Throughput Quantitative Analysis of EDCA 802.11e in Different Scenarios

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ABSTRACT

This document presents a quantitative analysis of the direct and relative throughput of IEEE 802.11e.

The global throughput of an 802.11e WLAN is determined by EDCA (Enhanced Distributed Channel Access) parameters, among other aspects, that are usually configured with predetermined and static values. This study carefully evaluates the Quality of Service (QoS) of Wi-Fi with EDCA in several realistic scenarios with noise and a blend of wireless traffic (e.g., voice, video, and best effort, with Pareto distribution). The metrics of the benefits obtained in each case are compared, and the differentiated impact of network dynamics on each case is quantified. The results obtained show that the default settings are not optimal, and that with an appropriate selection, can be achieved improvements of the order of 25 %, according to the type of traffic. In addition, it could be shown the quantitative impact of each parameter EDCA on the overall performance. This study proposes a new experimental scenario based on the relative proportion of traffic present in the network. Stations have been simulated using the Möbius tool, which supports an extension of SPN (Stochastic Petri Networks), known as HSAN (Hierarchical Stochastic Activity Networks).

Keywords: QoS, WLAN, EDCA 802.11e, MAC Parameters, Analysis of traffic

1. INTRODUCTION

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 and personal environments [1]. 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.

This paper presents a detailed analysis that verifies the success of priority-based traffic differentiation and eventually QoS specifications in Wi-Fi network communications. Specifically, the principal focus is analysing the quantitative behaviour of the EDCA IEEE 802.11e protocol in supporting QoS while in a shared communications setting with diverse traffic used by wireless networks.

The results may be compared to and complement those obtained by studies, as in the literature relating to Wi-Fi network behaviour. These studies propose creating a behavioural model for nodes in particular and the network in general based on the analysed or simulated trace collection.

Trace collection is a necessary first step in creating realistic models crucial to designing, simulating, and evaluating network protocols [2-10]. Unfortunately, a portion of authors tend to define a model as interpreting trace collections, although only conclusions can be drawn from traces while searching for the behavioural characteristics of the traffic in question.

The other method of analysing the performance of IEEE 802.11communication networks has been to develop evaluation models based on two different perspectives: analytical and simulation. Analytical models [11-17] have the advantage of providing expressions/formalisms that help analyse the influence of different parameters. Moreover, these models also usually provide quick results. However, this type of solution typically requires adopting simplifying suppositions. 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 exactly modelling other traffics difficult, 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) [18], OPNET [19], or IP TRAFFIC [20]. The NS-2 tool is an open-source simulator for discrete events, while OPNET Technologies, Inc. has developed the OPNET tool. Tools for generating simulated traffic are also useful, such as IP Traffic developed by ZTI Telecom. All of these tools are especially appropriate for analysing the performance of communication networks. Several studies [16, 21] show how NS-2 is used in real-time IEEE 802.11e behaviour simulations. However, several inconsistencies have been identified and explained [16], and the difficulty of implementing any type of light modification to protocols or the network’s timing characteristics has been described.

Few papers are available in the literature or research studies that use Stochastic Petri Nets (SPNs) [22] as a modelling formalism for analysing IEEE 802.11 communication protocols. In [23], an SPN simulation model was proposed for evaluating the performance of the original IEEE 802.11. The simulation model has the necessary detail for describing the main characteristics of the protocol. The model assumes certain ideal channel

characteristics and does not consider certain aspects of the protocol. The earlier simulation model has been extended to incorporate more details [24-25].
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. This is particularly due to the absence of a formalism in these modelling tools that would help automatically build model replications. This 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 [26] is thus adopted using HSANs [27-29], which closely follows the EDCA IEEE 802.11e standard and is executed on the Möbius simulator [30-32]. 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.
The principal contributions of this article are i) to specify a new research methodology that simulates Wi-Fi dynamics using different experimental scenarios with conclusive quantitative results concerning its impact over a WLAN 802.11e network with QoS configured using default static parameters, ii) to specify and experiment on variants of known scenarios, as well a new scenario offering metrics evaluation while maintaining a relative proportion for network traffic, iii) to demonstrate that the standard EDCA IEEE 802.11e mechanism using default static parameters provides traffic differentiation but does not on its own assure the desired QoS for supporting multimedia data traffic dynamics in real time and automatic control in next-generation administrative and industrial environments, and iv) 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.
Experimental conclusions are obtained through simulations using the IEEE 802.11a physical layer, a data rate of 36 Mbps, and in the presence of noise at 1.10-4 BER.
The rest of this document is structured as follows. Section II provides a general view of the EDCA 802.11e standard. Section III presents the wireless station model built with HSANs and simulation scenarios defined for experimental evaluation. Section IV presents the configuration values for experiment scenarios and gives the results for EDCA behaviour on these values. Section V summarizes the most significant conclusions and directions for future work

