An Evaluation of QoS for Intensive Video Traffic over 802.11e WLANs

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***Abstract*— With the continuing development of the wireless technologies (Wi-Fi, 3G, 4G, WiMax and Bluethooth), the study of wireless multimedia transmissions has gained lately more attention. For example, the expectations of the company leaders on the growth of Wi-Fi video traffic has updated the lines of research on the standard IEEE 802.11e introduced to provide QoS (Quality of Service) to WLAN (Wireless LAN) networks. A quantitative analysis has been performed by simulation. We use a node model EDCA (Enhanced Distributed Channel Access) 802.11e with the tool Möbius of the University of Illinois, which supports an extension of SPN (Stochastic Petri Networks), known as HSAN (Hierarchical Stochastic Activity Networks). This formalism favors the comparison of the results with those obtained from other tools, based mainly on simulation languages, for Wi-Fi stations with the capacity to transmit voice, video or best effort traffic in presence of error. This article introduces novel scenario that varies the load by increasing the number of active stations from 5 to 45 but maintaining their relative traffic proportion. The proportion of traffic injected by stations is 65% video, 2% voice, and 33% best effort. Measured performance metrics were absolute or direct performance, relative performance, average delay of queue, and average queue size.**

Keywords—tuning; EDCA parameters; modeling; simulation; WLAN 802.11e; throughput

I. INTRODUCTION

The services of wireless mobile data are on their way to meet the needs of many users on the network. The voice services with mobile devices are already considered as a necessity by most people. And the mobile devices for data services, video, and TV are rapidly becoming an essential part of the everyday life of consumers. The proliferation of handsets, laptops and tablets on mobile networks is a major traffic generator, because these devices offer the consumer content and applications not supported by previous generations of mobile devices. The projections for the next 5 years show a steady growth in the mobile video, despite macroeconomic conditions in many parts of the world. Because of that fact, the contents of mobile video have much higher bit rates than other types of mobile content, mobile video will generate much of the growth of future mobile traffic. It is expected for the 2018 that 65% of the total wireless traffic will be associated with video applications [1].

Up until a few years ago, the Wi-Fi traffic was more general, and included light flows of voice traffic. The greatest burden of the video traffic will be a test for the standard EDCA IEEE 802.11e and the algorithms of admission control, to sustain the QoS requested by the user.

The principal contributions of this article are i) to specify and experiment on a new scenario offering metrics evaluation while maintaining a video intensive proportion for network traffic in line with the expectations of the Wi-Fi traffic future, ii) to demonstrate that the standard EDCA IEEE 802.11e mechanism using default static parameters provides traffic differentiation enough in this context, and iii) the contributions and conclusions made using an EDCA model with either SPNs that complement, enrich, and facilitate comparison with precedents within Wi-Fi network knowledge obtained from pure trace collection or other types of analytical studies and modelling using mathematical tools for different real and hypothetical contexts.

Researchers and the industry could use these data for their proposals in the EDCA IEEE 802.11e devices.

The rest of this document is structured as follows. Section II introduces the fundamentals and principles of the work. Section III provides a general view of the EDCA 802.11e standard. Section IV presents the commercial deployment of the standard IEEE 802.11e EDCA. Section V describes the Wi-Fi station model built with HSANs and the simulation scenario defined for experimental evaluation. Section VI gives the absolute and relative performance, the queue size and the queue delay in the scenario. And section VII summarizes the most significant conclusions.

II. BACKGROUND AND RELATED WORKS

Providing Quality of Service (QoS) in Wi-Fi networks is a considerable challenge for data networks, due to the high levels of burst-like packet loss, latency, and jitter. Several ways to characterise QoS through strict requirements expressed using quantitative values include data velocity, throughput loss thresholds, packet loss rates, and maximum limits on delay and jitter.

The family of IEEE 802.11 protocols is the most promising framework for Wireless LAN (WLAN) networks; there is also hope that it can become the standard in industrial, multimedia and personal environments [2]. The protocol includes the 802.11e standard that proposes a new function for the MAC layer, known as the Hybrid Coordination Function (HCF).

This function uses a channel access method based on EDCA contention. EDCA is designed to provide prioritised QoS and improve the Distributed Coordination Function (DCF) belonging to the original 802.11 standard.

