Qos Parameters Performance Analysis of VoIP and Video traffic in a network using IEEE 802.11e EDCA

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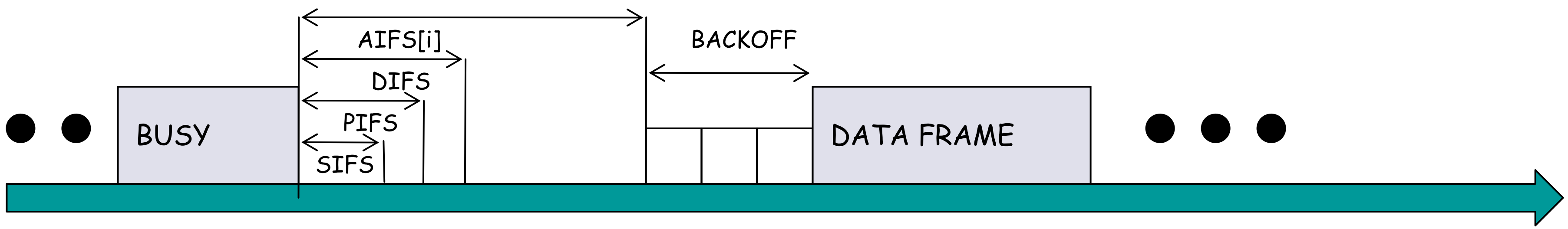
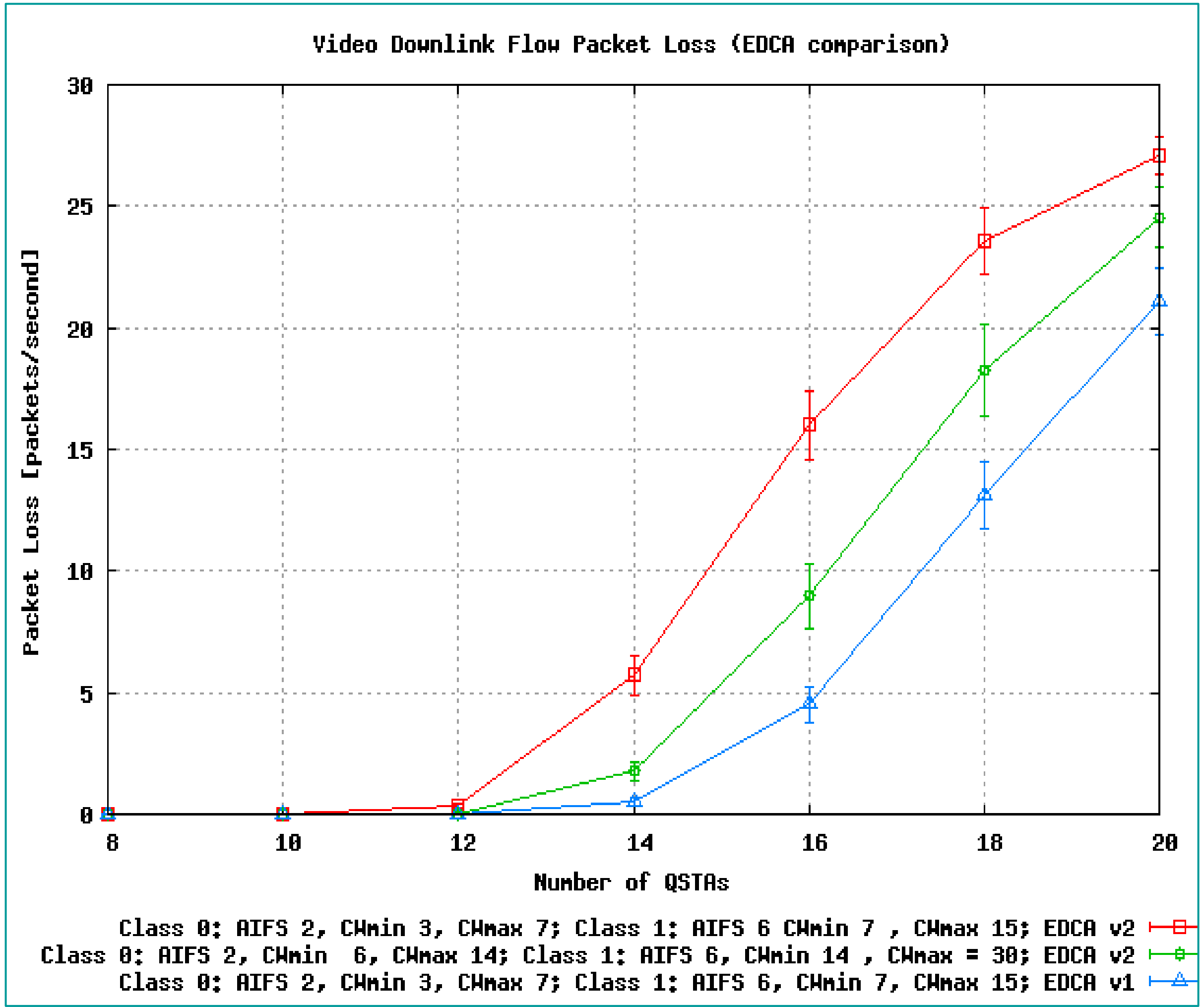
Introduction

- ✓ This work makes QoS parameters' performances analysis of a IEEE 802.11e wireless network having up to 2 QoS Access Points and a variable number of Qos Stations with real-time interactive traffic or, alternatively, real-time non interactive traffic. Analysis will be concentrated on EDCA, the contention-based part of IEEE 802.11e MAC protocol.
- ✓ The goal is to analyze behavior of main QoS features (delay, packet loss, jitter) when varying IEEE 802.11e parameters (AIFS, CW, TXOP).
- ✓ The adopted IEEE 802.11e software uses an EDCA implementation acting as follow:
  - Retry counter is increased due to internal collisions.
  - The residual backoff doesn't decrease for only an idle period of AIFS.
- ✓ There is another version of EDCA where the residual backoff also decrease by one for each idle period of AIFS. In this case MAC capacity seems to be slightly lower in saturated conditions:
  - under the same conditions throughput is lower
  - collision probability increases

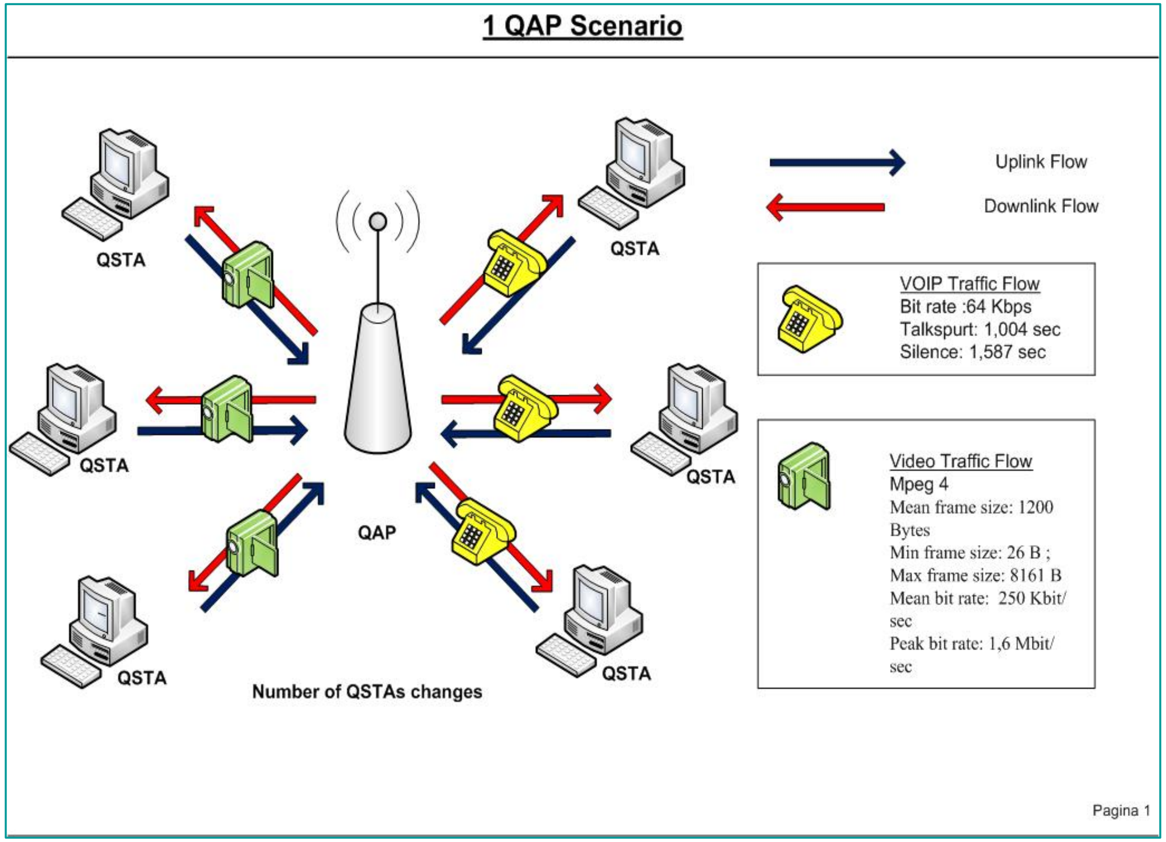


Comparison between EDCA Versions: Packet Loss

- For the same traffic and the same parameters, first EDCA version has better performances.
- Substantially, the new EDCA policy negatively affects amount of collision between packets of the same class, so can be counterbalanced augmenting CW parameters (on the contrary, changes on AIFS are not useful).
- This work uses the first version of EDCA (EDCA v1).

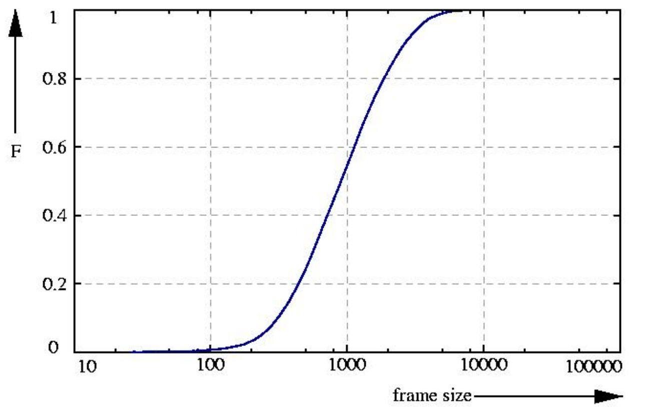


Max Frame Size Analysis: Scenario



✓Now it will be analyzed QoS parameters behavior when maximum frame size varies.

Video Stream frame length Probab. Func.



