has been considered until now [27]. In this technique, every station gets access to the medium for a fixed interval of time [28]. Once the station gets access to the medium, it jams the medium for certain duration. Consider a station that has higher priority than others, and it has data packets to transmit, so it senses the channel. Once it detects the channel has been idle for PIFS amount of time, it ahas the potential to transmit its frames. Hence, after waiting for a PIFS amount of time, it enters a black burst contention period. A jamming signal, which is called black burst, is then sent by this station to jam the channel. The length of this black burst signal is proportional to the amount of time a particular station must wait before getting access to the medium. After the station has transmitted its blackburst signal, it again listens to check if any other stations are also sending a black burst signal. The length of this blackburst signal is compared to check whether it is longer or shorter than its own. Subsequently, the station with the longest blackburst shows that it has been waiting for a longer amount of time to access the channel; hence it is the next station to access the channel. This technique is similar to how TDM shares the same medium among the different flows, and it is used in real-time traffic and synchronization [29].

PCF based

Distributed TDM

This mechanism uses a polling method as in the regular PCF mechanism, but time slots are also defined as in the TDM approach, and each of these time slots is assigned to a specific station. Once these time slots are assigned, each station knows when to transmit, and thus transmission of packets can be done with a very little involvement of the AP [25].

Hybrid Coordination Function

Hybrid coordination function (HCF) is a new coordination function proposed in IEEE 802.11e to enhance both DCF and PCF. HCF uses two methods: the first method is contention-based and it is known as enhanced distributed channel access (EDCA), and the second method is contention-free and it is known as HCF- controlled channel access (HCCA). HCF uses the AP as a traffic manager which is termed as the hybrid coordinator (HC) [30], which is a centralized coordinator. The HC negotiates the exchange of frames and the frame handling rules given in HCF. The HC is located within the range of AP and works both in the contention-based and contention-free periods. The traffic is composed of wireless station (STA) “streams” or pipes, with each STA stream associated with a set of QoS parameters [31] negotiated with the AP. The AP uses a polling method to control the traffic. It sends polling packets to the stations. When a station is polled, it replies to the poll in a frame that contains the response and the data to be transmitted. In this method, the polling is based upon the priority on which QoS has to be ensured [32].

3.3 ***QoS Scheduling***:

Strict Priority

In this algorithm, the buffer is partitioned into a number of different queues, which is equal to the number of different priority flows. The packets are then stored in these queues by the scheduler according to their own priority levels. The flows in the same queue are then sent using the FIFO scheme. The strict priority algorithm is easy to implement but it does not guarantee any bit rate and losses. Moreover, the lower priority flows may have a zero-valued throughput. In [33], [34], and [35], a network calculus method is used to evaluate the performance of a switch as it provides a good model of packet exchanges, and it determines end-to-end delay. Note that, the strict priority scheduling is implemented in Ethernet switches. A slight modification to the strict priority algorithm is proposed in [36], where the different flows are assigned with different parameters. The technique is important in the per-hop behavior of differentiated services network.

Weighted Fair Queuing

The same idea of assigning each flow with a certain priority is used, however the queues are not served on FIFO. Each flow is assigned a specific weight according to the QoS requirements. Hence, the bit rate varies with each flow. A certain upper bound on the buffer size is implemented to give all the flows a share of the bandwidth, which is unlike to what we have seen above. An interleaved WFQ scheme is implemented in [37], where a table specifies the queue sequence. The table is interleaved, so higher priority flows are visited more frequently. The scheme improves on latency and jitter which are associated with the traffic queues. In [38], the WFQ scheme that is backward compatible with the IEEE 802.11 standard is discussed. The simulation results show that the scheme can provide appropriate bandwidth distribution even in the presence of flows that need to be transmitted at all times.

Weighted Round Robin

Weighted round robin is a frame-based implementation of WFQ. The flows are segregated similarly in separate queues with a specific weight assigned to each queue. The management can get difficult at times with different packet sizes. A new scheduling algorithm, called the dynamic WRR is proposed in [39]. This algorithm is suitable for all traffic forms having variable and constant bit rates. The queues of traffic are assigned a dynamic weight. It helps the network in providing multimedia services even in the presence of bursty traffic. In [40], a modified dynamic WRR scheme is proposed. This scheme guarantees the delays in real-time traffic and provides efficient transmission of other forms of traffic.