Trace collection is a necessary first step in creating realistic models crucial to design, simulate, and evaluate network protocols [3-6]. The other method for analysing the performance of IEEE 802.11communication networks has been to develop evaluation models based on two different perspectives: analytical and simulation. Analytical models [7-17] have the advantage of providing expressions/formalisms that help analyse the influence of different parameters. Most of these models are the extension IEEE 802.11e EDCA of the analytical model of IEEE 802.11 DCF using Markov chains presented in [18]. To develop realistic scenarios like those anticipated in this study, we assume that using analytical models would not be an adequate approximation for the following reasons: a) simplifications usually used in these models cannot appropriately capture important aspects to evaluate, including various metrics obtained through simulation, b) most models assume Poisson traffic sources, thus making difficult an exact modelling of other traffics, c) greater flexibility in configuring and comparing different evaluation scenarios is possible with appropriate simulators.

For more realistic scenarios, several simulation analyses have been made using tools like Network Simulator (NS-2) [19], OPNET [20], QUALNET [21] or IP TRAFFIC [22]. All of these tools are especially appropriate for analysing the performance of communication networks. However, in some of them it is not practical for use in the sort of tests that are intended to make, and difficult to implement any type of light modification to protocols, the network's timing characteristics or to scenarios of modelling.

Few papers are available in the literature or research studies that use Stochastic Petri Nets (SPNs) [23] as a modelling formalism for analysing IEEE 802.11 communication protocols. Although early models have made important contributions from a modelling standpoint, their implementation in most SPN tools either suffers from limitations or entails overcoming significant difficulties in characterising more complex simulation scenarios. The replication is essential in evaluating scenarios comprising similar stations with a mix of different traffic types or when varying the proportional relationships of traffic in the presence of noise.

A base model [24] is thus adopted using HSANs [25], which closely follows the EDCA IEEE 802.11e standard and is executed on the Möbius simulator [26]. To the best knowledge of the authors, this report describes the first EDCA implementation using SPNs. These resources rectify the observations discussed above and facilitate a precise study of QoS in Wi-Fi networks.

This aspect is very critical, beyond the level of accuracy of the model is used, when it is intended to simulate different hierarchical scenarios with numerous stations, each with its own special features in configuration and/or traffic. Möbius allows to release to the analyst of the complexities of programming typical of low level (as happens in most of the simulators based on programming), for adjustments in the model or the scenarios for experimentation. The tool of mathematical modelling HSAN and the simulator Möbius guided the present work to a higher level, and allowed a rapid sequence of parametric reconfigurations in each context under studio to obtain the metrics of performance.

III. Brief Description of EDCA 802.11e

A. DCF y PCF in 802.11

The DCF (Distributed Coordination Function) 802.11 only provides the best-effort service [2]. As indicated previously, multimedia and real-time applications limited in time require certain guarantees. In DCF, all stations are competing for the channel with the same priority. There is no mechanism of differentiation to provide better service for multimedia traffic or real-time with regard to the application of common data. Although PCF (Point Coordination Function) 802.11 was designed to support multimedia applications limited in time, it presents problems which lead to a poor performance of QoS. This is due to the fact that PCF only defined a scheduling algorithm of round-robin for simple class or category of traffic, and several QoS requirements cannot be manipulated. On the other hand, a common problem of QoS, both for DCF and PCF, is that they do not specify any mechanism of admission control. When the traffic load is very high, the performance of both functions is degraded.

B. EDCA in 802.11e

The QoS limitations in DCF motivated many research efforts to improve MAC performance. For 802.11e, a new function has been proposed for MAC layer, known as Hybrid Coordination Function (HCF) [2] (Figure 1). HCF uses a contention-based channel access method, also known as Enhanced Distributed Channel Access (EDCA), which operates concurrently with a polling-based, HCF-controlled channel access method (HCCA). The access point (AP) and the stations (STAs) using QoS facilities are called QoS-enhanced AP (QAP) and QoS-enhanced STAs (QSTAs), respectively.

The optimization process of QoS of EDCA is based on a generalization of contention-based DCF. Initially heterogeneous traffic reaches the MAC layer including voice, video, best effort, background and they are mapped to the corresponding Access Categories (ACs). In the MAC layer there are 4 queues, one for each AC, which receive the packets according to a specific priority of upper layer.