Max size	750 Byte
Max Size	1000 Byte
Max Size	1500 Byte
Max Size	2048 Byte

Class 0	(VoIP)
CWmin	3
CWmax	7
AIFS	2
TXOP	0.003264

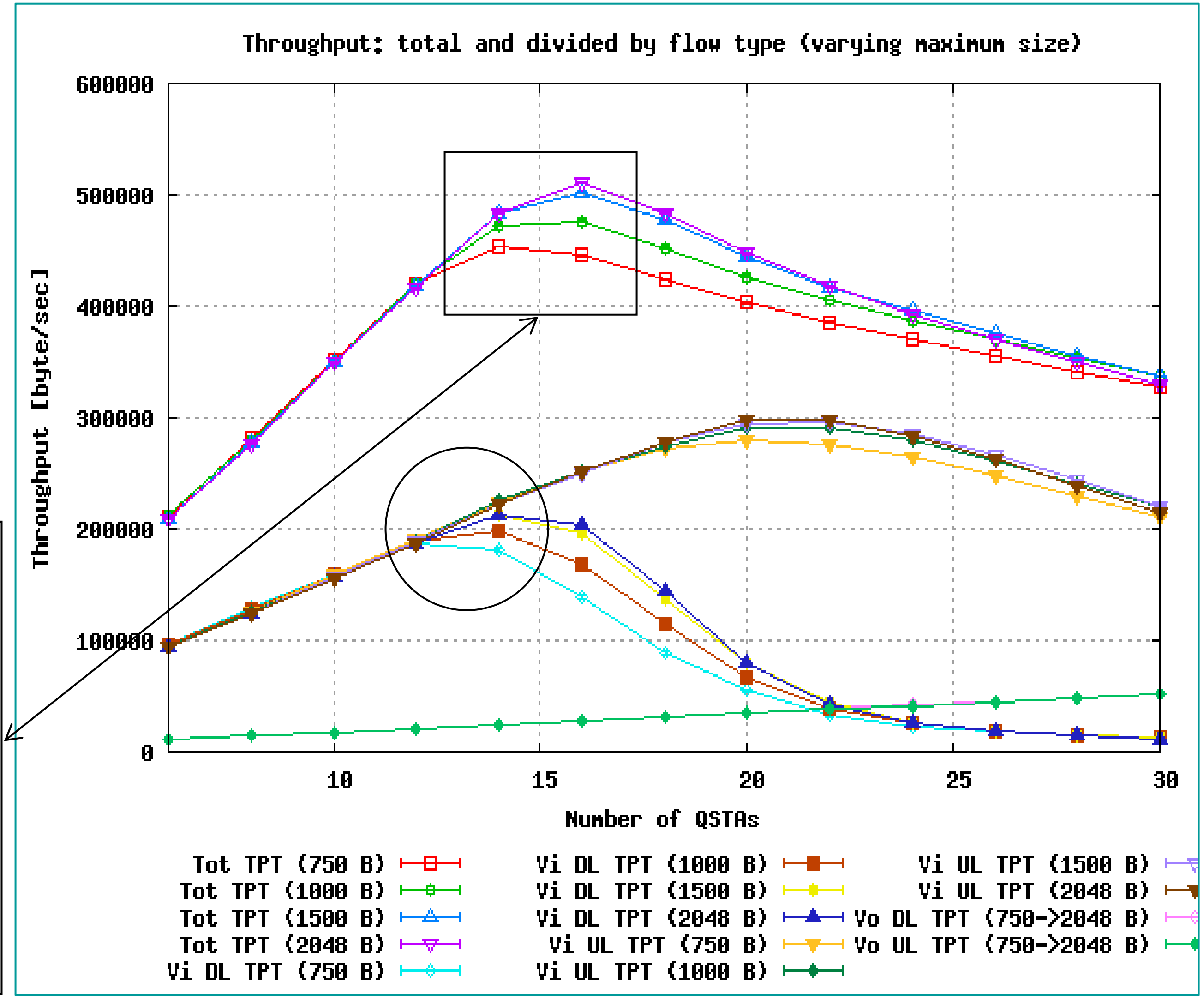
Class 1	(Video)
CWmin	7
CWmax	15
AIFS	4
TXOP	0.006016

MAX F. SIZE	NUM OF FRAMES NEEDED (avg)
750	~ 53
1000	~ 44
1500	~ 34
2048	~ 30

Max Frame Size Analysis : Cumulative Throughput

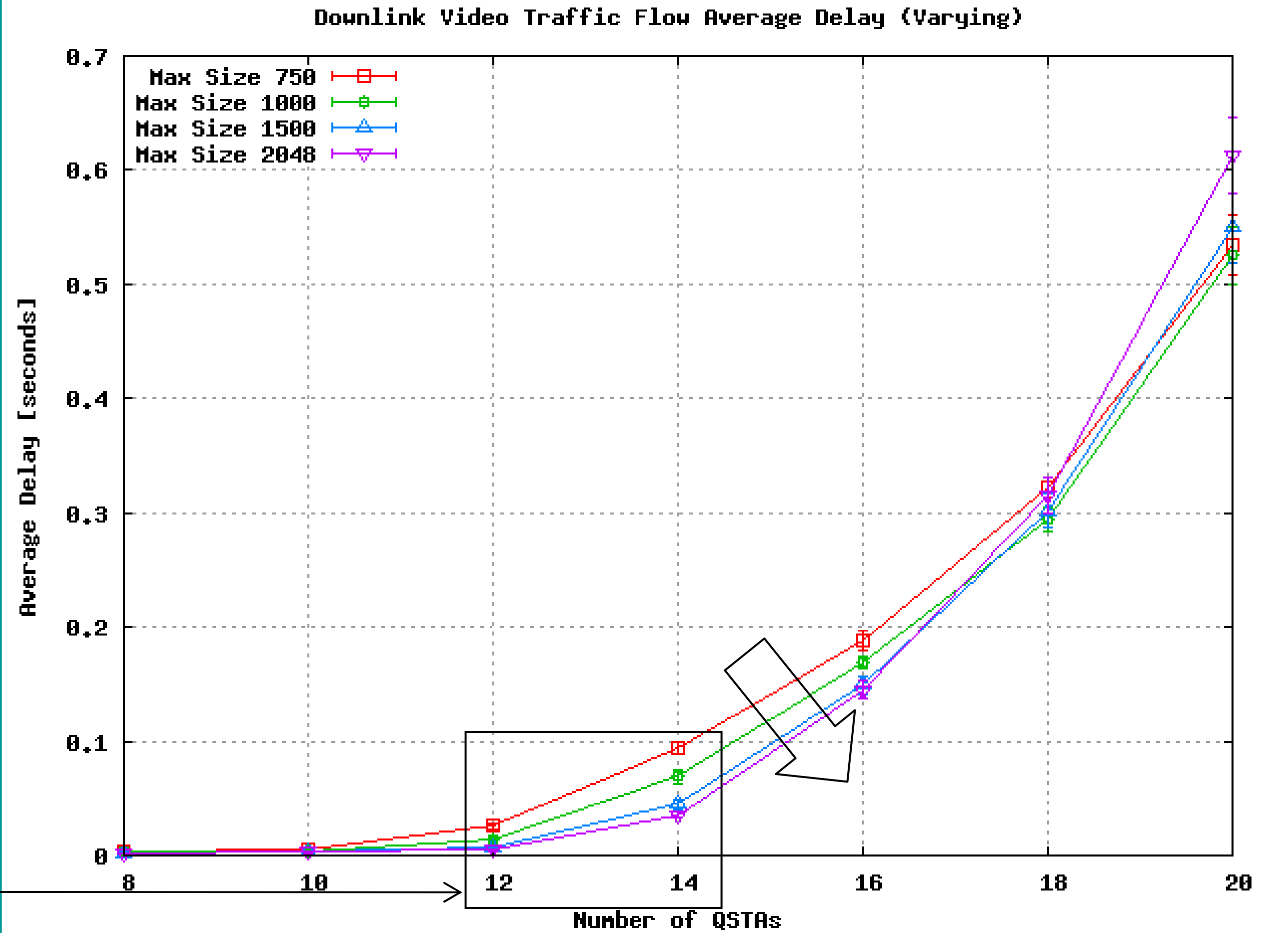
- Increasing max frame size, link utilization augments.
- Exceeding mean size of video packets, benefits reduce.

	14 QSTAs		16 QSTAs	
750	453765	-	445900	-
1000	472645	+4 %	476454	+7%
1500	484065	+6 %	502539	+12%
2048	484129	+6 %	511572	+14%



Max Frame Size Analysis: Downlink Video Average Delay

- Video packets delay reduces due to collisions reduction and lower overhead.

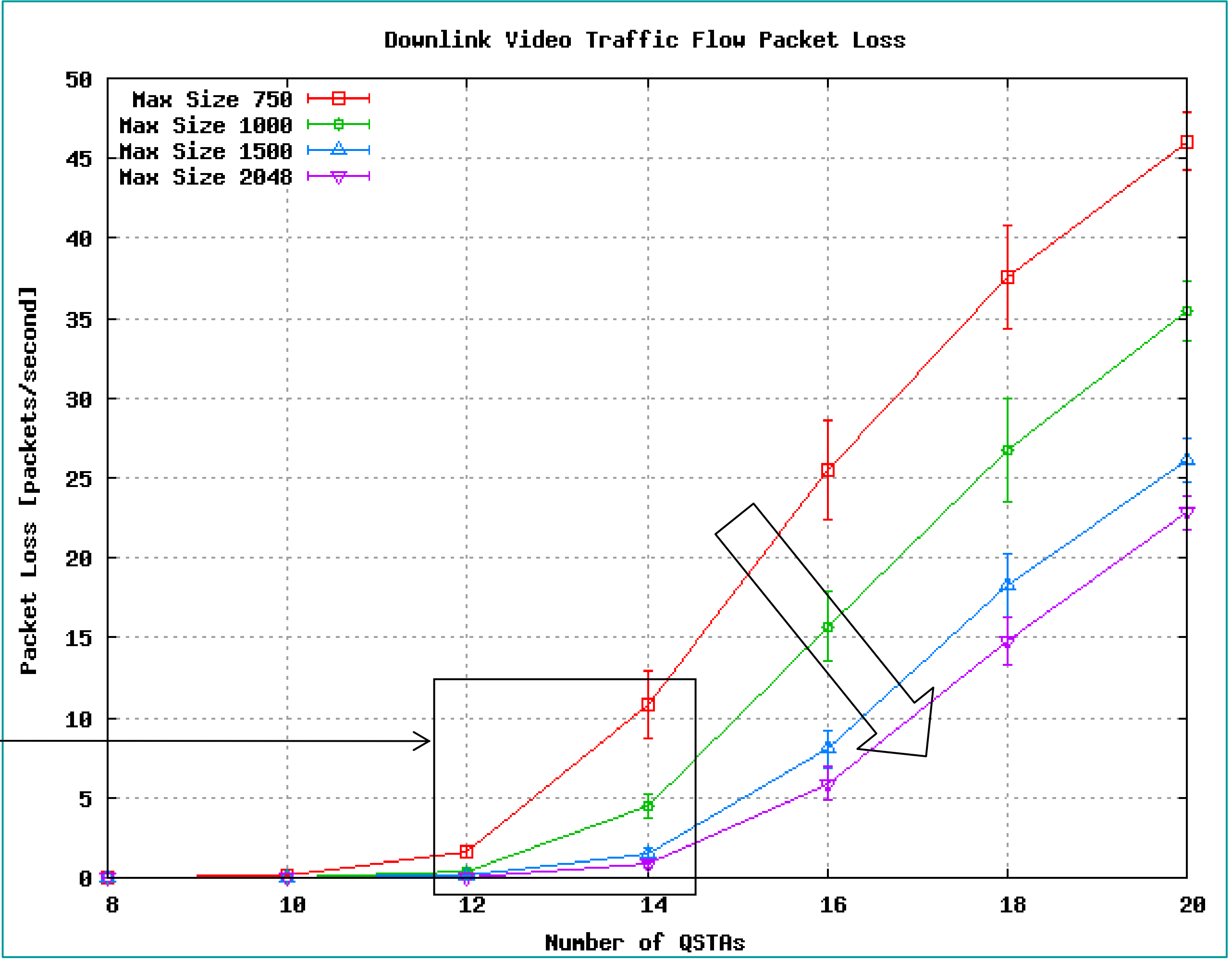


	12 QSTAs		14 QSTAs	
750	0.025	-	0.093	-
1000	0.013	-52%	0.069	-26%
1500	0.006	-76%	0.044	-53%
2048	0.004	-84%	0.035	-63%

Max Frame Size Analysis: Downlink Video Packet Loss

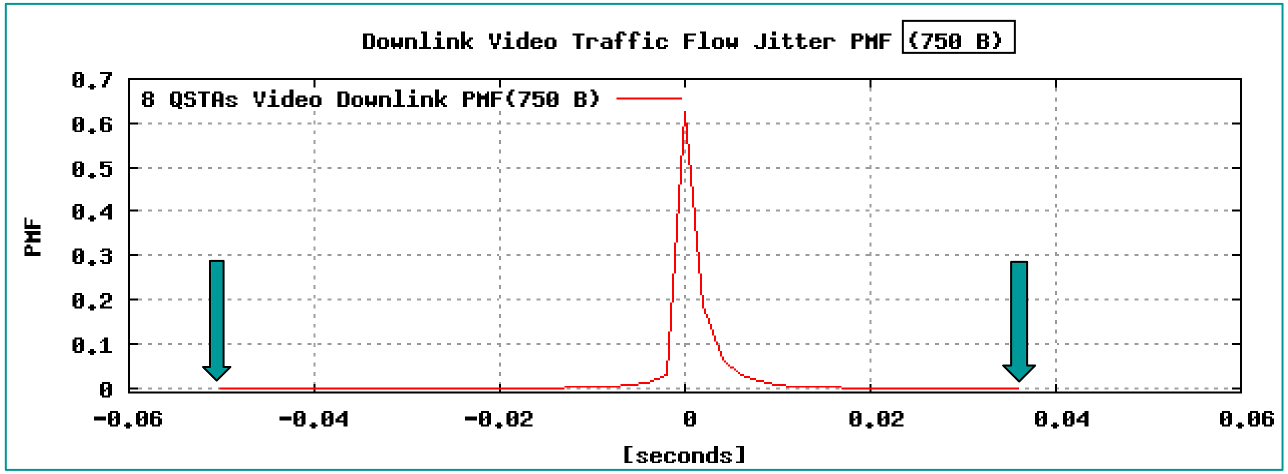
- Using a higher maximum size improves packet loss performances.