Earliest Due Date

In the normal EDD scheme for wired networks, packets of several different flows are assigned deadlines according to which packets are served first by the packet scheduler with the smaller deadline indicating higher priority. Since wireless networks show varying characteristics, the deployment of EDD is not an easy task. Therefore, in [41], a channel-dependent EDD (CD-EDD) is described. It depends on the channel state, and the packets are queued by the scheduler on the basis of earliest expiry time and other channel parameters. The prioritized flow consequently gets the highest transmission rate among all the flows.

3.***4 Traffic Shaping***

Traffic shaping is used to control the flows of traffic in a channel. The basic idea is to limit the amount of packets per station. A traffic controller is used to comply the QoS requirements of each flow. Traffic shaping can split the resources according to different requirements of different flows. The traffic shaper must adapt to the variations in a channel. The traffic shaping mechanism has a strong impact on the performance of a system [42]. Several traffic shaping parameters are used in the QoS model of IEEE 802.11 standard: e.g., the aggregation level and the bursting level. Aggregation level refers to the amount of packets that are aggregated into a single IEEE 802.11 packet. Bursting level refers to the amount of packets transmitted at each transmission opportunity [43].

4. IEEE 802.11 e QOS FEATURES

The IEEE 802.11 e is a specific standard to provide QoS [44] related to PHY implementation. In a wireless network nodes with IEEE 802.11 e are known as QoS Stations (QSTAs) and each node also has a QoS access point (QAP) to set QoS basic service set (QBSS).The main features of IEEE 802.11 e are (i) Data packet segregation based on priority. (ii) Access Point or central authority based negotiation QoS parameters. (iii) Admission control.

The IEEE 802.11 e standard provides a contention based scheme called extended DCF (EDCF) and a polling based scheme called HCF controlled channel access (HCCA). To achieve QoS provisioning in delay-sensitive applications (voice and video) the above techniques can be used. They are described in detail and some modifications are proposed in next section.

Extended DCF (EDCF)

In the DCF configuration, a contention window is set after a frame is transmitted. This is done to avoid any collisions. The window defines the contention time of various stations who contend with each other for access to channel. However, each of the stations cannot seize the channel immediately, rather the MAC protocol uses a randomly chosen time period for each station after that channel has undergone transmission [46]. EDCF uses this contention window to differentiate between high priority and low priority services [47]. The central coordinator assigns a contention window of shorter length to the stations with higher priority that helps them to transmit before the lower priority ones [45]. To differentiate further, inter frame spacing (IFS) can be varied according to different traffic categories. Instead of using a DIFS as for the DCF traffic, a new inter-frame spacing called arbitration inter-frame spacing (AIFS) is used. The AIFS used for traffic has duration of a few time slots longer than the DIFS duration. Therefore, a traffic category having smaller AIFS gets higher priority [48].

HCF Controlled Channel Access

The HCF controlled channel access (HCCA) is IEEE 802.11e specific, and it makes use of a Hybrid Coordinator (HC) to manage the bandwidth allocation of wireless medium The HC can obtain a transmission opportunity (TXOP) and initiate data deliveries to provide transmission opportunities to a station with a higher priority without any backoff that is to say, the HC can access the channels after a PIFS amount of time rather than a DIFS amount of time as for the other stations [50]. As PIFS is smaller than DIFS and AIFS, the HC has a priority over the DCF traffic, and also over the ECF traffic that uses AIFS.

5. PROPOSED METHOD (EDCF MODFICATION)

We have proposed a scheme in which the increasing of the contention window in case of a transmission failure as well as its resetting is done in a gradual and non-uniform manner in the Contention Window range. The manner in which the Contention window is made to vary depends upon the kind of traffic .For high priority traffic the Contention Window is varied linearly in case of a collision till it reaches a certain value after which it is increased at a faster rate. Same is the case for resetting the contention window. Linear increase in contention window size helps reducing the de- lay difference between packets sent from different rounds of back-off, while reducing the probability of collision in subsequent rounds.

In the above scheme the module Increase Contention Window which is called whenever there is a unsuccessful transmission occurs performs the following functions .First it checks the access category of the traffic flow .If it is high priority voice or video traffic it checks its current CW[i] value .If it is less than twice that of its CWmin[i] ,its CW is incremented linearly till it reaches twice the CWmin[i] .Beyond that the value of CW[i] is increased at a faster rate by multiplying with a factor of 1.5.The justification for this kind of modification is that the probability of three or more consecutive collisions is less hence linear increase of the CW will not affect the overall performance .Moreover the CWmin[i] value of the high priority traffic is kept low .If there are too many collisions the CW starts to increase at a faster rate once CW[i] becomes greater than 2*CWmin[i]. for low priority traffic the CW[i] value is increased consistently by multiplying by a factor of 1.5.

