Throughput Analysis of EDCA in Multimedia Environment

Blagoj Ilievski, Pero Latkoski and Borislav Popovski

Abstract – **This paper addresses issues that arise when end-to-end QoS has to be guaranteed in today's pervasive heterogeneous wired-cum-wireless networks. The basic IEEE 802.11 standard for local area networks can not cope with the emerging multimedia services such as voice, data and video. On the other hand, the wireless medium is very specific; there is no guarantee for any performances as in the wired medium, especially in the unlicensed spectrum. The new 802.11e MAC which is based on both centrally-controlled and contention-based channel access provides means for needed QoS in such conditions. Here we analyze the .11e's throughput performance and packet loss for different traffic types, compared with the basic standard, and its dependence of the network conditions.**

Keywords – **IEEE 802.11e, Network Simulator, performance evaluation.**

I. Introduction

IEEE 802.11 [1] introduces DCF (Distributed Coordination Function) and PCF (Point Coordination Function) on the MAC layer. DCF does not support priority mechanism [2]; all packets are treated using first-come-first-serve philosophy. On the other hand, PCF sustains several resource reservation methods. Although it can support some kinds of time-critical traffic, many inadequacies have been identified, such as unknown transmission duration of polled station, difficulty to predict the amount of frames one wants to send, no management interface defined to build up and control PCF operations. We can summarize that DCF can not provide QoS, and PCF is not capable enough [3].

The 802.11e standard is the result of the WLANs QoS issue. Due to the dynamic nature of these kinds of networks, it is impossible to apply QoS management techniques to negotiate quality between users and network. Nevertheless, it is possible to increase success probability of certain classes of traffic to get appropriate QoS. There are two kinds of QoS:

- Parameterized QoS – A strict QoS requirement expressed quantitatively in terms of data rate, delay bound etc.
- Prioritized QoS – Loose QoS requirement expressed in terms of relative delivery priority.

For different types of traffic, there are different requirements, but in case of WLANs the most common are two: bound delay (for real time traffic) and jitter. On the other hand, certain traffic stream is described by the transmission rate (peak and average), service interval (minimum and maximum) and the burst size of the peak rate.

All authors are with the Faculty of Electrical Engineering and Information Technologies – Skopje, Macedonia.

The term QoS of WLAN refers only to the MAC level. The new standard (IEEE 802.11e) defines "stations with QoS support" - QSTAs, and "access points with QoS support"- QAPs, different from the stations and the access point defined in the original standard (IEEE 802.11). Here, a new method is introduced to support the QoS requirements: Hybrid Coordination Function (HCF). HCF has two main parts. One is HCF Controlled Channel Access (HCCA), for the Integrated Services requirement. The other one is Enhanced Distributed Channel Access (EDCA/EDCF), for the Differential Services requirement. In other words, EDCF is responsible for contention, while HCF for contention free working regime. While the EDCF is appropriate for asynchronous data services, the HCCA provides means of time-bounded services.

In the new IEEE 802.11e standard, acknowledgement (ACK) for successful transmission of the frames sent by stations becomes no obligatory. It means that MAC layer will not send ACK frame after successful receiving of a data frame. This approach decreases the reliability, but the overall traffic transmission efficiency (e.g. VoIP) is upgraded.

II. EDCA Function

The EDCA function improves the basic DCF function by implementing priorities for different traffic classes. The EDCA defines four access categories (AC), in which the traffic is additionally classified into 8 different traffic classes-user priorities (UP). The traffic in a same class is considered to be of equal priority. Table 1 shows the mapping between access categories and user priorities.

Table 1. Traffic classes (TC) in IEEE 802.11e

Priority	User Priority	802.1D Designation	Access category (AC)	Designation
Lowest	0	BE	AC_BK	Background
.	1	BK	AC_BK	Background
.	2	_	AC_BE	Best Effort
.	3	EE	AC_BE	Video
.	4	CL	AC_VI	Video
.	5	VI	AC_VI	Video
.	6	VO	AC_VO	Voice
Highest	7	NC	AC_VO	Voice

Every AC differs by the parameters variety and has its own queue. The parameters value determinates the AC and the type of the traffic. Three of the parameters are crucial for this standard:

- **CW** - *Contention Window* - A random number is drawn from this interval, or window, for the back off mechanism;

- **AIFS** - *Arbitrary Inter Frame Space* – It is equal to DIFS plus a number of time slots. The value of AIFS differs for every traffic class to enhance the differentiation based on the priority of classes.
- **TXOP Limit** – Maximum aloud time for transmission, of one QSTA. During this period, medium belongs to the station.