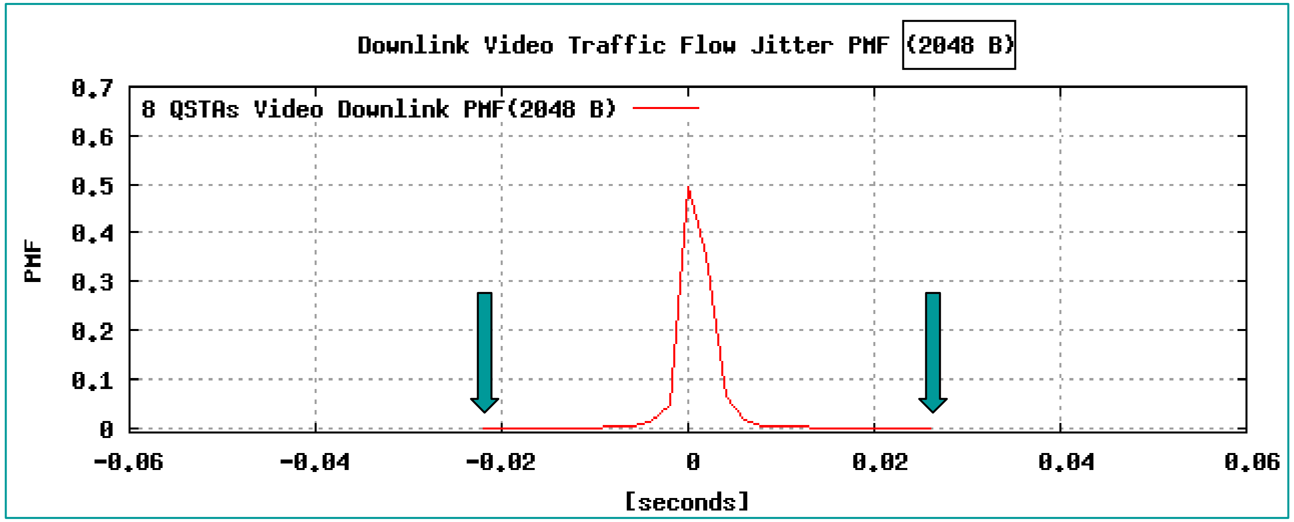
	12 QSTAs		14 QSTAs	
750 Byte	1.590		10.79	
1000 Byte	0.348	-79%	4.490	-59%
1500 Byte	0.069	-96%	1.479	-87%
2048 Byte	0.016	-99%	0.845	-93%



Max Frame Size Analysis : Downlink Video Jitter PMF

- ✓ On account of diagram's greater readability, 8 QSTAs case will be considered.
- ✓ Augmenting amount of QSTAS, quantities enlarge but propitious trend is about the same.

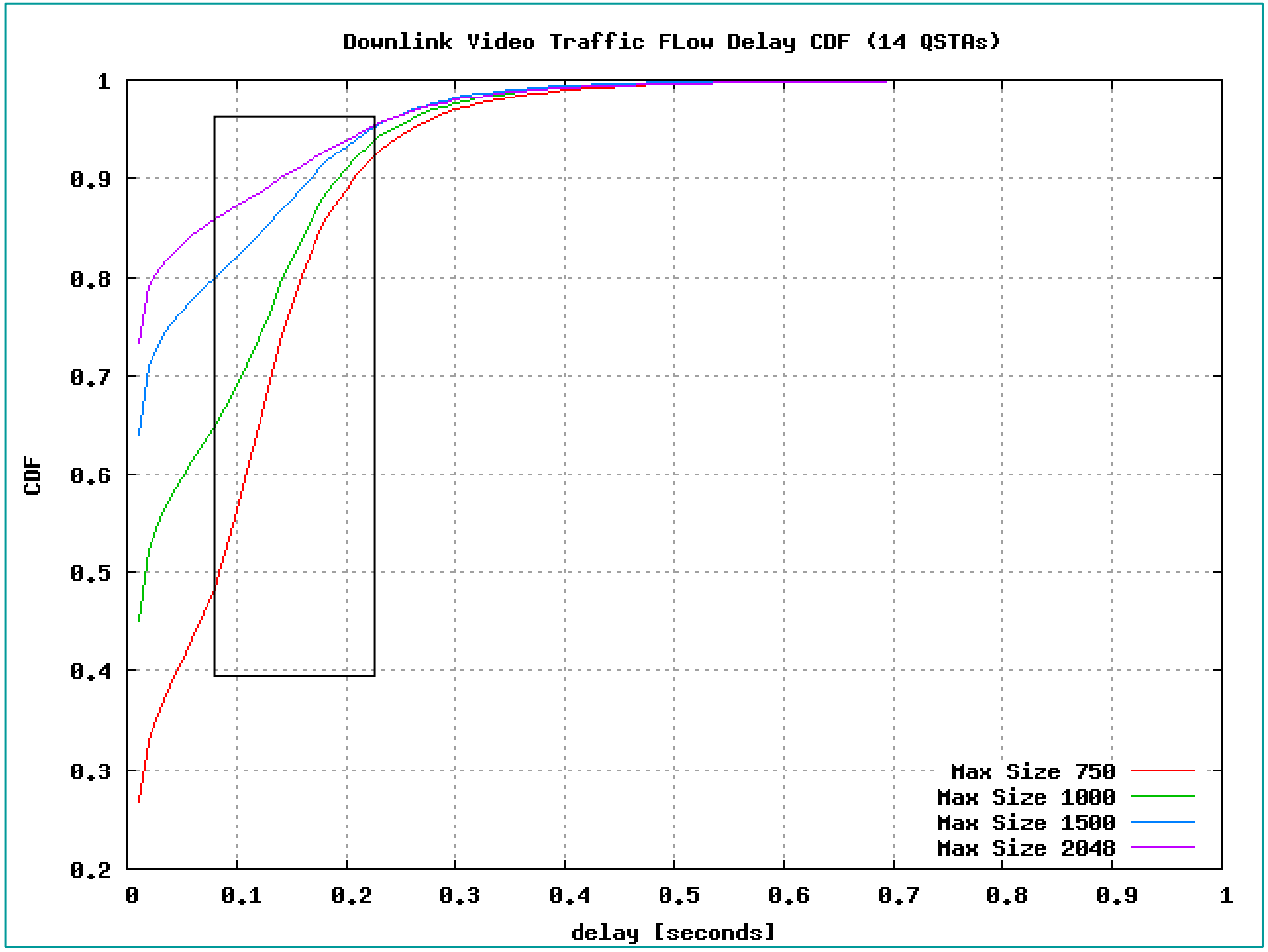




	750	2048	
MAX neg. shifting	-0.050	-0.022	-56%
Max pos. shifting	0.036	0.026	-28%

Max Frame Size Analysis: Downlink Video Delay Cumulative Distribution Function

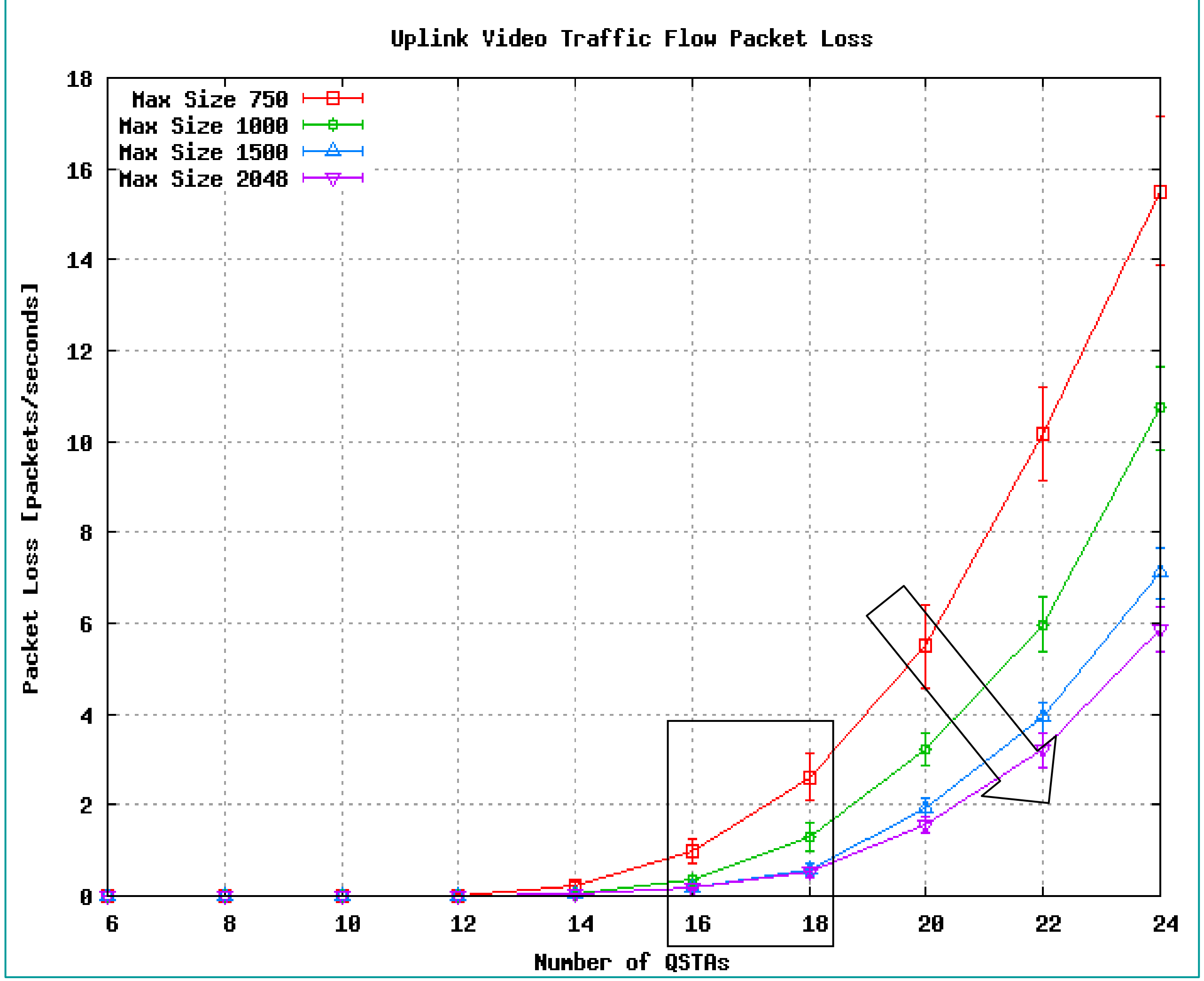
	0,1 sec	0,2 sec
750	**0.561**	**0.889**
1000	**0.689**	**0.909**
1500	**0.821**	**0.932**
2048	**0.872**	**0.938**



Max Frame Size Analysis: Uplink Video Packet Loss

- ✓ For uplink video flows, all QoS performances improves too.
- ✓ Since QSTAs has only one flow to handle problems come later.