2. BRIEF DESCRIPTION OF EDCA 802.11E

DCF (802.11 Distributed Coordination Function) provides only a best effort type of service [1]. Time-limited multimedia applications (e.g., voice over IP, video conferences) require certain guarantees for bandwidth, delay, and jitter. With DCF, all stations compete for a channel with the same priority; there is no differentiation mechanism to provide better service for real-time multimedia traffic than for data applications.
The QoS limitations in DCF have inspired many research efforts to improve MAC performance [33-36]. For 802.11e, a new function has been proposed for MAC layer, known as Hybrid Coordination Function (HCF) (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.

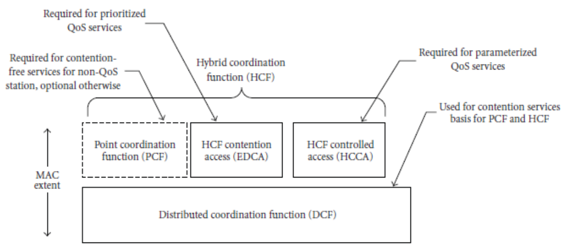

Fig. 1 MAC Architecture

The optimization process of QoS of EDCA is based on a generalization of contention-based DCF[37-38]. 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. 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, and SlotTime is the duration of a time slot [1], and SIFS is the Short Inter-Frame Space of DCF. The highest priority will be given to the AC with the smallest AIFS.

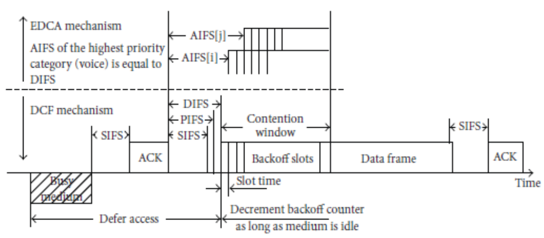

Fig. 2 IFS Relationships

In general, smaller values of CWmin[AC], CWmax[AC], AIFS[AC], shorter delays of channel access to the corresponding AC, and the higher the priority for access to he 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.

3. MODEL AND SIMULATION SCENARIOS

To experimentally evaluate the function of the EDCA 802.11e mechanism, a simulation model is adopted that uses Hierarchical Stochastic Activity Networks (HSAN) executed on a Möbius simulator. HSANs are a variety of Stochastic Petri Nets (SPNs). This model comprises a precise and detailed EDCA implementation function associated with QoS stations, considering both functional and temporal perspectives. Several international authors have sufficiently validated the model in the literature [39-43].

From the modelling perspective, the model also shows 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 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.

Moreover, the station model includes an error submodel, which is a variation of the Gilbert-Elliot error model [44]. 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%.

Two simulation scenarios are proposed. These scenarios consider the behaviour of the highest access categories (voice and video) in the EDCA mechanism when these categories interact with each other in the presence or absence of best effort traffic sources or when the relative proportion of stations belonging to different types of network traffic changes.

Scenario 1 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 3.

Different situations are established in this scenario, according to the type of traffic injected by stations: a) Stations with all traffic flows present (voice, video, and best effort), b) Stations without voice traffic, c) Stations without video traffic, and d) Stations without best effort traffic.

Scenario 2 considers only one type of traffic generated by each station, varying the load by increasing the number of active stations from 5 to 45 but maintaining their relative proportion, as in Figure 4. This scenario is novel (to the best of our knowledge, it has not yet been analysed), and it amounts to a view that is closer to a realistic situation.

Different situations are posed within this scenario according to the proportion of traffic injected by stations: a) 60% voice stations, 20% video, and 20% best effort, b) 20% voice stations, 60% video, and 20% best effort, and c) 20% voice stations, 20% video, and 60% best effort.

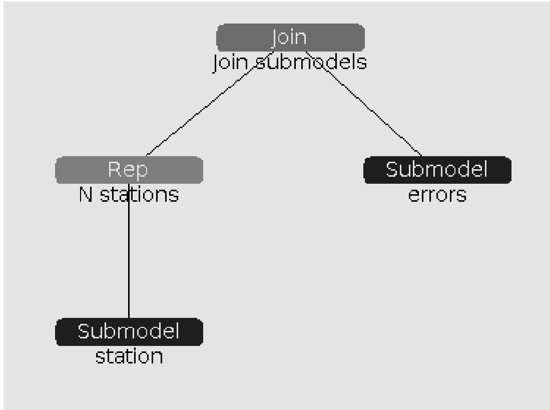

Fig. 3 Representation of Scenario 1 using the Möbius tool.