Algorithm 1: Increase in Contention Window:

Begin

If(i_2) //For video and voice traffic

If(CWi<2*CWmin)

CW[i] = min(CW[i]+1,2*CWmin[i])

Else

CW[i]=min(CW[i]*1.5,CWmax[i])

Endif

Elseif(i_0 and i<2) //For best effort and background traffic

CW[i]=min(CW[i]*1.5,CWmax[i])

Else (Display Invalid Access category)

Endif

End

Algorithm 2: Reset Contention Window:

The above module Reset Contention Window which is called whenever there is a successful transmission performs the following functions .Instead of immediately resetting the CW[i] value to CWmin[i] for a particular Access Category in case of a successful transmission it checks its priority .If it belongs to video or voice traffic the Contention window is linearly decremented if CW[i] is less than twice that of CWmin[i] otherwise it is decreased by a factor of 0.5 as in the slow decrease scheme mentioned in. Forall other traffics the CW[i] is decreased by 0.5 till it reaches the CWmin[i] .This slow decrease scheme includes linear decrease for high priority traffic.

Begin

If(i_2) // For video and voice traffic

If(CW[i]<2*CWmin[i])

CW[i]=max(0.5*CW[i],2*Cwmin[i])

Else

CW[i]=max(CW[i]-1,Cwmin[i])

Endif

Else(i_0and i<2) //For best effort and background traffic

CW[i]=max(0.5*CW[i], Cwmin[i]);

Else(Display Invalid Access Category);

Endif

End

6. CONCLUSION.

In this paper we studied QoS Enhancement schemes in IEEE 802.11 wireless networks. Surveyed various QoS requirements of IEEE 802.11 MAC protocol and different MAC layer QoS enhancements were identified and a new technique related to Extended DCF was proposed which increase the performance of IEEE 802.11 e protocol for multimedia applications like VOIP and live video streaming. The algorithm works by increase in contention window and reset contention window. In future the proposed algorithm will be simulated on network simulated and compared with existing techniques. New enhancements like QoS scheduling techniques and policies to be implemented in research work.

REFERENCES

[1] C. Aurrecoechea, A. T. Campbell, and L. Hauw, "A survey of QoS architectures," Multimedia systems, vol. 6, no. 3, pp. 138–151, 1998.

[2] C. Aurrecoechea, A. T. Campbell, and L. Hauw, "A survey of QoS architectures," Multimedia systems, vol. 6, no. 3, pp. 138–151, 1998.

[3] I. Mahadevan and K. M. Sivalingam, "Quality of service architectures for wireless networks: Intserv and diffserv models," in Parallel Architectures, Algorithms, and Networks, 1999.(I-SPAN'99) Proceedings. Fourth InternationalSymposium on. IEEE, 1999, pp. 420–425.

[4] L. Zhang, S. Deering, D. Estrin, S. Shenker, and D. Zappala, "RSVP: A new resource reservation protocol," Network, IEEE, vol. 7, no. 5, pp. 8–18, 1993.

[5] D. D. Clark, S. Shenker, and L. Zhang, Supporting real-time applications in an integrated services packet network: Architecture and mechanism. ACM, 1992, vol. 22, no. 4.

[6] S. Shenker, C. Partridge, and R. Guerin, "Specification of guaranteed quality of service, RFC 2212, september 1997," Internet RFC 2212, Tech. Rep.

[7] R. Braden, D. Clark, S. Shenker et al., "Integrated services in theinternet architecture: an overview. RFC 1633." 1994.

[8] S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, and W. Weiss, "An architecture for differentiated services, RFC 2475." RFC 2475,1998.

[9] V. Jacobson, K. Nichols, K. Poduri et al., "An expedited forwarding PHB. RFC 2598." RFC 2598, 1999.

[10] K. Nichols and V. Jacobson, "A two-bit differentiated services architecture for the internet," RFC 2638, 1999.

[11] H. Chaouchi and A. Munaretto, "Adaptive QoS management for IEEE 802.11 future wireless ISPs," Wireless Networks, vol. 10, no. 4, pp.413–421, 2004.