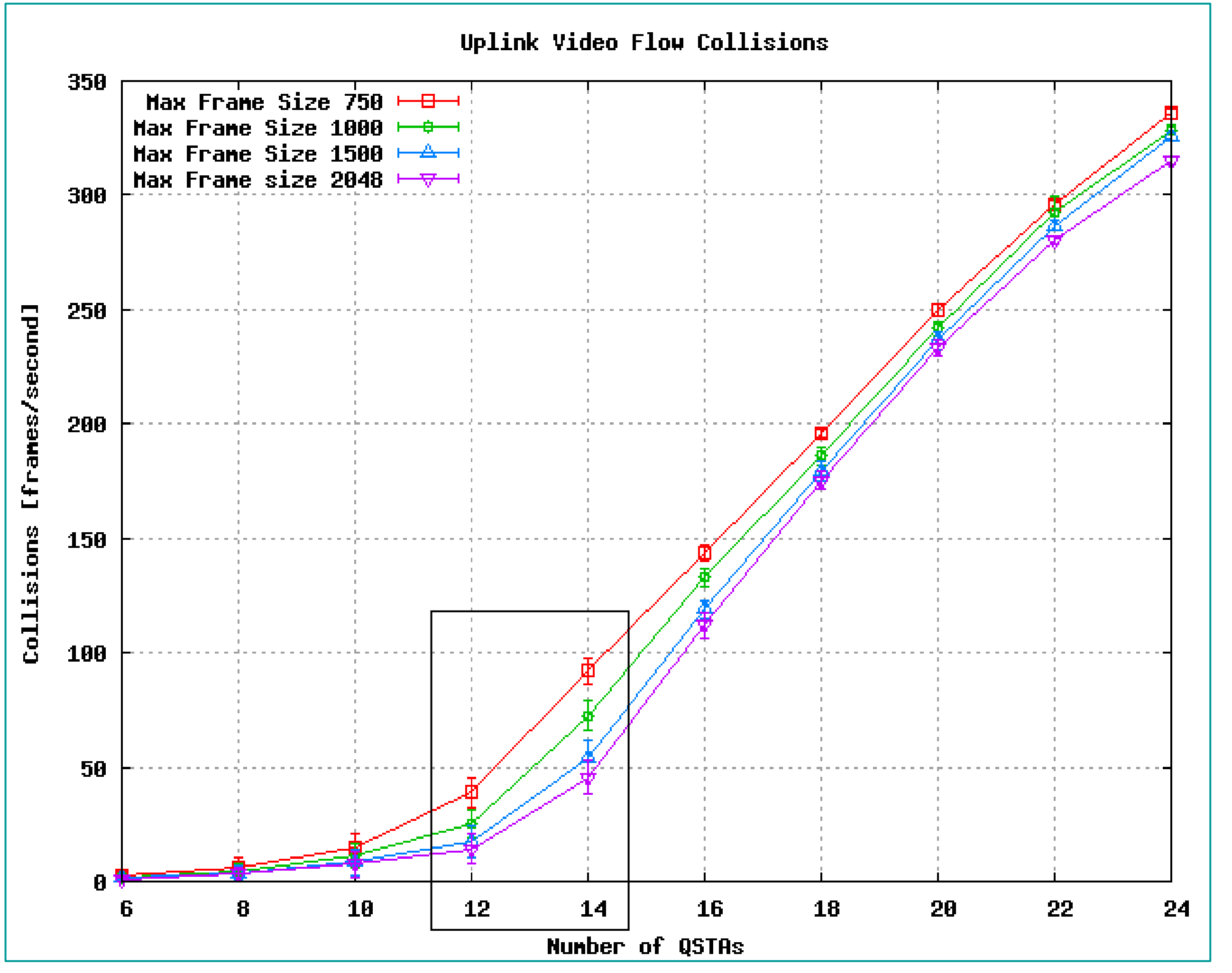
	16 QSTAs		18 QSTAs	
750	1.590		10.79	
1000	0.348	-79%	4.490	-59%
1500	0.069	-96%	1.479	-87%
2048	0.016	-99%	0.845	-93%



Max Frame Size Analysis: Uplink Video Frames Collisions

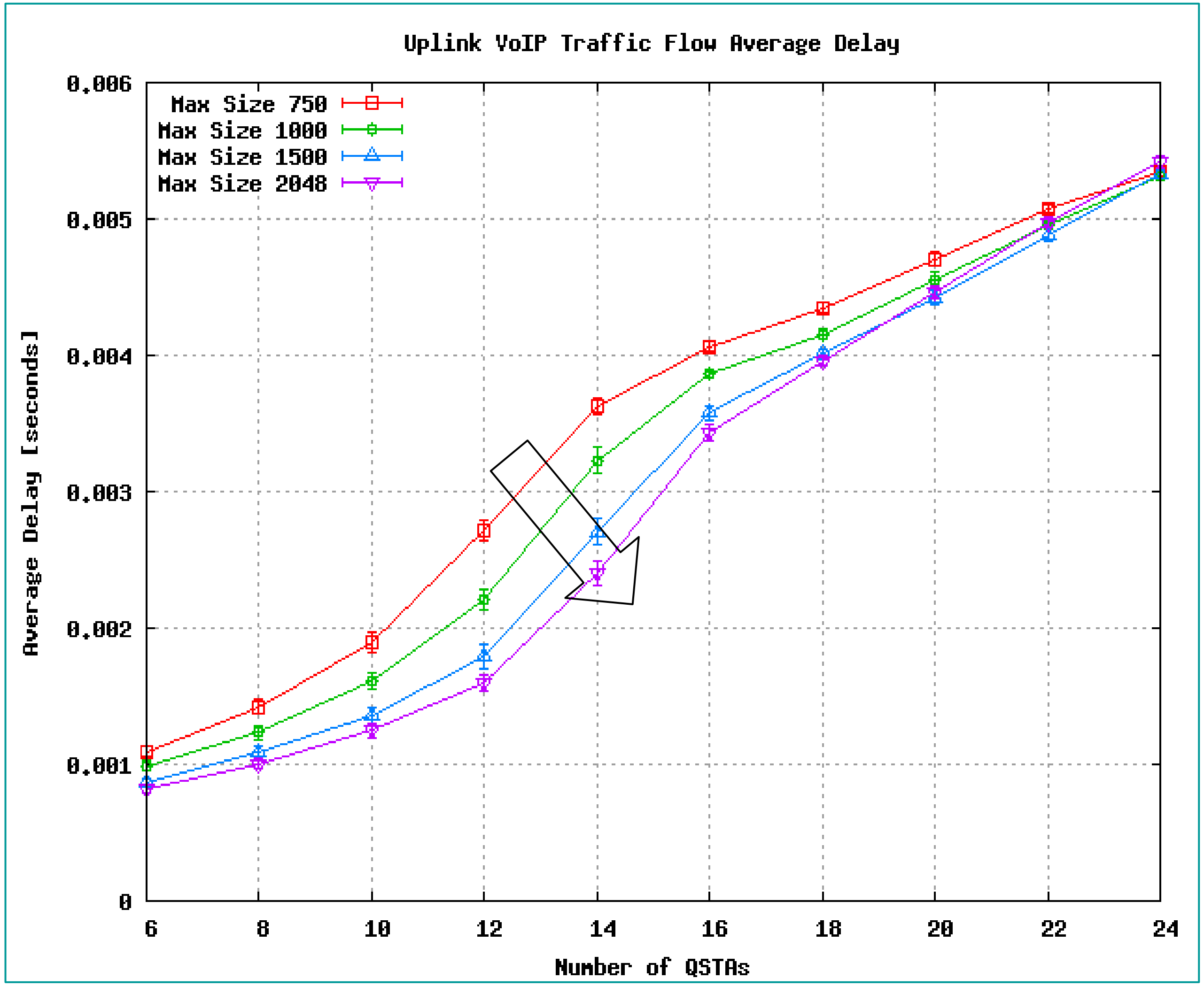
- Using higher max frame size, for the same traffic, collisions remarkably reduce.

	12 QSTAs		14 QSTAs	
750	39.14		91.89	
1000	25.20	-36%	72.34	-22%
1500	17.64	-55%	54.33	-41%
2048	14.32	-64%	45.55	-50%



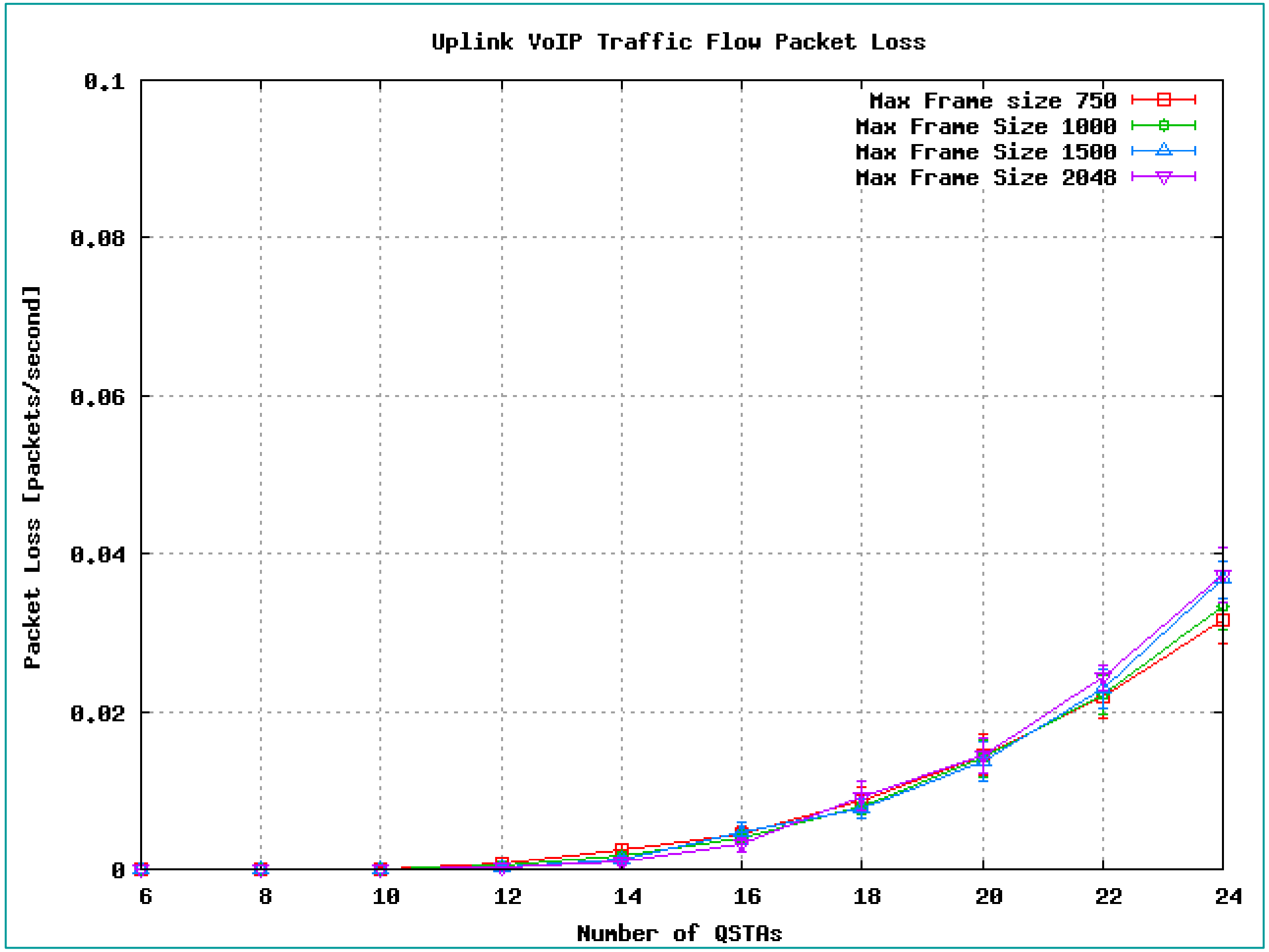
Max Frame Size Analysis: VoIP Uplink Average Delay

- For all VoIP Flows, delay parameters (little) improves too.