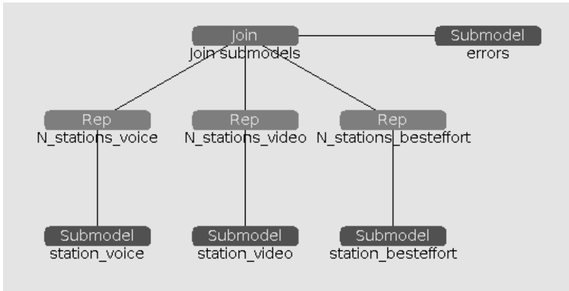

Fig. 4 Representation of Scenario 2 using the Möbius tool.

All experimental simulations are obtained using the previously described EDCA model with a confidence interval of 95% and a precision of 5%.

Measured performance metrics are absolute throughput, relative throughput, packet loss, average delay of queue, and average queue size.

4. CONFIGURING AND EXPERIMENTING ON SIMULATION SCENARIOS

Our analysis used general 802.11a parameters at 36 Mbps and default EDCA configuration [45-46]. Stations were configured according to the scenario for the transmission of one, two, or three different traffic types: an isochronic voice steam with fixed periods of 20 ms, a video stream with Poisson distribution, and a best effort stream with Pareto distribution [47] and 1.9 shape parameter (with average throughput equivalent to the Poisson distribution). The Table 1 shows all parameters and configuration values.

To propose instances for comparison in different scenario configurations, we decided to evaluate metrics using the following critical points:

- Average Maximum Throughput
- Fall or loss of 1, 5, and 10 % Relative Average Throughput
- Average Delay of Queue in Maximum Throughput
- Average Delay of Queue by 10 stations
- Average Delay of Queue (maximum) by 20 stations
- Average Size of Queue by 10 stations
- Average Size of Queue by 20 stations

	Voice	Video	Best Effort
AIFSN	2	2	3
CW min	3	7	15
CW max	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 µs		
aPLCPHeaderLength	4 µs		
Maximum size of queue	50		
Nº max retries	7		
BERaverage	1.10^{-4}		

Table 1 802.11 parameters in 36 Mpbs and default EDCA used in the experiment

Experimental scenario 1

With all traffic types present using default parameters: Figure 5 shows the average values obtained for direct throughput while varying the load from 1 to 20 stations. Throughput for the highest-priority voice and video streams is more stable than for the lower-priority best effort stream. The voice stream reaches a peak of 0.924 Mbps with 19 stations with a gradual loss of throughput. Video traffic reaches a maximum throughput of 10.856 Mbps with 18 stations and decays, whereas the best effort traffic reaches a peak of 10.285 Mbps with 10 stations, and throughput decays rapidly.

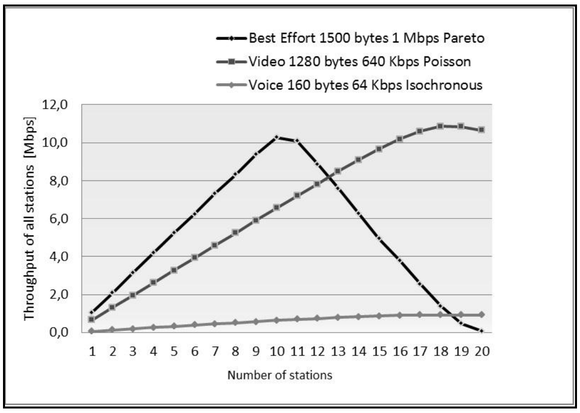

Fig. 5 Voice, video, and best effort traffic throughput in Scenario 1

Table 2 shows the main values for different metrics obtained in the experiment.

	Voice	Video	Best Effort
Maximum throughput [Mbps]	0,924	10,856	10,285
Loss of 1 % throughput	10 stations	15 stations	9 stations
Loss of 5 % throughput	13 stations	18 stations	10 stations
Loss of 10 % throughput	15 stations	19 stations	11 stations
Delay of queue in maximum throughput [ms]	13,637	6,777	45,303
Delay of queue by 10 stations [ms]	2,889	2,330	45,303
Delay of queue by 20 stations [ms]	14,944	11,912	197000,000
Size of queue by 10 stations [packets]	0,142	0,148	3,912
Maximum size of queue by 20 stations [packets]	0,539	0,619	~50

Table 2 Measures in Scenario 1 with all types of traffic present

Simulation analysis for this scenario shows the following facts: i) the growing number of stations in the network domain strongly influences traffic behaviour, always producing a growing average queue size, although bounded by voice and video traffic unity and a relatively decreasing throughput independent of traffic; ii) the average voice queue size grows up to two orders of magnitude as the load increases to 20 stations; an undesired effect is observed for voice throughput in applications with strict requirements. In all cases, the throughput loss threshold is verified before reaching the specified delay threshold. This criterion is also verified for video traffic; iii) the greater impact on communications quality is due to virtual and real collisions, losses, and the EDCA 802.11e protocol configuration; the error characteristics in the wireless medium have a significantly lower impact; iv) lower-priority best effort traffic is noticeably affected in all metrics after 10 stations, to the benefit of other traffic types. The drastic fall in best effort performance occurs at approximately the same point, which is common for all traffic types, similar to what would be observed if the scenario ran on DCF.