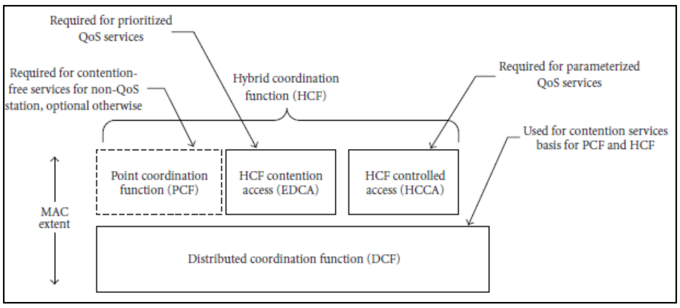

Figure 1. MAC Architecture.

Each AC acts as a separate DCF entity competing according to its own contention parameters (CWmin[AC], CWmax[AC], AIFS[AC] and TXOPLimit[AC]). Each AC maintains a contention window size variable (CW), which is initialized to CWmin. The CW is incremented after transmission failures until it reaches CWmax, and is reset to CWmin after a successful transmission. The maximum allowed duration for each acquired transmission opportunity is determined by TXOP limit. Once a station acquires a transmission opportunity, it may transmit multiple frames within the assigned TXOP limit. Assigning different TXOP values to ACs, therefore, achieves differential airtime allocations.

To achieve differentiation in EDCA, instead of using fixed DIFS (Distributed Interframe Space) as in the DCF, an AIFS (arbitrary IFS) is applied (Figure 2), where the AIFS for a given AC is determined by the following equation:

$$AIFS[AC] = SIFS + AIFSN[AC] * SlotTime$$

where AIFSN is AIFS number and determined by the AC and physical settings, SlotTime is the duration of a time slot, and SIFS is the Short Inter-Frame Space of DCF. The highest priority will be given to the AC with the smallest AIFS.

In general, the smaller values of CWmin[AC], CWmax[AC], AIFS[AC], the shorter delays of channel access to the corresponding AC, and the higher priority for access to the medium. And to larger values of TXOP[AC], more time to retain the channel corresponding to the AC.

A contention-based mechanism for admission control is also suggested for 802.11e, which calls for both QAP and QSTA support.

IV. Deployment Aspects of EDCA 802.11e

There are commercial products that implement some features of EDCA so common, although the adoption of 802.11e is still not complete and with some years of experience in the voice traffic, but little mature using video. As with several standards, and due to the fact that there are optional components and suggestions of implementation, some manufacturers solve their own evolution of QoS in WLANs with proprietary alternatives and in their high-end devices. As a first step agreed, groups of industries (such as the Wi-Fi Alliance) and industry leaders defined in 2004 the fundamental requirements of the WLAN QoS through its EDCA/WMM (Wi-Fi MultiMedia) [27-29], securing the support of the key features and interoperation through its certification programs.

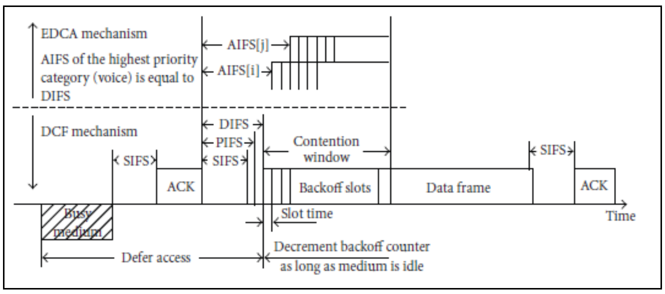

Figure 2. IFS Relationships.

The APs and network boards are commercially available under the name WMM. The WMM certification is mandatory for the equipment that support the 802.11n standard.

In WMM the mapping of categories of services given by ToS (Type of Service) or DS (Differentiated Services) of the IP header, or by CoS (Class of Service) of standard VLANs 802.1Q, is used with EDCA 802.11e. Some low-cost products only support the empowerment of the WMM QoS service. In this way, the AP is configured with the default EDCA IEEE 802.11e parameters. In a complementary manner, with proprietary solutions, some manufacturers allow the manual configuration of the EDCA parameters, in the lines of advanced wireless products [30].