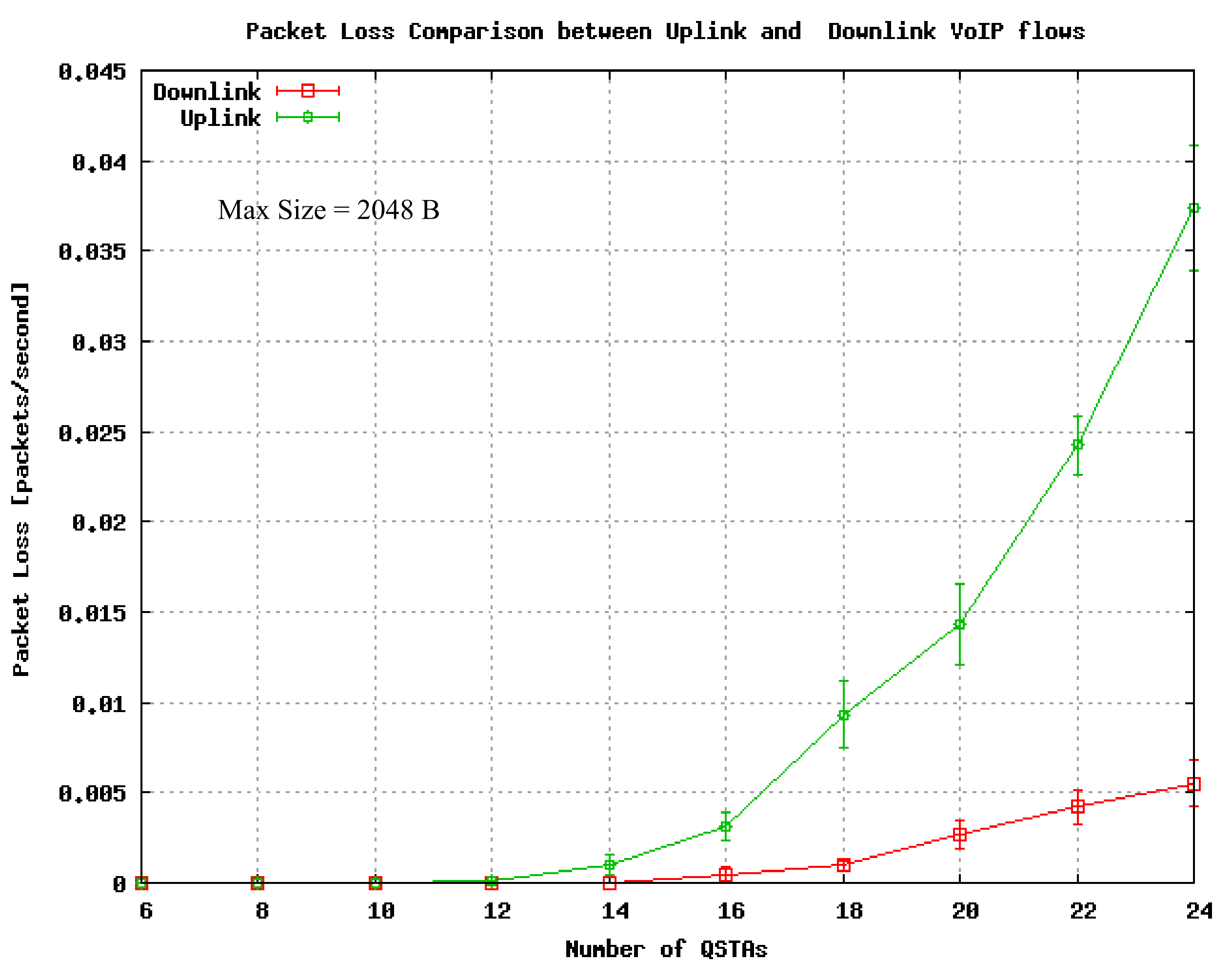
Max Frame Size Analysis: VoIP Uplink Packet Loss

- VoIP flows' packet loss keeps very low and has no meaningful changes.



Observation: Comparison Downlink-Uplink VoIP Packet Loss

- ✓ Downlink VoIP flows have better packet loss (and lelay) than uplink.
- ✓ Since QAP has more VoIP flows to handle, often has also more than one packet to transmit. So the first packet gets access, the others use the same TXOP. The more are VoIP flows, the greater are improvements.



Max Frame Size Analysis: conclusions

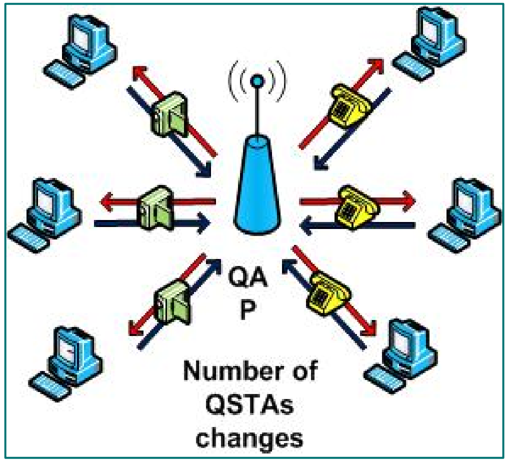
- ✓ Augmenting the maximum frame size, overhead decrease, collision risk reduces and link utilization improves.
- ✓ Incidentally, in a real environment, due to BER influence, max frame size must not exceed 2048 B.

AIFS Analysis :

✓Class 0 AIFS = 2, is practically unavoidable (due to legacy STAs) .
✓Augmenting AIFS has to main effects:

1. to augment isolation between Access Categories
2. to reduce chances to access medium (for the corresponding class).

✓For class 0 traffic, augmenting Class 1 AIFS increments isolation and improves performances .
✓For class 1 traffic, behavior changes whether or not AIFS exceeds an "optimal" value. While value ≤ 6 augmenting AIFS improves class 1 QoS performances (collisions' reduction prevails). For AIFS ≥6, Video QoS performances get worse since there are no more collisions' reduction, but chances to access medium reduce.



Class 0	(VoIP)
Cwmin	3
CWmax	7
AIFS	2
TXOP	0.003264
Class 1	**(Video)**
Cwmin	7
CWmax	15
TXOP	0.006016

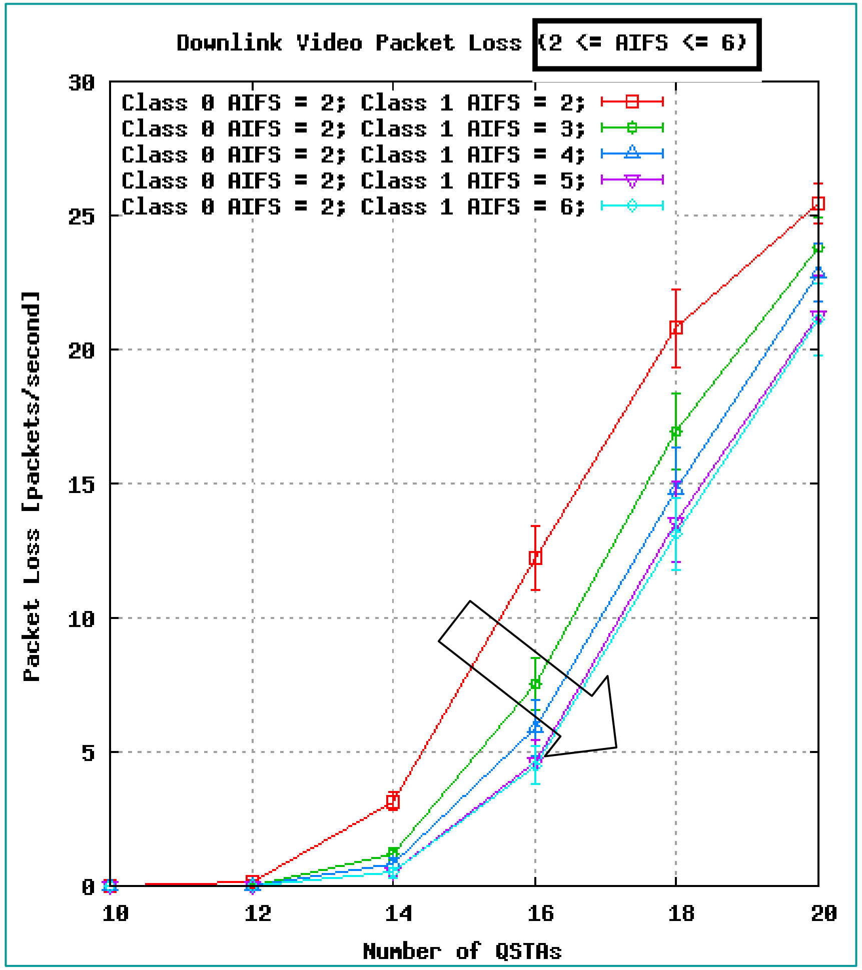
<u>Left</u>
(AIFS ≤ 6)

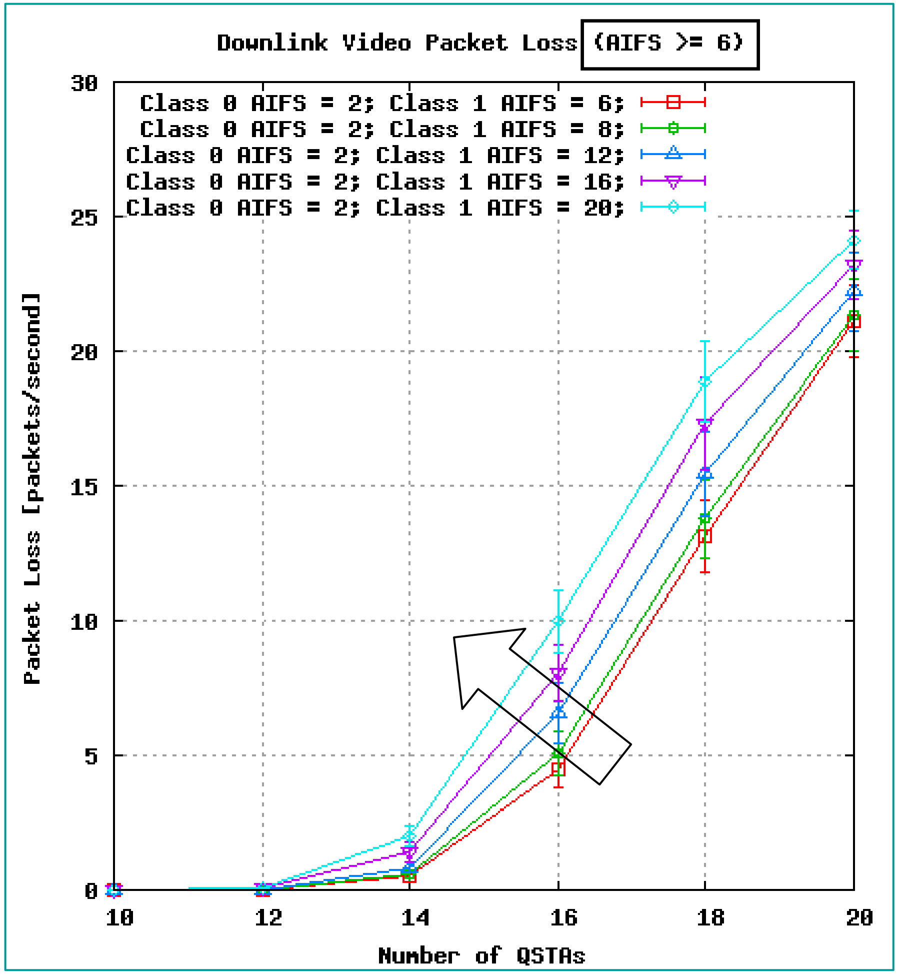
Class 1	
AIFS	2
AIFS	3
AIFS	4
AIFS	5
AIFS	6