Without voice traffic, video traffic, or best effort traffic using default parameters: Tables 3, 4, and 5 show the primary values for different metrics obtained in the experiment without voice, video, or best effort traffic, respectively.

	Video	Best Effort
Maximum throughput [Mbps]	13,071	12,391
Loss of 1 % throughput	-	12 stations
Loss of 5 % throughput	-	13 stations
Loss of 10 % throughput	-	14 stations
Delay of queue in maximum throughput [ms]	3,269	258,869
Delay of queue by 10 stations [ms]	0,942	3,556
Delay of queue by 20 stations [ms]	3,269	1743,13
Size of queue by 10 stations [packets]	0,060	0,310
Maximum size of queue by 20 stations [packets]	0,208	48,286

Table 3 Measures in Scenario 1 with video and best effort traffic

	Voice	Best Effort
Maximum throughput [Mbps]	1,133	15,524
Loss of 1 % throughput	12 stations	12 stations
Loss of 5 % throughput	15 stations	16 stations
Loss of 10 % throughput	20 stations	17 stations
Delay of queue in maximum throughput [ms]	4,105	228,995
Delay of queue by 10 stations [ms]	1,920	1,174
Delay of queue by 20 stations [ms]	4,105	691,479
Size of queue by 10 stations [packets]	0,095	0,102
Maximum size of queue by 20 stations [packets]	0,181	40,334

Table 4 Measures in Scenario 1 with voice and best effort traffic

	Voice	Video
Maximum throughput [Mbps]	0,967	11,303
Loss of 1 % throughput	12 stations	17 stations
Loss of 5 % throughput	15 stations	19 stations
Loss of 10 % throughput	17 stations	20 stations
Delay of queue in maximum throughput [ms]	7,659	8,298
Delay of queue by 10 stations [ms]	1,840	0,658
Maximum delay of queue by 20 stations [ms]	16,173	34,595
Size of queue by 10 stations [packets]	0,091	0,042
Maximum size of queue by 20 stations [packets]	0,587	1,831

Table 5 Measures in Scenario 1 with voice and video traffic

Tables 2 to 5 indicate that the dynamics of traffic types present in Wi-Fi networks with QoS have a differential effect on network behaviour. The different values for metrics used in each situation are verified. The maximum video throughput varies from 10.856 Mbps to 13.071 Mbps (20% increase), and voice queue delay for 20 stations is found between 4.105 ms and 16.173 ms (4 times more), depending on the Scenario 1 in question.

Experimental summary for Scenario 1: To review Scenario 1, graphics for the average values obtained for direct and relative throughput for each traffic type are shown, superimposing the cases where all traffic types are present or when one is absent.

Figures 6 and 7 show the voice traffic cases. For direct throughput, Figure 6 shows an improvement of 18.73% with 20 stations when video traffic is not present, compared to when all types of traffic are present in the scenario. Voice throughput without best effort traffic is found within these curves at the moment of network saturation. Relative throughput stands out in Figure 7 with a loss of 11.48% at 20 stations with no video traffic, but it falls to 28.06% and 27.39% when all traffic types are present or when there is no best effort traffic, respectively.

Video response cases have been superimposed in Figures 8 and 9. In Figure 8, an improvement of 18.43% with 20 stations is observed when voice traffic is not present compared to when all traffic types are present in the scenario. Video throughput without best effort traffic is found within these curves at the moment of network saturation. Figure 9 shows relative throughput with a loss of 0.41% with 20 stations when there is no voice traffic, but it falls to 19.01% and 17.38% when all traffic types are present or when there is no best effort traffic, respectively.