[12] J. A. Garcıa-Macıas, F. Rousseau, G. Berger-Sabbatel, L. Toumi, and A. Duda, "Quality of service and mobility for the wireless Internet," Wireless Networks, vol. 9, no. 4, pp. 341–352, 2003.

[13] E. W. Knightly and N. B. Shroff, "Admission control for statistical QoS : Theory and practice," Network, IEEE, vol. 13, no. 2, pp. 20–29, 1999.

[14] H. G. Perros and K. M. Elsayed, "Call admission control schemes: a review," IEEE Communications Magazine, vol. 34, no. 11, pp. 82–91, 1996.

[15] I.-H. Hou, V. Borkar, and P. Kumar, "A theory of QoS for wireless," in INFOCOM 2009, IEEE, April 2009, pp. 486–494.

[16] N. Christin and J. Liebeherr, "A QoS architecture for quantitative service differentiation," Communications Magazine, IEEE, vol. 41, no. 6, pp. 38–45, 2003.

[17] I. Aad and C. Castelluccia, "Differentiation mechanisms for IEEE 802.11," in INFOCOM 2001. Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE, vol. 1. IEEE, 2001, pp. 209–218.

[18] S. Keshav, "An engineering approach to computer networking: ATM networks, the internet, and the telephone network," Reading MA, vol. 11997, 1997.

[19] L. Vicisano, J. Crowcroft, and L. Rizzo, "TCP-like congestion control for layered multicast data transfer," in INFOCOM'98. Seventeenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE, vol. 3. IEEE, 1998, pp. 996–1003.

[20] X. Xiao and L. M. Ni, "Internet qos: a big picture," Network, IEEE, vol. 13, no. 2, pp. 8–18, 1999.

[21] O. Aboul-Magd, Wireless Local Area Networks Quality of Service: An Engineering Perspective. IEEE, 2009.

[22] Z. Wang, Internet QoS: architectures and mechanisms for quality of service. Morgan Kaufmann, 2001.

[23] J. A. Garcıa-Macıas, F. Rousseau, G. Berger-Sabbatel, L. Toumi, and A. Duda, "Quality of service and mobility for the wireless Internet," Wireless Networks, vol. 9, no. 4, pp. 341–352, 2003.

[24] N. Sundareswaran, G. F. Riley, K. Boyd, and A. Nainani, "Improving quality of service in MAC 802.11 layer," in Modeling, Analysis, and Simulation of Computer and Telecommunication Systems, 2007. MASCOTS'07. 15th International Symposium on. IEEE, 2007, pp. 38–45

[25] Y. Drabu, "A survey of QoS techniques in 802.11," Internet'Online, pp. 0001–03, 1999.

[26] I. Aad and C. Castelluccia, "Introducing service differentiation into IEEE 802.11," in Computers and Communications, 2000. Proceedings. ISCC 2000. Fifth IEEE Symposium on. IEEE, 2000, pp. 438–443.

[27] V. Sharma, J. Malhotra, and H. Singh, "Quality of service (qos) evaluation of IEEE 802.11 WLAN using different phy-layer standards," Optik-International Journal for Light and Electron Optics, vol. 124, no. 4, pp. 357–360, 2013.

[28] Z. Wang, T. Jiang, L. Zhang, and Y. Liu, "Mobility and QoS oriented 802.11p MAC scheme for vehicle-to-infrastructure communications," in Communications and Networking in China (CHINACOM), 2011 6th International ICST Conference on. IEEE, 2011, pp. 669–674.

[29] Q. Ni, L. Romdhani, and T. Turletti, "A survey of QoS enhancements for IEEE 802.11 wireless LAN," Wireless Communications and Mobile Computing, vol. 4, no. 5, pp. 547–566, 2004.

[30] Y.-S. Chen, M.-Y. Chuang, F.-C. Tseng, and C.-H. Ke, "High performancedistributed coordination function with QoS support in IEEE802.11e networks," in Australasian Telecommunication Networks and Applications Conference (ATNAC), 2011. IEEE, 2011, pp. 1–6.

[31] J. Kowalski, "Hybrid coordination in an IEEE 802.11 network," Jun. 25 2013, uS Patent 8,472,416.

[32] P. Garg, R. Doshi, R. Greene, M. Baker, M. Malek, and X. Cheng, "Using IEEE 802.11e MAC for QoS over wireless," in Performance, Computing, and Communications Conference, 2003. Conference Proceedings of the 2003 IEEE International. IEEE, 2003, pp. 537–542.