<u>Right</u>
(AIFS ≥ 6)

Class 1	
AIFS	6
AIFS	8
AIFS	12
AIFS	16
AIFS	20

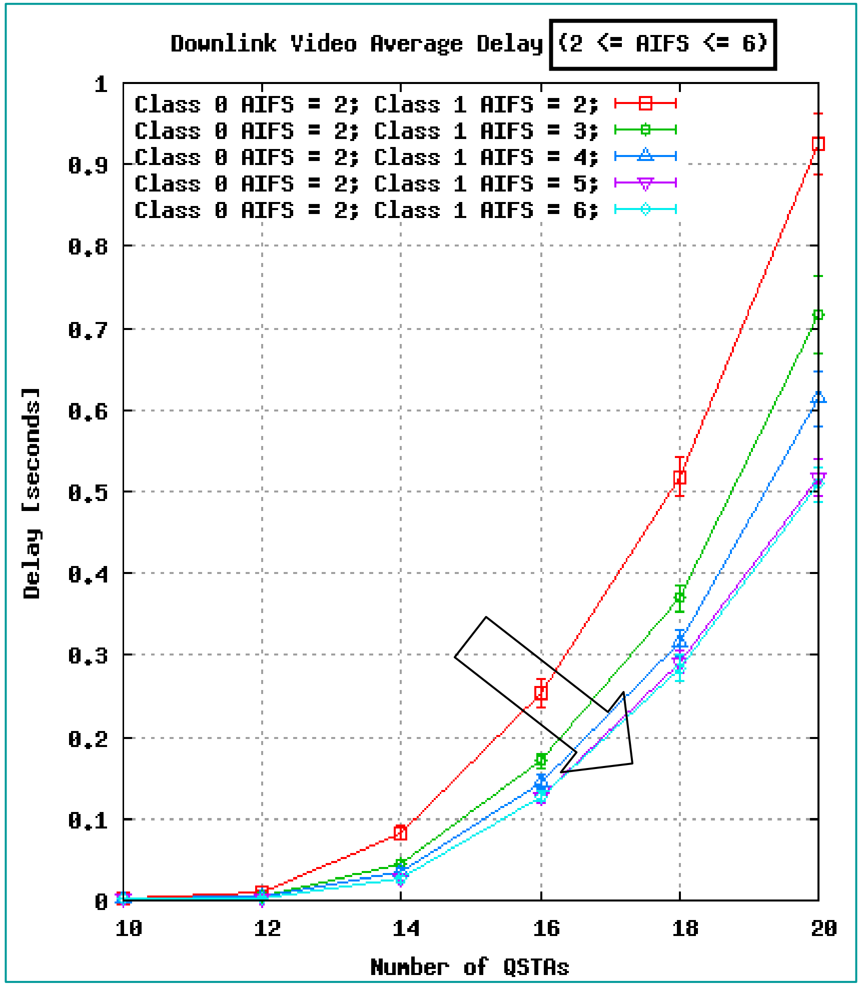
Augmenting Class 1 AIFS: Downlink Video Packet Loss

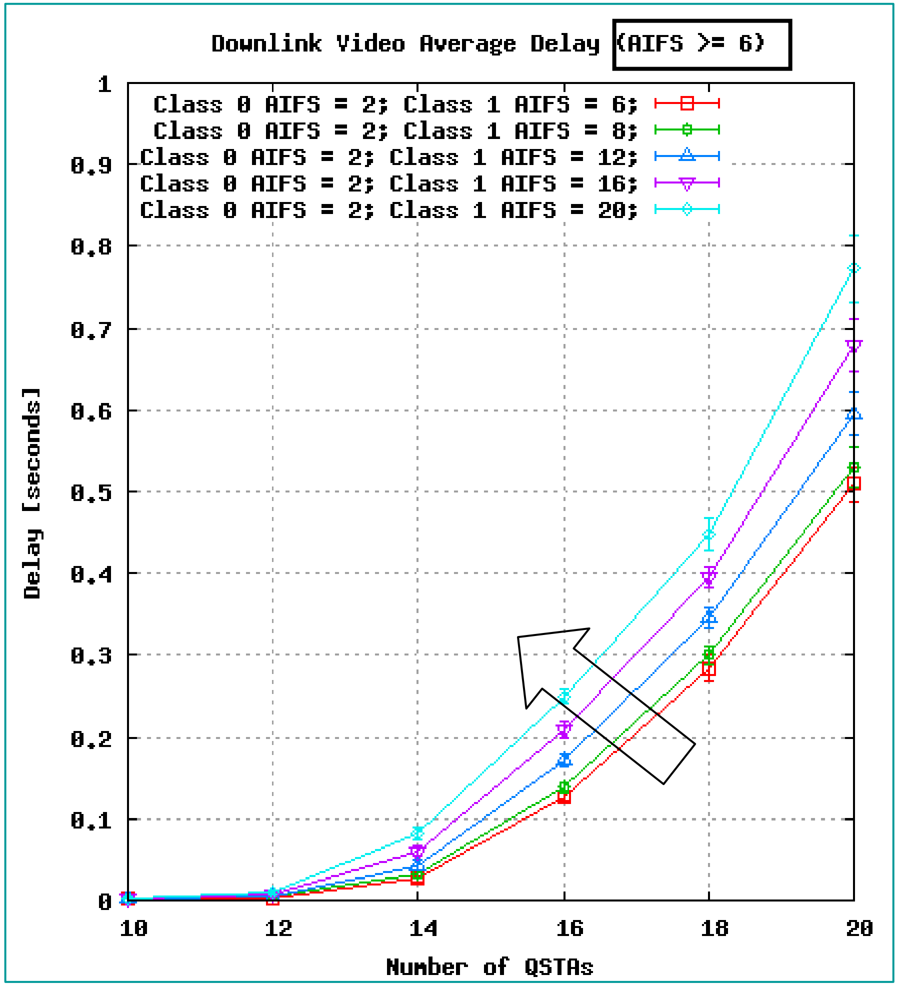




✓For AIFS ≤ 6, Video packet delay cuts due to reduction of collisions with VoIP traffic.
✓For AIFS ≥ 6 chances to access medium reduces and there is no more collisions' reduction.