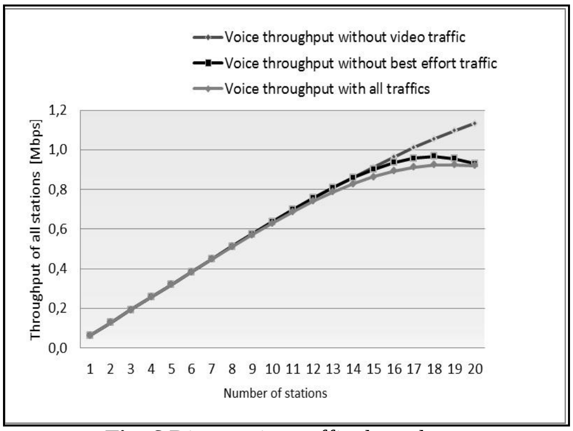

Fig. 6 Direct voice traffic throughput

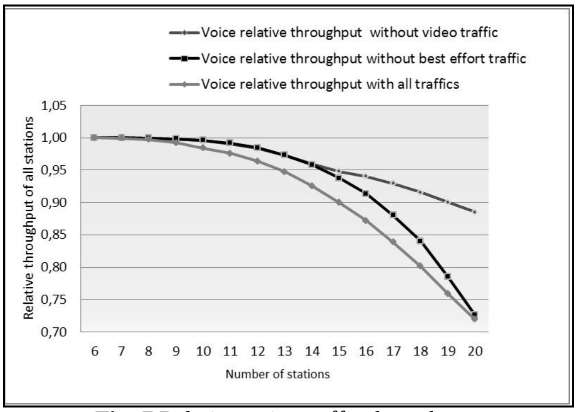

Fig. 7 Relative voice traffic throughput

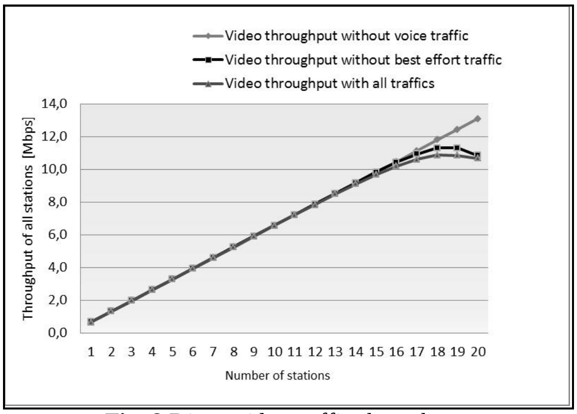

Fig. 8 Direct video traffic throughput

Finally, response cases for best effort traffic have been superimposed in Figures 10 and 11. Figure 10 highlights an improvement of 33.75% with 16 stations when video traffic is not present compared to when all traffic types are present in the scenario, and maximum throughput is achieved with 10 stations. Best effort throughput without voice traffic is found within these curves at a peak throughput with 13 stations. Figure 11 shows that relative throughput for best effort has a loss of 33.75% with 20 stations when there is no video traffic, but it falls to 99% and 68.70% when all traffic types are present or when there is no voice traffic, respectively.

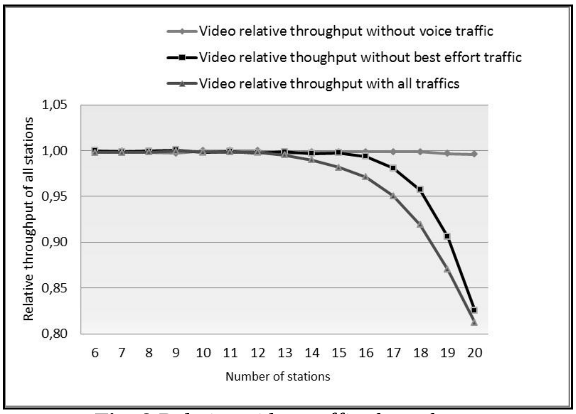

Fig. 9 Relative video traffic throughput

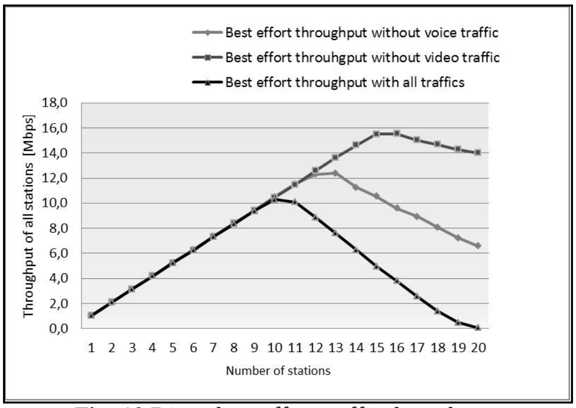

Fig. 10 Direct best effort traffic throughput

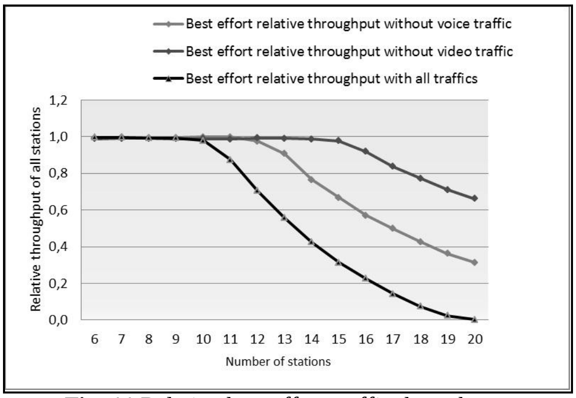

Fig. 11 Relative best effort traffic throughput

Experimental Scenario 2

With 60% voice traffic, 20% video, and 20% best effort using default parameters: Figure 9 shows the average direct throughput values, with loads varying from 5 to 45 stations and a proportion of 60% voice traffic, 20% video, and 20% best effort.