On this basis, the natural evolution in this field of study has been and still is to analyze the mechanisms of inclusion of enhanced Admission Control Algorithms in order to ensure the stability of the system. Precisely, and even though the signalling messages required to support the procedure of admission control are defined in the 802.11e standard, the rules of admission are still open.

In this way, it is noted that the latest versions of 802.11e and some commercial equipment allow a basic mechanism of update of the EDCA parameter, before any changes could be determined in the network. This implies a greater ease at the time of the effective implementation of the improvements that decided to run the network administrator using these configurations as variables of the Wi-Fi system.

The optimization of the EDCA parameters is a simple and effective mechanism to increase the capacity of handling simultaneous heterogeneous traffic and with certain restrictions of QoS, and therefore to use less APs by quantity of STAs, allowing the reduction of costs for equipment.

V. Model and Simulation Scenario

Since the appearance of the standard EDCA IEEE 802.11e EDCA, the analysis of its behavior has generated extensive research work.

Scenarios used by the majority of the authors usually consider equal experimentation stations that inject a mixture of voice traffic, video, and best effort. Therefore, there is a 33% of traffic flow number on each. Although the actual traffic load injected in the scenario depends on its characteristics. For these proportion in the number of traffic flows, the typical charge of voice traffic is low (5-10 %), and the remaining charge is distributed between the video traffic (40-45 %) and best effort (55-45 %).

In previous works [31-34] we considered traffic generated by stations operating on the same frequency bands while varying the load by increasing the number of active stations from 1 to 20. And different situations were established in this scenario, according to the type of traffic injected by stations. But in line with the expectations of the Wi-Fi video traffic future, in this paper we model the EDCA standard in its entirety, include interference and propose a novel scenario. This scenario (to the best of our knowledge, it has not yet been analysed) considers the studio of prospective [1] and the proportion of flow numbers is 60% video, 20% voice and 20% best effort. The relationship of the weighted real traffic injected by stations is 65% video, 2% voice stations, and 33% best effort, according to the settings given in Table I.

It is noted that for this scenario the weighted real voice traffic impacts very little in the load of the scenario not only by their low proportion in the total number of flows present (20 %), but also by its small packet size (8 times less than the video). The load of a single video flow is virtually equivalent to 8 flows of voice, according to the configurations assumed. This aspect will be critical when in the future the contexts of use of the Wi-Fi have three video flows for each voice flow.

TABLE I
SIZES Y RATES OF TRAFFICS IN THE SCENARIO

	Voice	Video	Best Effort
Packet size	160 bytes	1280 bytes	1500 bytes
Rate	64 Kbps	640 Kbps	1024 Kbps

A. Experimental Model

The model adopted comprises a precise and detailed EDCA implementation function associated with QoS stations, considering both functional and temporal perspectives, and it is executed on the Möbius simulator (Figure 3 y 4).

Several international authors have sufficiently validated the model in the literature [31-35]. The modeling with HSANs favors the comparison with the contributions of the authors that use other simulators.

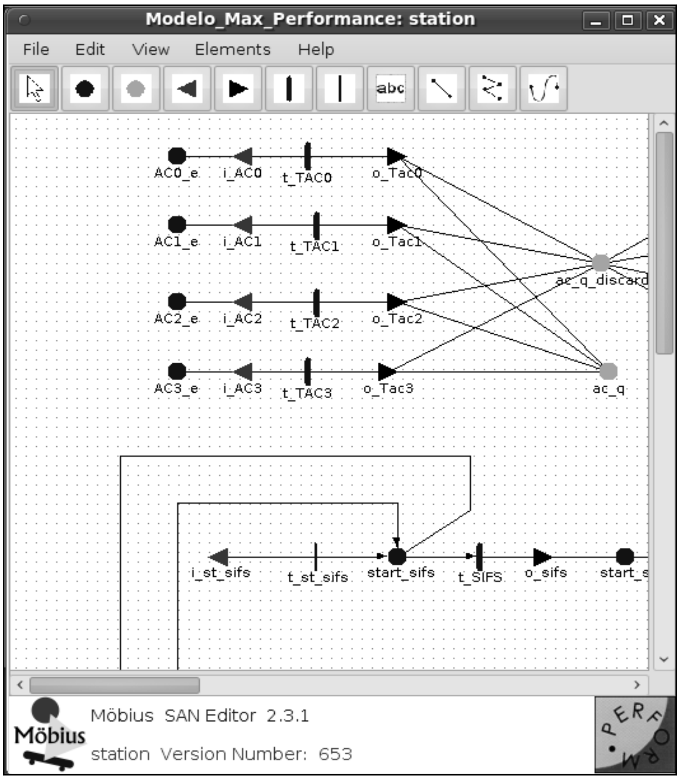

Figure 3. Partial view of the model on the interface of the Project Editor of Möbius.