[33] J.-P. Georges, T. Divoux, and E. Rondeau, "A formal method toguarantee a deterministic behaviour of switched ethernet networks for time-critical applications," in Computer Aided Control Systems Design,2004 IEEE International Symposium on. IEEE, 2004, pp. 255–260.

[34] J. Jasperneite, P. Neumann, M. Theis, and K. Watson, "Deterministic real-time communication with switched Ethernet," in Proceedings of the 4th IEEE International Workshop on Factory Communication Systems. Citeseer, 2002, pp. 11–18.

[35] J.-P. Georges, T. Divoux, and E. Rondeau, "Strict priority versus weighted fair queueing in switched ethernet networks for time critical applications," in Parallel and Distributed Processing Symposium, 2005. Proceedings. 19th IEEE International. IEEE, 2005, pp. 141–141.

[36] Y. Jiang, C.-K. Tham, and C.-C. Ko, "A probabilistic priority scheduling discipline for multi-service networks," Computer Communications, vol. 25, no. 13, pp. 1243–1254, 2002.

[37] Y.-M. Chen, H. Chung, E. Lee, and Z. Tong, "Interleaved weighted fair queuing mechanism and system," Dec. 13 2005, uS Patent 6,975,638.

[38] A. Banchs and X. Perez, "Distributed weighted fair queuing in 802.11 wireless lan," in Communications, 2002. ICC 2002. IEEE International Conference on, vol. 5. IEEE, 2002, pp. 3121–3127.

[39] T.-G. Kwon, S.-H. Lee, and J.-K. Rho, "Scheduling algorithm for realtime burst traffic using dynamic weighted round robin," in Circuits and Systems, 1998. ISCAS'98. Proceedings of the 1998 IEEE International Symposium on, vol. 6. IEEE, 1998, pp. 506–509.

[40] J.-Y. Kwak, J.-S. Nam, and D.-H. Kim, "A modified dynamic weighted round robin cell scheduling algorithm," ETRI journal, vol. 24, no. 5, pp. 360–372, 2002.

[41] K. M. Elsayed and A. K. Khattab, "Channel-aware earliest deadline due fair scheduling for wireless multimedia networks," Wireless Personal Communications, vol. 38, no. 2, pp. 233–252, 2006.

[42] K. J. Morris, D. J. Hudson, and A. Goyal, "Automatic adaptive network traffic prioritization and shaping," Dec. 2 2008, uS Patent 7,460,476.

[43] D. Zhang and D. Ionescu, "QoS performance analysis in deployment of Diffserv-aware MPLS traffic engineering," in Software Engineering, Artificial Intelligence, Networking, and Parallel/Distributed Computing, 2007. SNPD 2007. Eighth ACIS International Conference on, vol. 3. IEEE, 2007, pp. 963–967.

[44] S. Mangold, S. Choi, G. R. Hiertz, O. Klein, and B. Walke, "Analysis of IEEE 802.11e for QoS support in wireless LANs," Wireless Communications, IEEE, vol. 10, no. 6, pp. 40–50, 2003.

[45] P. Krithika and M. Pushpavalli, "Quality of service optimization in IEEE 802.11e networks using enhanced distributed channel access techniques," International Journal of Computer Networks and Wireless Communications (IJCNWC), 2012.

[46] X. Yang and N. H. Vaidya, "Priority scheduling in wireless ad hoc networks," in Proceedings of the 3rd ACM international symposium on Mobile ad hoc networking & computing. ACM, 2002, pp. 71–79.

[47] L. Romdhani, Q. Ni, and T. Turletti, "Adaptive EDCF: enhanced service differentiation for IEEE 802.11 wireless ad-hoc networks," in Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE, vol. 2. IEEE, 2003, pp. 1373–1378.

[48] J. Villal´on, F. Mic´o, P. Cuenca, and L. Orozco-Barbosa, "Provisioning QoS support for multimedia traffic in IEEE 802.11 WLANs: A performance evaluation."

[49] M. Khan, T. A. Khan, and M. Beg, "Optimization of wireless network MAC layer parameters," International Journal of Innovative Technology and Exploring Engineering (IJITEE), 2013.

[50] S. Mangold, S. Choi, G. R. Hiertz, O. Klein, and B. Walke, "Analysis of IEEE 802.11e for QoS support in wireless LANs," Wireless Communications, IEEE, vol. 10, no. 6, pp. 40–50, 2003.