In this scenario, EDCA provides the desired service differentiation between different traffic types, favouring higher-priority traffics. However, losses occurring among voice stations are unavoidable, due to their higher relative proportion. Figure 12 shows that stream throughput for highest-priority voice and video remains more stable than the lower-priority best effort stream. The voice stream reaches a peak of 1.273 Mbps when 45 stations are present. When there are 40 stations, best effort traffic reaches a peak of 8.185 Mbps with throughput decaying rapidly thereafter. Video traffic throughput reaches a maximum level of 5.838 Mbps when there are 45 stations.

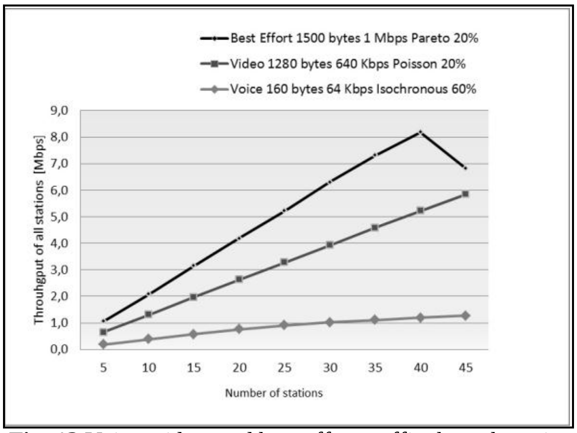

Fig. 12 Voice, video, and best effort traffic throughput in Scenario 2

Table 6 shows the main values obtained in this experiment.

	Voice	Video	Best Effort
Maximum Throughput [Mbps]	1,273	5,838	8,185
Loss of 1% throughput	20 stations	45 stations	35 stations
Loss of 5 % throughput	25 stations	-	45 stations
Loss of 10 % throughput	30 stations	-	45 stations
Delay of queue in maximum throughput [ms]	9,172	3,526	22,669
Delay of queue by 25 stations [ms]	3,196	0,890	1,270
Maximum delay of queue by 45 stations [ms]	9,172	3,526	598,841
Size of queue by 25 stations [packets]	0,152	0,056	0,110
Size of queue by 45 stations [packets]	0,337	0,223	38,086

Table 6 Measures in Scenario 2 with 60% voice, 20% video, and 20% best effort

With 20% voice, 60% video, and 20% best effort traffic and 20% voice, 20% video, and 60% best effort traffic using default parameters: Tables 7 and 8 show the main values obtained in the experiment for these cases, respectively.

	Voice	Video	Best Effort
Maximum Throughput [Mbps]	0,435	15,044	6,177
Loss of 1% throughput	30 stations	35 stations	30 stations
Loss of 5 % throughput	35 stations	40 stations	35 stations
Loss of 10 % throughput	40 stations	45 stations	35 stations
Delay of queue in maximum throughput [ms]	46,826	130,793	74,754
Delay of queue by 25 stations [ms]	1,939	1,300	3,869
Maximum delay of queue by 45 stations [ms]	46,826	130,793	254745,092
Size of queue by 25 stations [packets]	0,096	0,083	0,338
Size of queue by 45 stations [packets]	1,783	7,123	49,998

Table 7 Measures in Scenario 2 with 20% voice, 60% video, and 20% best effort

As in Scenario 1, Tables 6 through 8 show the impacts of different relative traffic proportions. Different values for metrics are also obtained in these figures. A loss of 1% of voice traffic throughput can arise between 20 and 45 stations (with over double the number of stations), and the video queue size for 45 stations can vary between 0.117 and 7.123 packets (60 times more) according to the Scenario 2 version in question.