Augmenting Class 1 AIFS: Downlink Video Average Delay

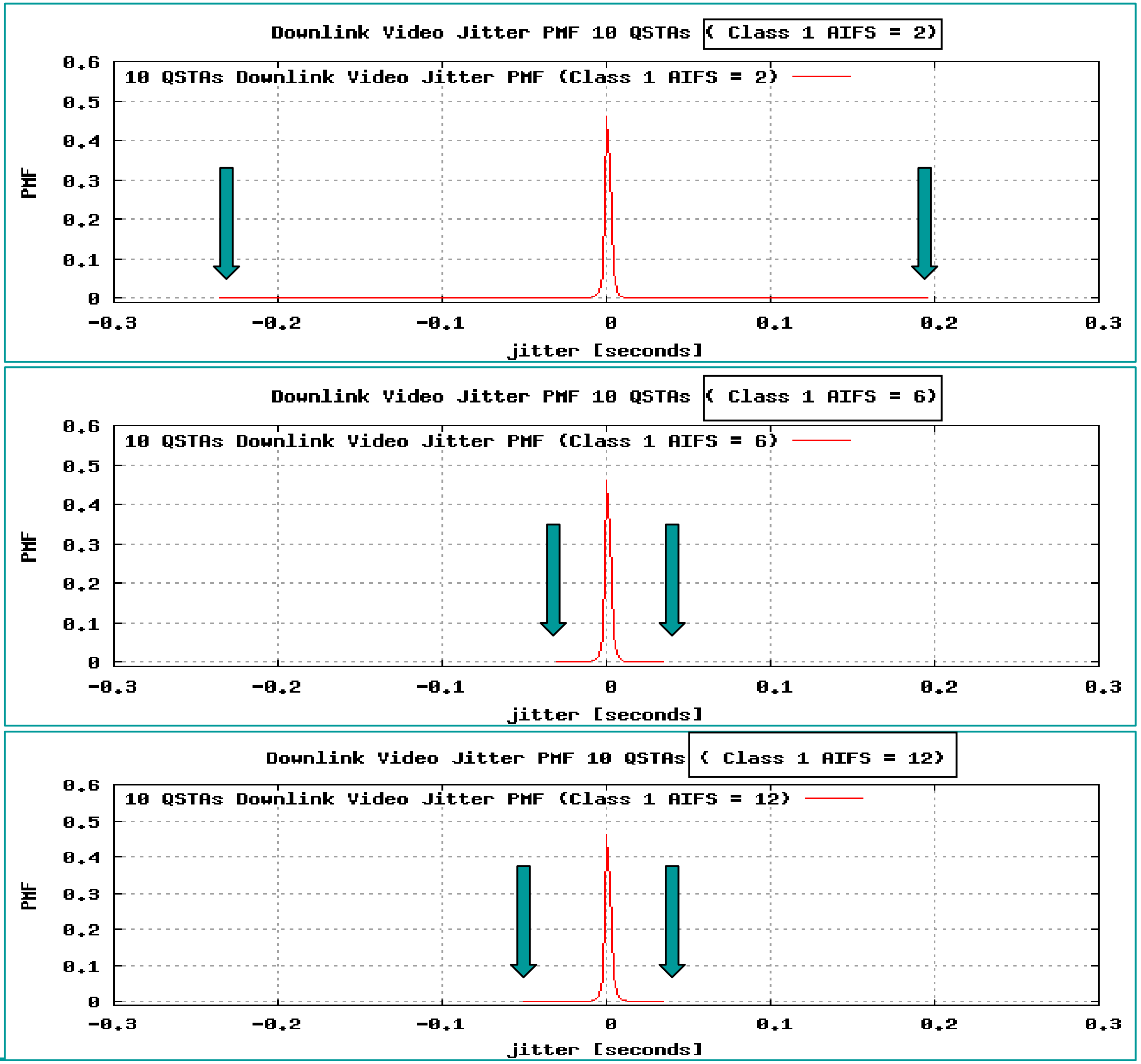




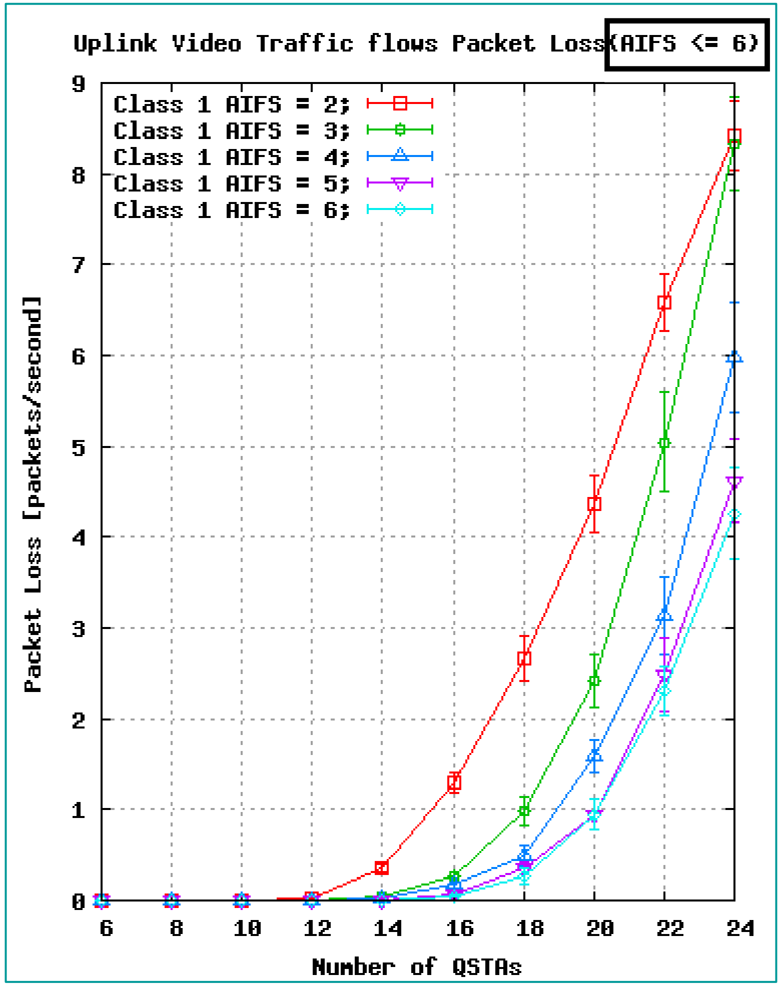
✓For AIFS ≤ 6 delay reduces, then starts to grow.

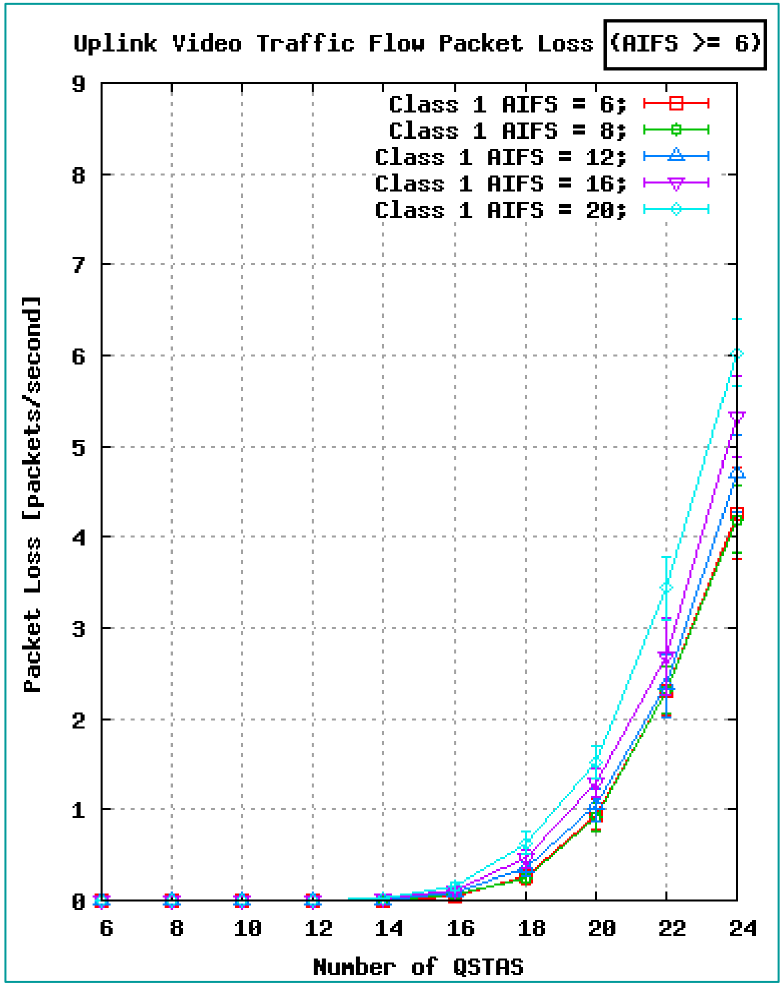
Augmenting Class 1 AIFS: Downlink Video Jitter PMF

- ✓ Augmenting AIFS there's a reduction on Jitter's worst cases.
- ✓For AIFS > 6 jitter starts to get worse (slowly).



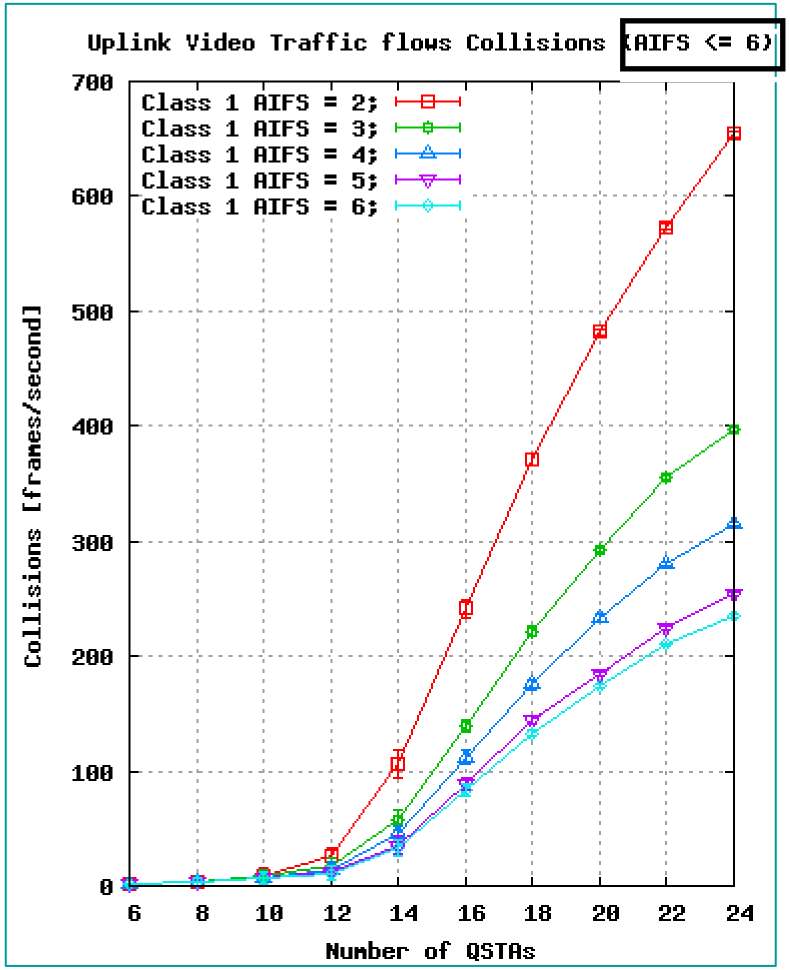
Augmenting Class 1 AIFS: Uplink Video Packet Loss

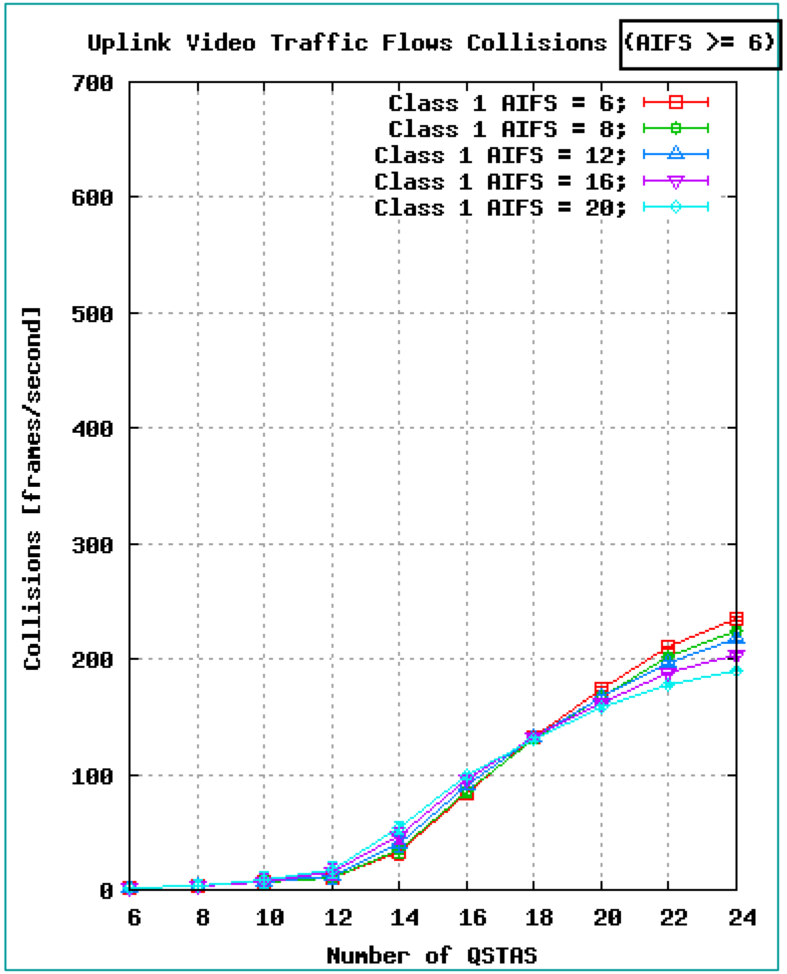




✓With respect to Video downlink flows, trend is about the same. Uplink flows ha less packets to handle, so troubles on QoS parameters come later.

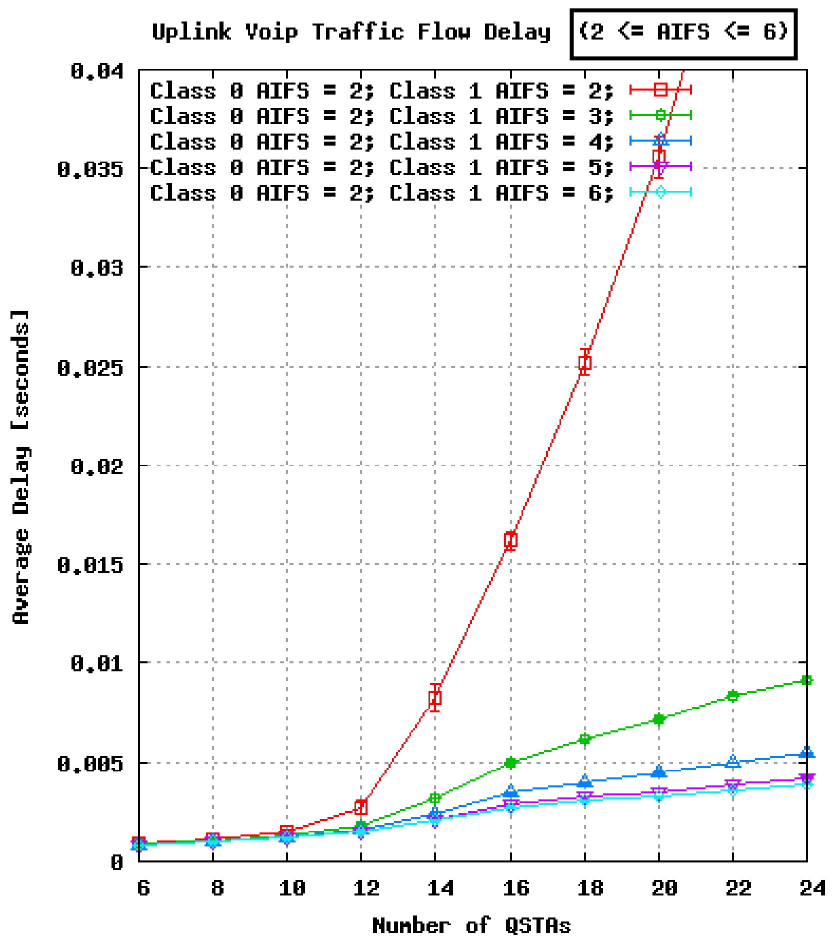
Augmenting Class 1 AIFS: Uplink Video Frames Collisions