A station may implement up to eight transmission queues realized as virtual stations inside a station, with different QoS parameters that determine their priorities [4]. When two or more TCs in a single station start transmitting at the same time, a scheduler inside the station avoids the virtual collision.

Before station starts to transmit, MAC layer classifies the traffic into appropriate AC. Every new MSDU frame finds its place into adequate AC. The frames from different categories compete for the EDCF-TXOP. Each class differs by varying the minimum contention window (CWmin) and the interframe space which are used for data transmission. A class with smaller default contention window will result in generating shorter backoff intervals and as a result it gains priority over a station with a larger CWmin [5].

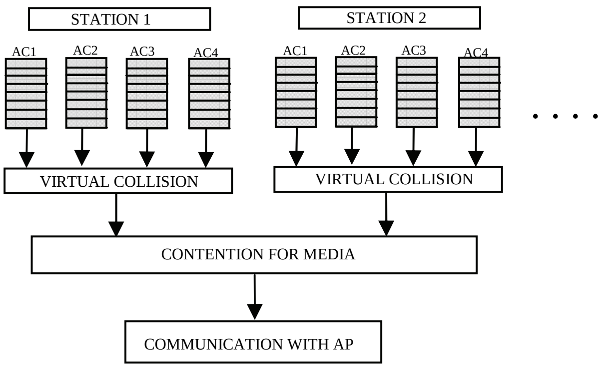

Fig.1. EDCF function

In the IEEE 802.11e EDCA, different ACs use different AIFS values and contention window size when contend for the channel access.

The value of AIFS depends on the AC, and the value of the aSlotTime parameter depends on the used PHY Layer (in our case 802.11b). The number of backoff procedure slots is uniformly distributed random variable between 0 and CW-1. The CW is the contention window whose value is between CWmin and CWmax. After each successful transmission, the CW is reset to CWmin, and on each failure packet transmission the backoff procedure doubles the CW value until the value reaches the CWmax. In IEEE 802.11e the values of CWmin and CWmax are different for each AC and used PHY Layer (Table 2).

Table 2. Parameters for three types traffic in IEEE 802.11e

Type	**AC**	**AIFS**	**CWmin**	**CWmax**	**TXOP Limit**
Voice	3	2	7	15	0.003
Video	2	2	15	31	0.006
Data	0	7	31	1023	0

The winner virtual station of the internal competition has right to compete with the rest of the winners of the other stations to transmit over the medium.

The problem of the traffic differentiation is solved by adding field into the MAC header that describes the characteristics of the traffics (Table 3).

Table 3. IEEE 802.11e MAC header

octets: **2**	**2**	**6**	**6**	**6**	**2**	**6**	**2**	**n**	**4**
Frame Control	Duration / ID	Address 1	Address 2	Address 3	Sequence Control	Address 4	**QoS Control**	Frame Body	FSC

There is an option in IEEE 802.11e standard called *packet bursting* - CFB (Contention Free Bursting). This feature, improves the performance of smaller packets (time bounded services) in WLANs [6]. The CFB decreases the overhead and in such a way the delay is decreased and the throughput is increased. The station with included CFB sends multiple small packets as a burst without intermediate contention, as soon as the station gains access to the medium. It is possible to send packets to different destinations in one burst frame. Between an ACK and the following packet only a time interval of SIFS (Short IFS) is required. Therefore the station maintains control over the medium for the whole burst (not longer then TXOP). Sending multiple small packets in a burst avoids contention for each single packet and increases the efficiency. However, the medium access time might be increased because packet bursts occupy the medium for a longer period, therefore the overall network jitter and delay may increase. By adjusting the parameters, especially TXOP Limit one can optimize the network functioning.

III. Simulation Results

The network will be analyzed using NS2 (Network Simulator) [7]. In fact, this simulator is the most widely used simulator for analysis of the wireless networks.

The scenario is consisted of one access point (AP) connected with a host via switch and surrounded by six wireless stations (WS) (Fig.2). We assume two directions of the traffic stream: from the station towards the server (uplink) and from the server towards the station (downlink). We shall analyze the uplink throughput performance.