	Voice	Video	Best Effort
Maximum Throughput [Mbps]	0,565	5,887	15,633
Loss of 1% throughput	45 stations	30 stations	30 stations
Loss of 5 % throughput	-	-	30 stations
Loss of 10 % throughput	-	-	30 stations
Delay of queue in maximum throughput [ms]	3,188	1,842	43,239
Delay of queue by 25 stations [ms]	2,160	1,117	43,239
Maximum delay of queue by 45 stations [ms]	3,188	1,842	1441,013
Size of queue by 25 stations [packets]	0,107	0,071	3,753
Size of queue by 45 stations [packets]	0,156	0,117	47,501

Table 8 Measures in Scenario 2 with 20% voice, 20% video, and 60% best effort

Experimental summary for Scenario 2: Figures 13 and 14 show the average values obtained for direct and relative voice traffic throughput while varying the load from 5 to 45 stations. Different situations have been superimposed on comparative analysis effects, according to the proportion of traffic injected by stations. These are a) 60% voice stations, 20% video, and 20% best effort, b) 20% voice stations, 60% video, and 20% best effort, and c) 20% voice stations, 20% video, and 60% best effort.

Logically, direct throughput for voice is higher when there is a greater proportion of voice stations, as in Figure 13. Moreover, there is a better response when there is a greater proportion of best effort traffic than when there is a greater proportion of video traffic.

Figure 14 shows that relative throughput has a loss of 26.31% with 45 stations when there is a higher proportion of voice stations. The loss is 24.45% and only 1.76% when there is a greater proportion of video or best effort stations, respectively

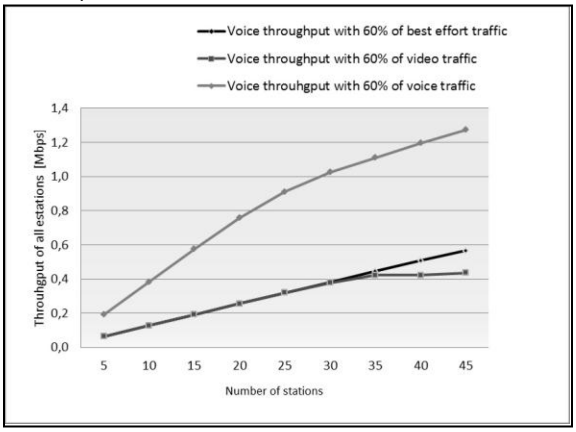

Fig. 13 Direct voice traffic throughput

Figures 15 and 16 show the average values obtained for direct and relative video traffic throughput while varying the load from 5 to 45 stations. Different situations have been superimposed for a comparative analysis according to the proportion of traffic injected by stations. Figure 15 shows the direct video throughput. As expected, greater throughput arises when there is a greater proportion of video stations. Moreover, there is a practically similar response when there is a higher proportion of voice or best effort traffic.

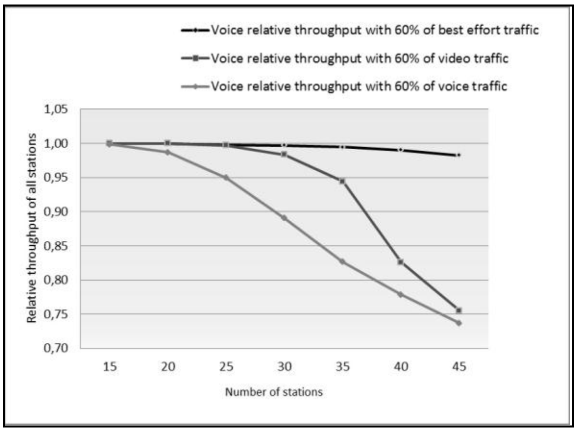

Fig. 14 Relative voice traffic throughput

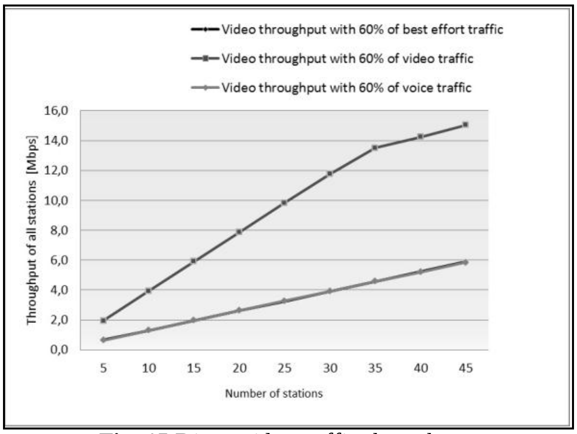

Fig. 15 Direct video traffic throughput

Figure 16 shows that the relative video throughput drops to 15.15% at 45 stations when there is a greater proportion of video stations. The loss is 1.21% and only 0.38% when there is a greater proportion of voice or best effort stations, respectively.