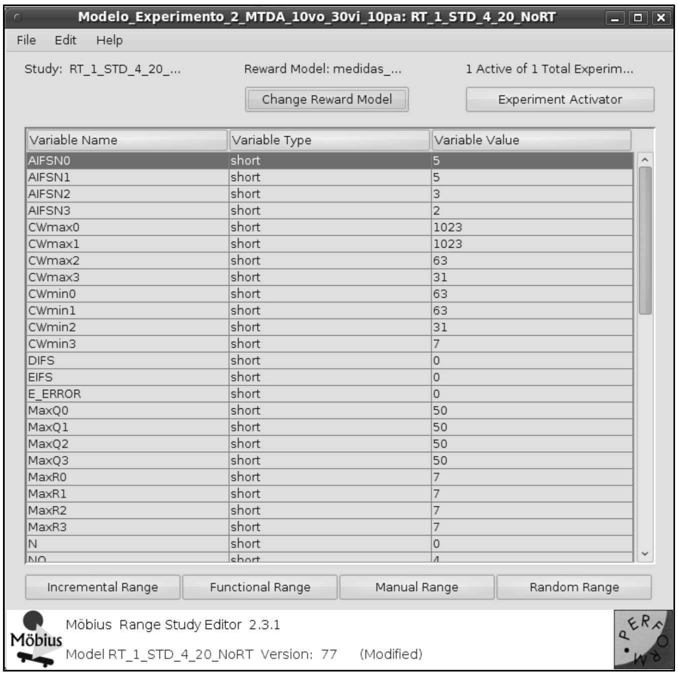

Figure 4. Partial view of the model on the interface of the Möbius strip Study Editor.

From the modelling perspective, the model also provides significant flexibility in the following aspects: ease of including modifications or refinements, many different performance metrics may be obtained without structural modifications, and it may be used as a base structure for building more complex and higher-order-of-abstraction models.

To avoid the process of building a network model for each simulation scenario, an important advantage is that the adopted model represents a simple QoS-supporting station. This model is later replicated to obtain the required simulation scenario. The user parameterises the number of replications, which the Möbius modelling tool completely automates. This tool provides significant flexibility in the evaluation process, including a faster analysis of different network scenarios. The user parameterises the number of replications, which the Möbius modelling tool completely automates. This tool provides significant flexibility in the evaluation process, including a faster analysis of different network scenarios.

B. Experimental scenario

The experimentation scenario includes an error model, which is a variation of the Gilbert-Elliot error model [36]. An average bit error rate (BER) of 10-4 was used as was the steady state probability of encountering the channel in interference at 13,3%. It considers traffic generated by stations operating on the same frequency bands while varying the load by increasing the number of active stations from 1 to 20, as in Figure 5.

This scenario was chosen to assess the behaviour of the highest access categories, with voice 20% and video 60% , in the EDCA mechanism when these categories interact with each other in the presence of best effort traffic sources 20%.

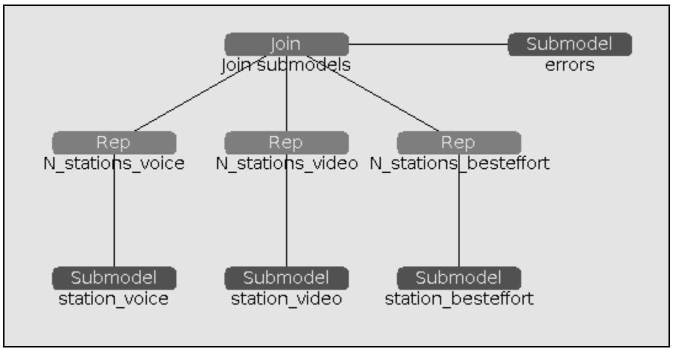

Figure 5. Representation of Scenario using the Möbius tool.