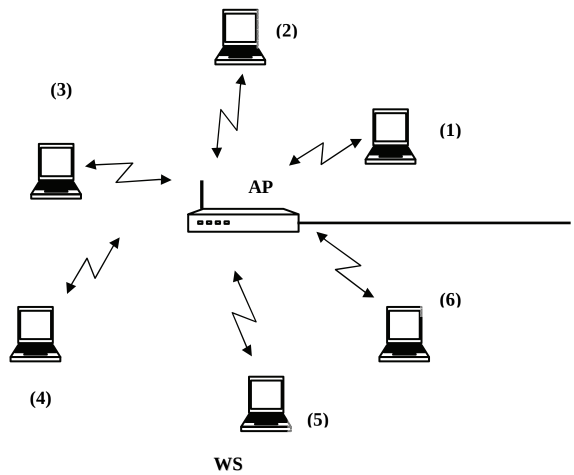

Fig. 2. Simulated WLAN scenario

Table 4 contains the used types of traffic and its parameters. It will be discussed the impact of the “e” standard over these three different types of traffic. All the stations will send packets with included CFB option. In this scenario two stations (5 and 6) generate and receive voice traffic (with the highest priority – AC4), two stations (3 and 4) generate and receive video traffic (AC2); stations 1 and 2 generate and receive data traffic (AC1). The AP transmits three types of traffic generated from the host towards wireless nodes (downlink) and receives also three categories of traffic from wireless nodes (uplink). Voice and video traffic is assumed to be of constant bit rate (CBR). Data traffic is assumed to be FTP traffic.

Table 4. Three types of traffic used in the simulation

Type	**Agent/ Application**	**Frame Size (bytes)**	**Data Rate (Mbps)**
Voice	UDP/CBR	32	0.032
Video	UDP/CBR	1280	1
Data	TCP/FTP	1536	1

We measure the uplink throughput performance and its dependence of the frame size, load and the number of the active stations in the network. First parameter that is changed is packet size. The network is loaded with 40% of its capacity.

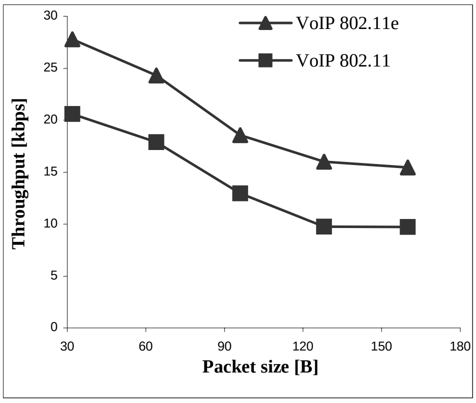

Fig.3. Voice traffic throughput dependence from pck size

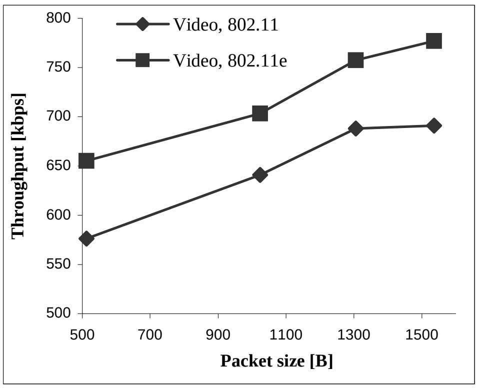

Fig.4. Video traffic throughput dependence from pck size

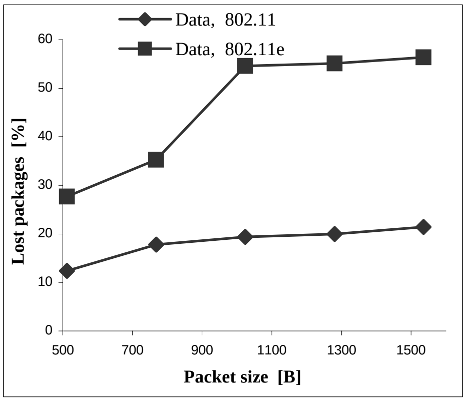

Fig. 5. Lost data packets dependence from pck size

Simulation results show opposite behavior when voice and video traffic are analyzed. The reason is TXOP, which for voice is smaller than the TXOP for video traffic. Data traffic with implemented QoS option is very sensitive of packet size change (Fig.5).

Next three figures will give the dependence from the traffic load parameter.