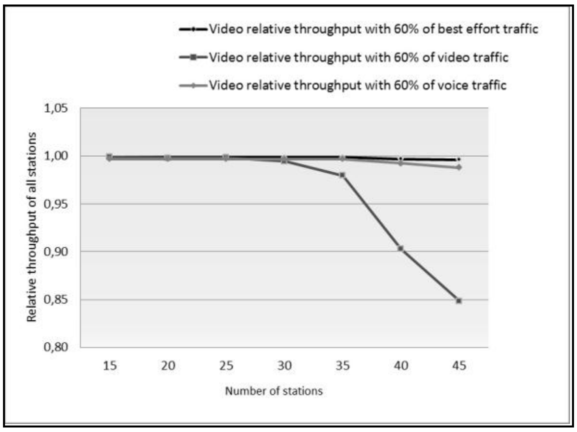

Fig. 16 Relative video traffic throughput

Average values obtained for direct and relative throughput of best effort traffic, varying the load from 5 to 45 stations, are shown below. Different situations have been superimposed in Figures 17 and 18 for a comparative analysis according to the type of traffic injected by stations. As with other traffic types, Figure 17 shows that there is greater throughput when there is a higher proportion of best effort stations. Moreover, there is a better response for best effort traffic when there is a greater proportion of voice traffic, peaking at 8.185 Mbps with 40 stations compared to when there is a greater proportion of video traffic, reaching 6.117 Mbps at 30 stations. Figure 18 shows that the relative throughput for best effort has a near-100% loss at 45 stations when there is a higher proportion of video stations. The loss drops to 62.45% and 27.72% when there is a greater proportion of best effort or voice stations, respectively.

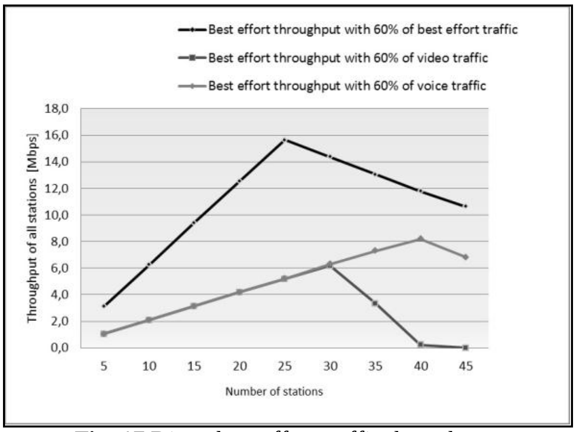

Fig. 17 Direct best effort traffic throughput

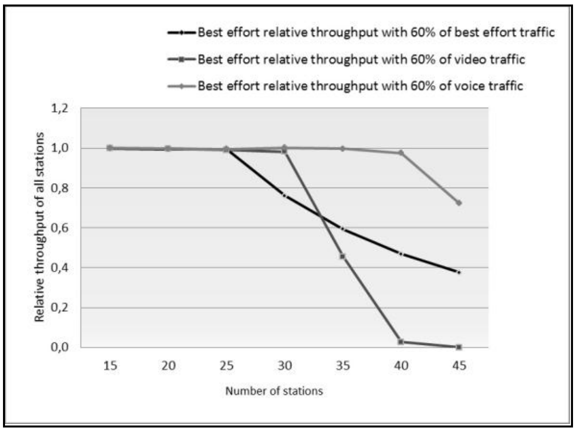

Fig. 18 Relative best effort traffic throughput

5. CONCLUSIONS

This study used simulation model variants built with HSANs to evaluate EDCA 802.11e protocol conditions for supporting QoS in 802.11a scenarios at 36 Mbps. Scenarios included diverse traffic, electromagnetic interferences, and static default parameters for AIFSN, CWmin, CWmax, and TXOP. Simulation scenarios considered traffic interactions with different priorities.

In this context and for all proposed scenarios (including the novel experience of modifying traffic proportions), metrics were exhaustively analysed for direct and relative throughput, queue size, delay of queue, queue loss, and collision.

We presented a detailed quantitative study for each case in Scenario 1 and 2, where the variation in relative proportion of different traffic types in wireless nodes with QoS had a differential affect on the WLAN network behaviour and general state. The state of the Wi-Fi network with QoS was essentially a dynamic one, where the values of different metrics for each traffic type and the network as a whole depended on the characteristics of existing traffic types.

New approaches must therefore be proposed that help the EDCA 802.11e mechanism support these multimedia and real-time communications while satisfying QoS restrictions for such high-priority traffic. These proposals should consider searching for parameters that optimise default configuration metrics while dynamically assuring the desired QoS conditions for current high-priority traffics, even under near-saturation conditions.

We foresee future studies offering a quantitative EDCA behaviour evaluation at different 802.11 physical layers. These studies would precisely determine the best general network behaviour for higher Wi-Fi velocities. These study aspects could be linked to a proposal for a self-tuning algorithm and selecting appropriate analytical models for the station-admission process. Finally, a new line of study could be developed regarding the impact of queue length on maximum throughput for each context.

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