All experimental simulations are obtained using the previously described EDCA model with a confidence interval of 95% and a precision of 5%. And measured performance metrics were absolute or direct performance, relative performance, average delay of queue, and average queue size.

Our analysis used general 802.11a parameters at 36 Mbps and default EDCA configuration [2]. Stations were configured for the transmission of one of three different traffic types: an isochronic voice stream with fixed periods of 20 ms, a video stream mixture with Poisson average distribution, and a best effort stream with Pareto distribution [37-40] and 1,9 shape parameter (with average throughput equivalent to the Poisson distribution). The Table II shows all parameters and configuration values.

TABLE II
802.11 PARAMETERS IN 36 MPBS AND DEFAULT EDCA USED IN THE EXPERIMENT

	Voice	Video	Best Effort
AIFSN	2	2	3
CWmin	3	7	15
CWmax	7	15	1023
TXOP	1504 ms	3008 ms	--
Packet	160 bytes	1280 bytes	1500 bytes
Rate	64 Kbps	640 Kbps	1024 Kbps
Rate 803.11a		36 Mbps	
aSIFSTime		16 µs	
aSlotTime		9 µs	
ACCATime		4 µs	
aAirPropagationTime		1 µs	
aRxTxTuranroundTime		2 µs	
aPreambleLenght		16 µ	
aPLCPHeaderLenght		4µ	
Maximun size of queue		50	
N°max retries		7	
$BER_{average}$		1.10^{-4}	

VI. EXPERIMENTING ON SIMULATION SCENARIO

A. Absolut and Relative Performance

Figures 6 and 7 shows EDCA that provides the differentiation of service that is expected between the different types of traffic, resolving in favor of the traffics of highest priority, even when a greater proportion of video traffic is present.

Is observed that the performance of the flows of voice and video of highest priority, remain more stable than the flow of best effort, lowest priority.

In the Figure 6, the performance of video traffic of greater proportion, with 27 video stations and 45 active stations in total, reaches a maximum throughput of 15,044 Mbps. The flow of the 9 stations of voice reaches a peak of 0,435 Mbps when they are present 45 stations in total. While when there are present 30 stations in total (6 stations of best effort), the best effort traffic reaches a peak 6,177 Mbps, and then the performance falls quickly.

Figure 7 presents the relative performance of the flows that appears virtually without significant losses up to 30 stations (18 of video, 6 of voice and 6 of best effort). The flows of voice and video produce in the 45 stations (27 of video, 9 of voice and 9 of best effort) a loss of 24,45 % and 15,05 %, respectively; while the best effort traffic already lost more than 55 % percent the performance on the 35 stations.

Figure 8 shows the average queue size of stations. It is noted the sudden growth of the size of the queue for the best effort traffic from the 30 stations, in concordance with the previous metric. From there, the curve of the size of the queue becomes asymptotic to the maximum amount of packets of the buffer. Queue sizes for voice and video traffic remain below 0.4 packets for 35 stations. Then, both queues begin a growth on the unit, especially the average video queue that reaches 7,123 packets when there are 45 stations. While Figure 9 shows the situation in more detail.

