Per-flow service differentiation via virtual MAC

Mari Carmen Domingo Aladren, David Remondo Bueno

Per-Flow Service Differentiation via Virtual MAC

Mari Carmen DOMINGO ALADRÉN and David REMONDO BUENO
Telematics Engineering Department, Catalonia University of Technology (UPC)
Av del Canal Olímpic s/n. Castelldefels. 08860 Barcelona, Spain
Tel. +34 93 413 7051/7053 E-mail: {cdomingo,remondo}@mat.upc.es

ABSTRACT

The support of quality of service in IEEE 802.11 requires adequate service differentiation. A distributed algorithm named Virtual Source can be used to monitor the channel passively and estimate parameters related to the quality of service. In this way the optimal packet rate and packet size for a concrete application can be chosen so that the delay and delay variance is minimal and thus it can be decided to establish or not a session. If these algorithms combine their functioning with the use of per-flow differentiation, the differentiation effect between priority classes will be enhanced.

1. Introduction

The preferred means of communication will soon be wireless [1]. For this reason, wireless communications must be prepared to offer multimedia applications, where Quality of Service (QoS) parameters such as bandwidth, drop rate, delay and jitter are involved.

QoS support is particularly difficult in wireless environments because bandwidth is scarce and wireless links have variable characteristics. To deal with these problems many modifications have been proposed to enhance the QoS support in the IEEE 802.11 standard.

This paper is organized as follows. The second section describes the functioning of the IEEE 802.11 DCF protocol. In Section 3 we introduce some service differentiation methods in literature. In Section 4 we explain the concept of per-flow differentiation. In Section 5 we present the Virtual Source algorithm, which estimates the service quality level that can be achieved in the medium. The sixth section shows the advantages of using per-flow differentiation combined with the Virtual Source algorithm to enhance service differentiation. Finally, Section 7 concludes this paper.

2. The IEEE 802.11 DCF protocol

The basic scheme for DCF is the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) [2]. When a station wants to send a packet, it must first sense the medium. If the channel is sensed idle for a time interval equal or greater than a Distributed Inter-Frame Space (DIFS), then the station can send the packet; otherwise the station waits a random time after the channel being idle for DIFS, named the backoff time, and then it sends the packet. The backoff time interval can be computed as follows:

$$T_{backoff}=Rand(0,CW)*T_{slot},$$

where T_{slot} represents the time slot selected by the physical layer. This formula means that the node chooses a backoff time equal to a random number of time slots between 0 and a contention window CW. The backoff interval is used to initialize a backoff timer; which will be decreased for each station while the medium is idle and will be frozen when the transmission from another station is detected. If the medium remains idle for a period greater than DIFS, the backoff timer is periodically decremented by one for every time slot. When the backoff timer expires the station accesses immediately the medium. It can happen that two or more stations start transmission at the same time slot and so a collision occurs.

To reduce the probability of consecutive collisions, the CW is doubled after each unsuccessful transmission attempt until a maximum value (CW_{max}) is reached. After a successful transmission, the CW is reset to CW_{min}.

The hidden terminal effect can be reduced through the use of RTS-CTS handshake packets [2].

3. Service differentiation mechanisms

Several authors have proposed modifications of the IEEE 802.11 DCF that introduce service differentiation.

The DENG scheme [3] is a modified CSMA/CA protocol that assigns different Inter-Frame Spaces (IFSs) and backoff windows to four different priority levels.

The IEEE 802.11e or Enhanced DCF [4] provides differentiated DCF access to the medium for eight prioritized traffic categories. Each category has a different minimum contention window value (CW_{min}) to assure service differentiation. Besides, the different traffic classes use different IFSs named Arbitration Inter-Frame Spaces (AIFSs), where the DIFS plus some (possibly zero) time slots are added.

The Adaptative Enhanced DCF (AEDCF) [5] is a modification and improvement of the EDCF protocol that aims at establishing different priority classes to access to the wireless medium. After a successful transmission, the EDCF mechanism resets the contention window of the class *i* to $CW_{min}[i]$. It would be better to update the value of CW more slowly. AEDCF ensures different priorities by adjusting the size of the Contention Window (CW) of each traffic class accordingly to applications requirements and network conditions.

In the Distributed Fair Scheduling (DFS) scheme fair queuing is applied to the wireless domain [6].

Blackburst [7] is a distributed scheme whose main goal is to minimize the delay for real-time traffic.

4. Per-flow differentiation

In the described methods the differentiation effect in the MAC layer is not very good because packets are put in the same queue in a node, with independence of their priority [8]. In this situation a packet with lower priority accesses the medium before another packet with higher priority that has arrived to the same node later only because the first one has been put in the queue before. For this reason a station could be contending to access the medium using contention rules that correspond to a packet with lower priority even if it holds packets with higher priority that should access the medium sooner.

Therefore it would be better to use a different queue for each priority in the same node. In this way we can ensure that the highest priority packets will contend to access the channel if they are in the queue, thereby enhancing the differentiation effect.

5. The Virtual Source algorithm

The above modifications of the IEEE 802.11 DCF provide service differentiation but even so we cannot guarantee the behaviour of individual traffic types. The Virtual Source (VS) algorithm [9] is useful for estimating whether the medium can support new service demands in a wireless environment. The VS algorithm comprises the Virtual Application (VA) and the Virtual MAC (VMAC).