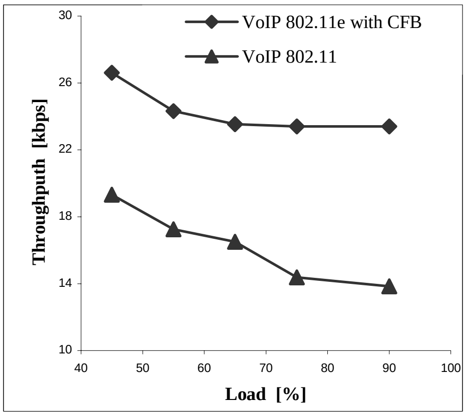

Fig.6. Voice traffic throughput depends from Load

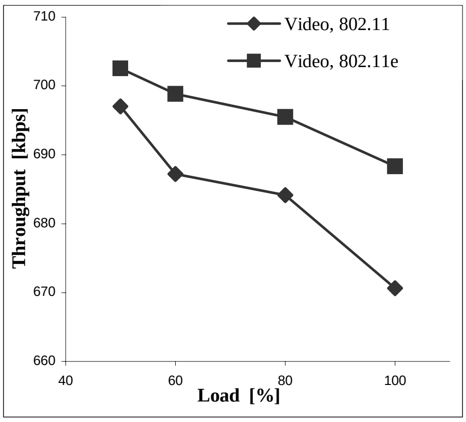

Fig.7. Video traffic throughput depends from Load

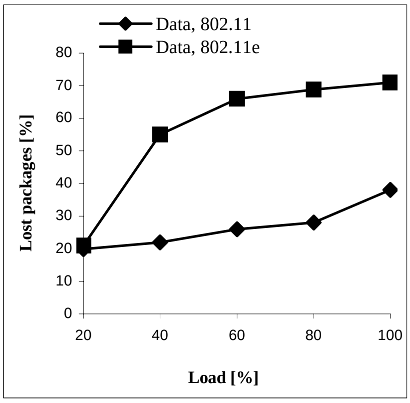

Fig.8. Lost data packages depends from traffic Load

When we discuss the load in the network, the “e” standard shows improvement compared to the basic standard. For voice the throughput is not changing significantly (10% difference in the throughput, for 50% and 90% load – Fig. 6). But the other two categories are very sensitive and deteriorate rapidly compared to the basic standard (Fig. 7, Fig. 8).

The number of the stations in the network is another important parameter. When the number of active stations is large the probability of collision increases as well.

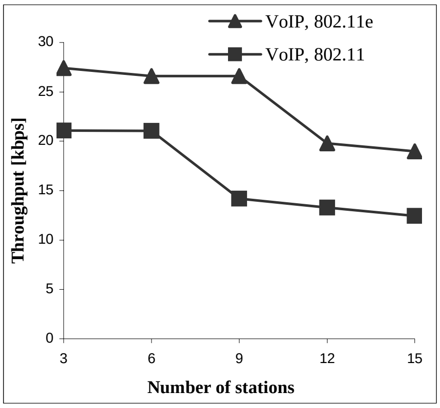

Fig.9. VoIP traffic dependence from number of stations

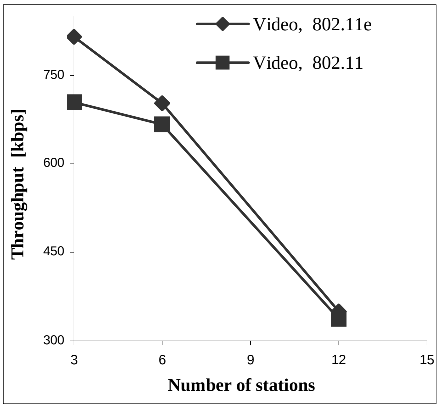

Fig.10. Video traffic dependence from number of stations

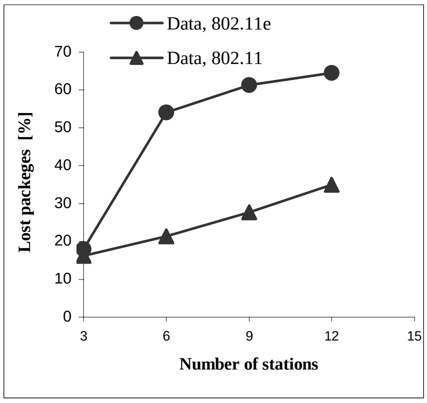

Fig.11. Lost data packages dependence from number of active stations

When the number of the wireless stations in the network is increased, “e” standard gains the voice traffic wining probability over the medium. Video and data has no significant chance when medium is shared by very large number of stations (Fig. 9, Fig. 10, Fig. 11).

IV. Conclusion

Our simulator implements the new EDCF function. This function is an upgrade of wireless stations and enables QoS support. By simulations we find that EDCF shows weakness at low-level categories of traffic. It is evidently that the high priority categories of traffic dominantly occupy the medium. The throughput of the different services traffic is very sensitive of the changes in the network (number of the stations, traffic load), or the size of the packets. Also the characteristics of the data traffic deteriorate compared to the basis standard. This implies requirement for further improvements in the 802.11 MAC to increase the quality of the data traffic compared to the basic standard performance.

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