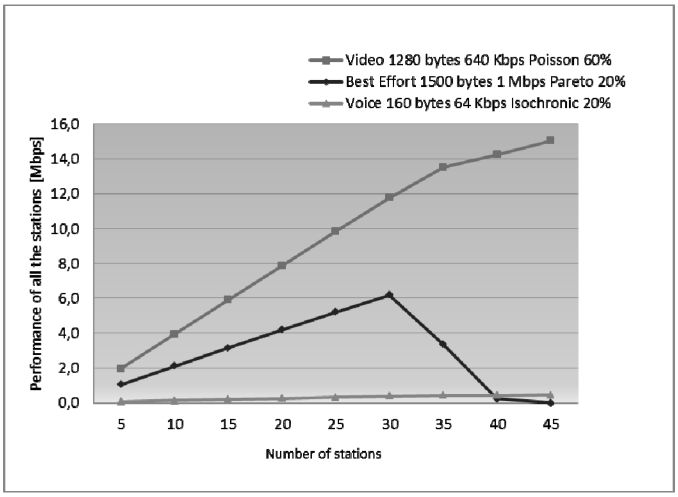

Figure 6. Performance of voice, video and best effort traffic

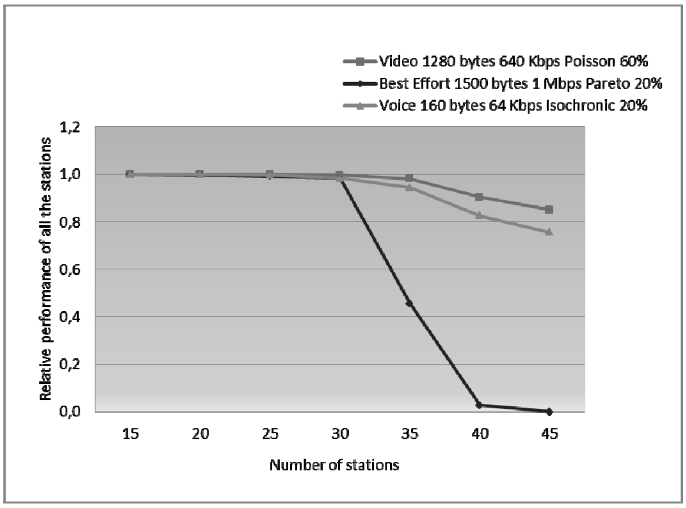

Figure 7. Relative performance of voice, video and best effort traffic

Finally, Figure 10 presents the delays in traffic on the stations. The average delay of voice grows to 46 ms, and the video reaches the 130 ms for 45 stations.

On the contrary, the average delay the flow of best effort has grown rapidly since the 30 stations.

Figure 11 shows more details for this situation.

Carrying out an analysis to this scenario, which maintains a preponderance of the video stations, has been verified that:

i) Metrics of voice and video traffic degrade from the 35 stations,

ii) the best effort traffic, lower priority, drops significantly in all its metric from the 30 stations, for the benefit of other traffic, and

iii) The delays of voice and video traffics are within the thresholds of QoS up to 40 stations.