With the VMAC [10] it is possible to estimate the MAC-level statistics that refer to QoS like delay, delay variation, packet collision rate and packet loss rate. Afterwards it can be decided whether a new session between mobile hosts and access points can be established with a particular service level. The quality parameters for the different traffic classes are estimated by monitoring the channel passively, so that no additional load is introduced in the channel.

The VA generates virtual real-time packets, putting a timestamp in the packet headers, and then they are placed in a virtual buffer. Then the packets contend to access the channel in the same way as real packets would do, but with the difference that they are not really transmitted. Nevertheless, the probability of collision is estimated.

The packets from a particular application suffer the following delay: delay due to their packetization, delay caused due to the waiting time in the queues and the delay motivated by the wireless MAC access. The last one comprises the time expended in receiving a packet in the MAC and the time used to send the corresponding ACK when the next packet will be serviced. With the help of the VS it is possible to estimate the total delay from the packets, while the VMAC algorithm is responsible for estimating the MAC delay.

The data bitrate $p_{data\_bitrate}$ can be calculated as:

$$p_{size}*p_{rate}= p_{data\_bitrate}=\text{const},$$

where p_{size} represents the size of the application level packet and p_{rate} is the packet inter-arrival time.

There is a trade off between packetization and MAC delays because higher packet rates cause more collisions and operate with smaller data packets so that the MAC delay will be higher. In contrast, lower packets rates mean bigger data packets and increased packetization delay.

The virtual delay curve p_{rate} gives the average delay of virtual packets generated by the VS algorithm at a particular rate $p_{rate.}$ The terminal executes the VS algorithm taking different values for $p_{rate,}$ so that a delay curve can be constructed. Then the node can select optimal values for the packet rate and the packet size so that the delay and the delay variance that the application demands are satisfied.

6. Per-flow service differentiation using VS

The VS algorithm has been designed to provide service differentiation between different types of traffic. However, the internal functioning of the VS algorithm reduces the service differentiation effect since all the virtual packets generated by the VA for a station are put in a single virtual buffer.

We argue that a better solution would be to use a queue for each of the priority levels within a node. Our proposal implies using different buffers both for the real packets and for the virtual buffers that are part of the VS algorithm. We argue that this combination of per-flow services differentiation and the VS algorithm will improve service differentiation in IEEE 802.11 DCF.

Specifically, ad-hoc networks are networks that are able to configure themselves without the presence of a system administrator or central point of control and therefore distributed algorithms such as VS are highly recommendable. Using multiple virtual and real buffers in the nodes does not prevent us from applying the proposal to such networks.

7. Conclusions and future work

Service differentiation in IEEE 802.11 DCF can be achieved in many different ways like for example manipulating the contention window limits. But it is also desirable to guarantee that certain QoS requirements can be satisfied. One interesting proposal to do this is the VS algorithm.

We have come to the conclusion that the differentiation effect will be enhanced by combining per-flow differentiation at each node for both real packets and virtual packets belonging to the VS algorithm.

Future work includes using simulations and emulators to demonstrate that the analysis that has been realized theoretically can also be demonstrated in practice.

REFERENCES

[1] *The Essential Guide to Wireless Communications Applications.* A. Dornan, ed. Prentice Hall PTR, 2000.

[2] *Mobile Communications.* J.H. Schiller, ed. Addison Wesley Professional, 2000.

[3] D-J. Deng, R-S. Chang. A priority scheme for IEEE 802.11 DCF access method. *IEICE Transactions on Communications*, E82-B(1), January 1999.

[4] M. Benveniste, G. Chesson, M. Hoeben, A. Singla, H. Teunissen, M. Wentink. EDCF proposed draft text. *IEEE working document 802.11-01/131r1*, March 2001.

[5] L. Romdhani, Q. Ni, T. Turletti. AEDCF: enhanced service differentiation for IEEE 802.11 wireless ad-hoc networks. *INRIA Research Report No. 4544*, 2002.

[6] N.H. Vaidya, P. Bahl, S. Gupta. Distributed fair scheduling in a wireless LAN. In *6th Annual Int. Conf. on Mobile Computing and Networking*, Boston, Aug. 2000.

[7] J.L. Sobrinho, A.S. Krishnakumar. Quality-of-Service in ad hoc carrier sense multiple access networks. *IEEE J. Selec. Areas Commun.*, 17(8):1353–1368, August 1999.

[8] I. Aad, C. Castelluccia. Remarks on per-flow differentiation in IEEE 802.11, *European Wireless 2002*, Florence, Italy, February 25th-28th, 2002.

[9] M. Barry, A.T. Campbell, A. Veres. Distributed Control Algorithms for Service Differentiation in Wireless Packet Networks. In *Proc. IEEE Infocom'01*, April 2001.

[10] A. Veres, A.T. Campbell, M. Barry, L.-H. Sun. Supporting Service Differentiation in Wireless Packet Networks Using Distributed Control, *IEEE J. Selec. Areas Commun.*, Vol. 19, No. 10, pp. 2094-2104, October 2001.