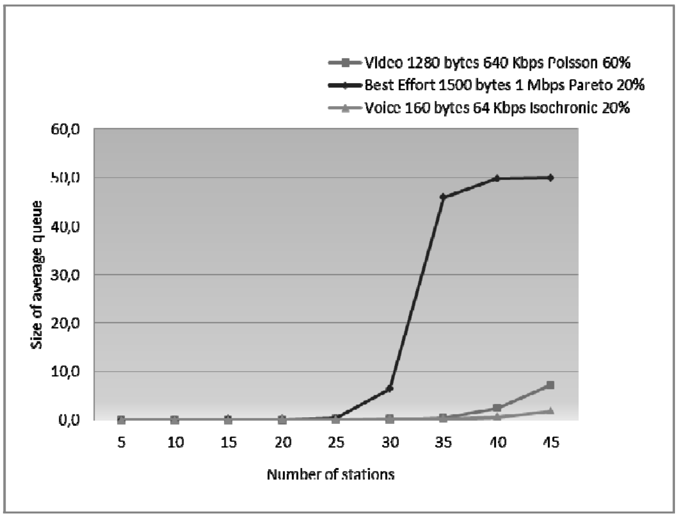

Figure 8. Queue Size of voice, video and best effort traffic

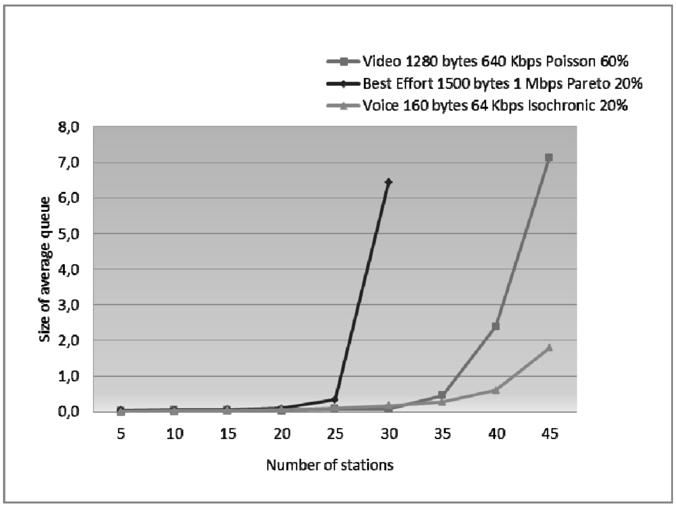

Figure 9. Queue Size of voice, video and best effort traffic

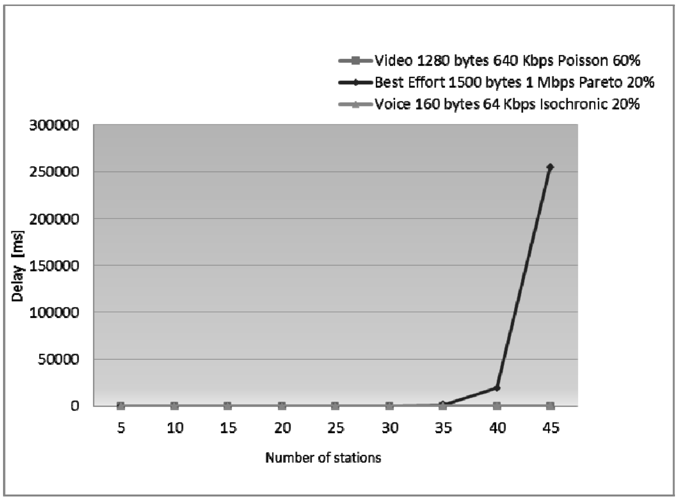

Figure 10. Delays of voice, video and best effort traffic

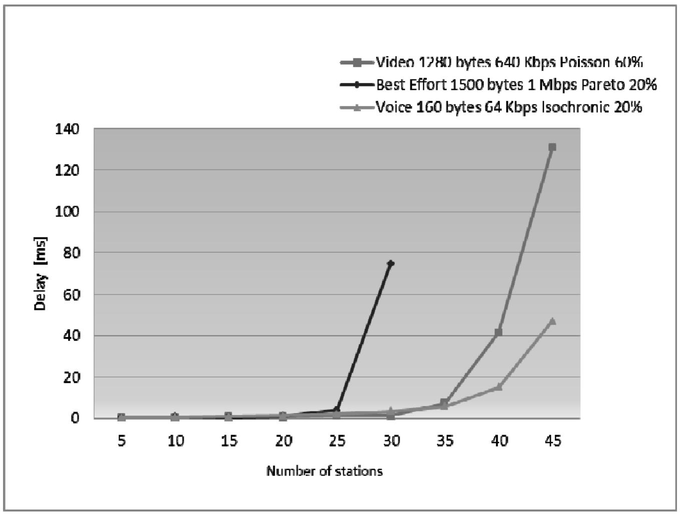

Figure 11. Delays of voice, video and best effort traffic

Table III summarizes the most important characteristics of this scenario.

TABLE III
SUMMARY OF THE RESULTS OF THE METRIC AT CRITICAL POINTS

	Voice	Video	Best Effort
Maximum Performance [Mbps]	0,435	15,044	6,177
Loss 1% Performance	30 stations	35 stations	30 stations
Loss 5 % Performance	35 stations	40 stations	35 stations
Loss 10 % Performance	40 stations	45 stations	35 stations
Delay of Queue in Maximum Performance [ms]	46,8	130,7	74,7
Delay of Queue for 25 stations [ms]	1,9	1,3	3,8
Maximum Delay of Queue 45 stations [ms]	46,8	130,7	254745
Size of Queue for 25 stations [packets]	0,09	0,08	0,3
Size of Queue for 45 stations[packets]	1,7	7,1	49,9

VII. CONCLUSION

This study used simulation model variants built with HSANs to evaluate EDCA 802.11e protocol conditions for supporting QoS in a 802.11a scenario at 36 Mbps with mainly video traffic and electromagnetic interferences.

In this context and for the proposed novel scenario, metrics were exhaustively analysed for direct and relative performance, queue size, and delay of queue. Figures show that EDCA provides the differentiation of service that is expected between the different types of traffic, resolving in favor of the traffics of highest priority, even when a greater proportion of video traffic is present.

It is noted the sudden growth of the size of the queue for the best effort traffic from the 30 stations. Queue sizes for voice and video traffic remain below one for 35 stations. Finally, the average delay of voice grows to 46 ms, and the video reaches the 130 ms for 45 stations. The average delay the flow of best effort has grown rapidly since the 30 stations.

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