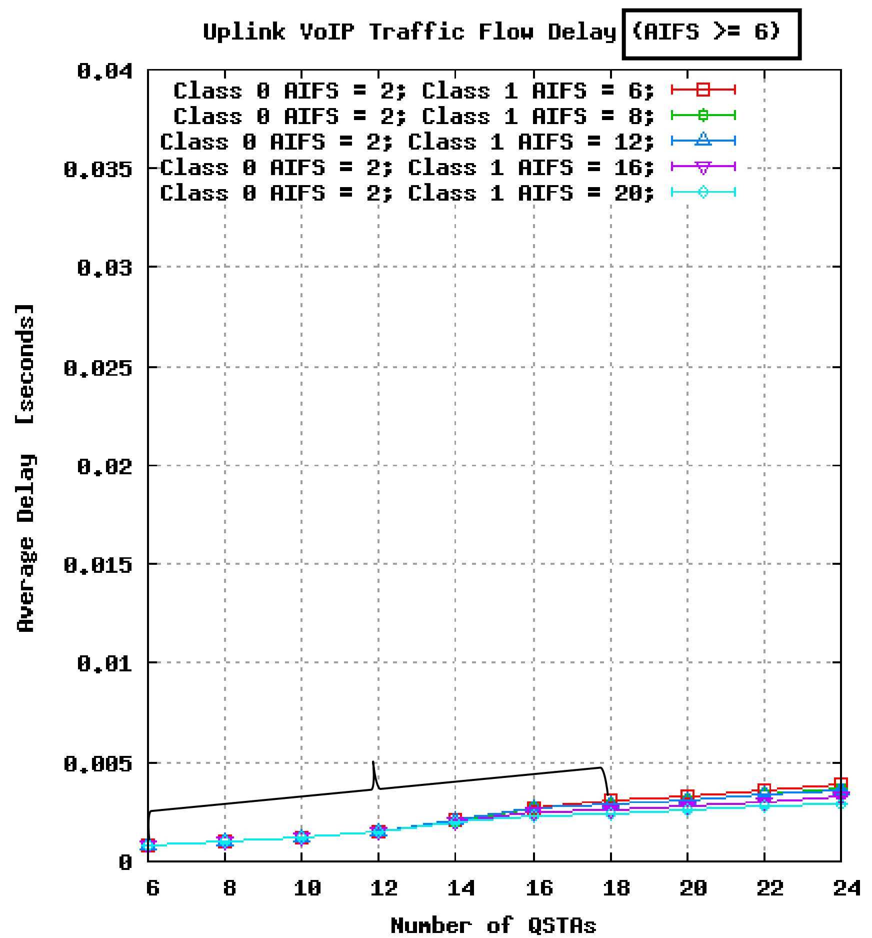




✓Here is collisions trend (reflecting what previously said).
✓For AIFS > 6 and amount of QSTAs > 18, collision reduction comes from decrease of successful contentions.

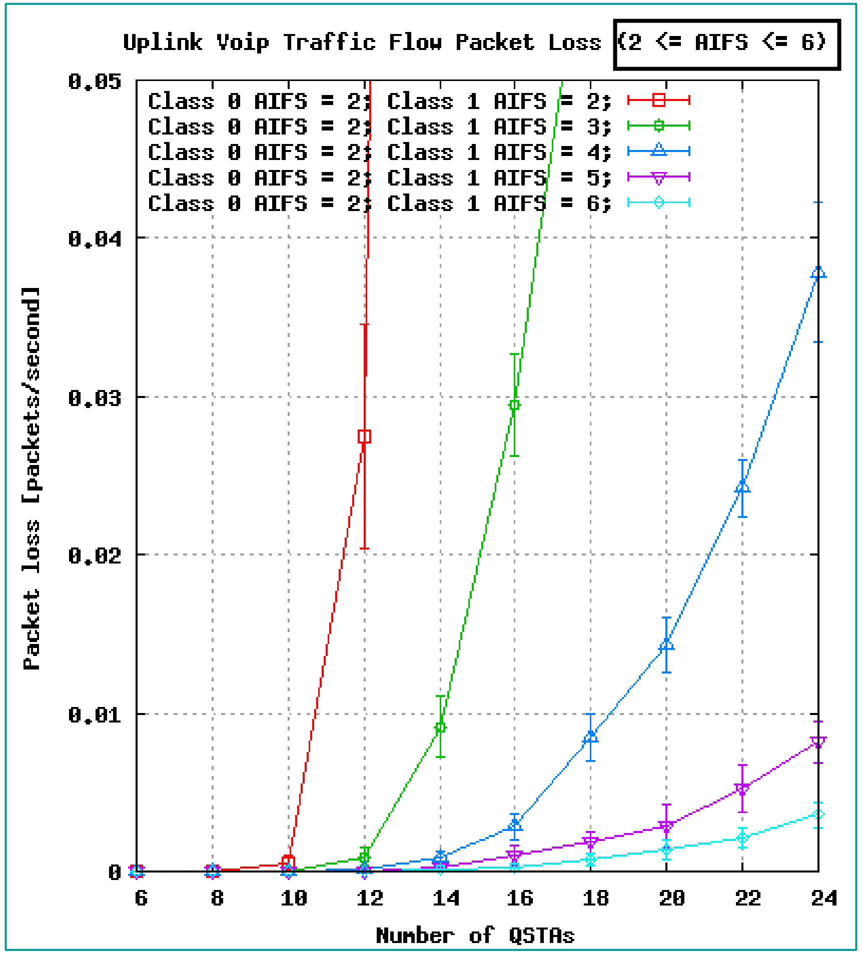
Augmenting Class 1 AIFS: Uplink VoIP Average Delay

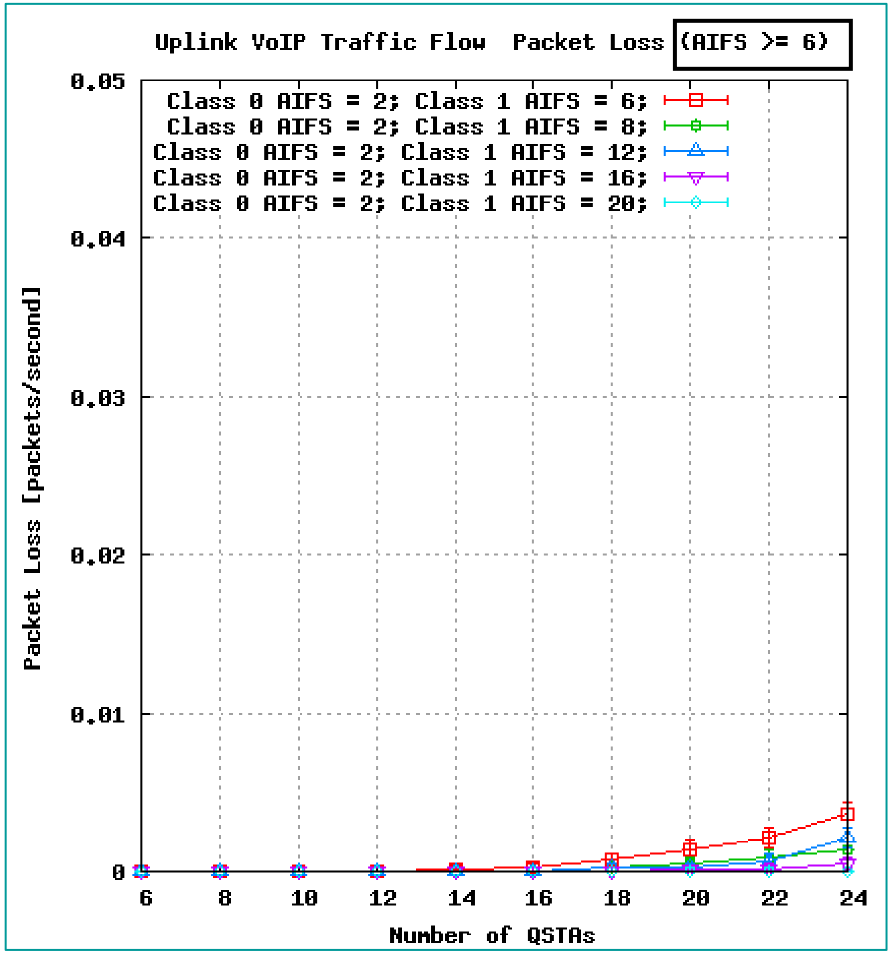




✓Initially, when augmenting AIFS , VoIP packet delay cuts (due to collisions' reduction with respect to video flows).
✓For AIFS > 6, augmenting AIFS substantially improves no more.

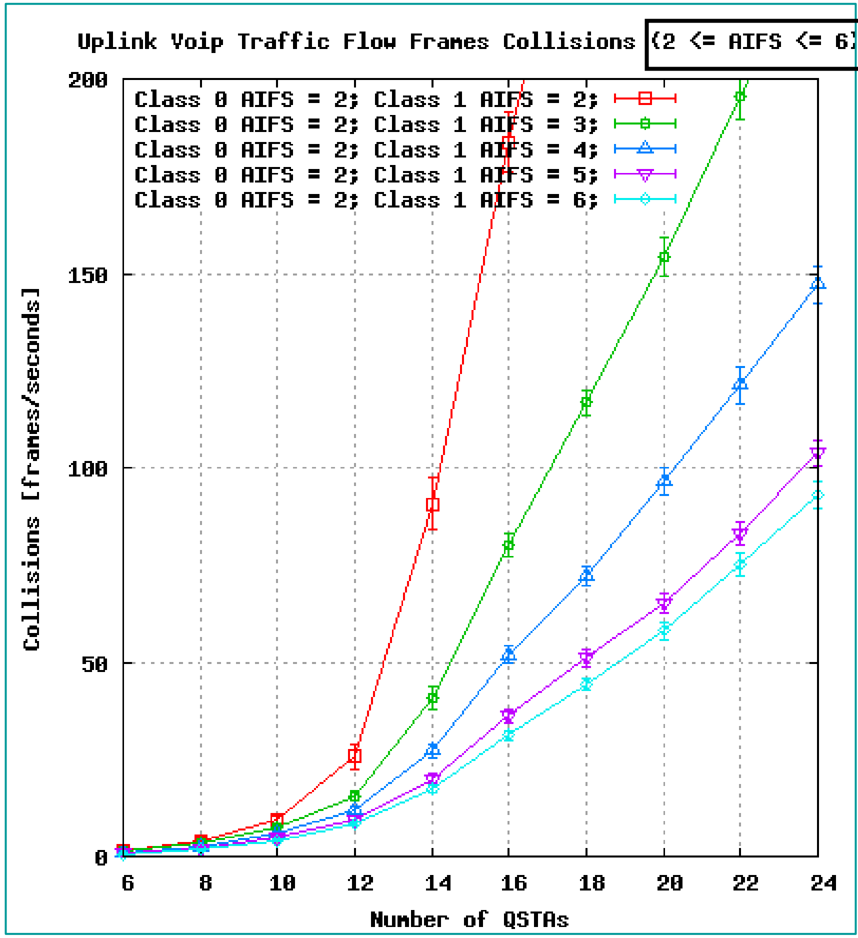
Augmenting Class 1 AIFS: Uplink VoIP Packet Loss

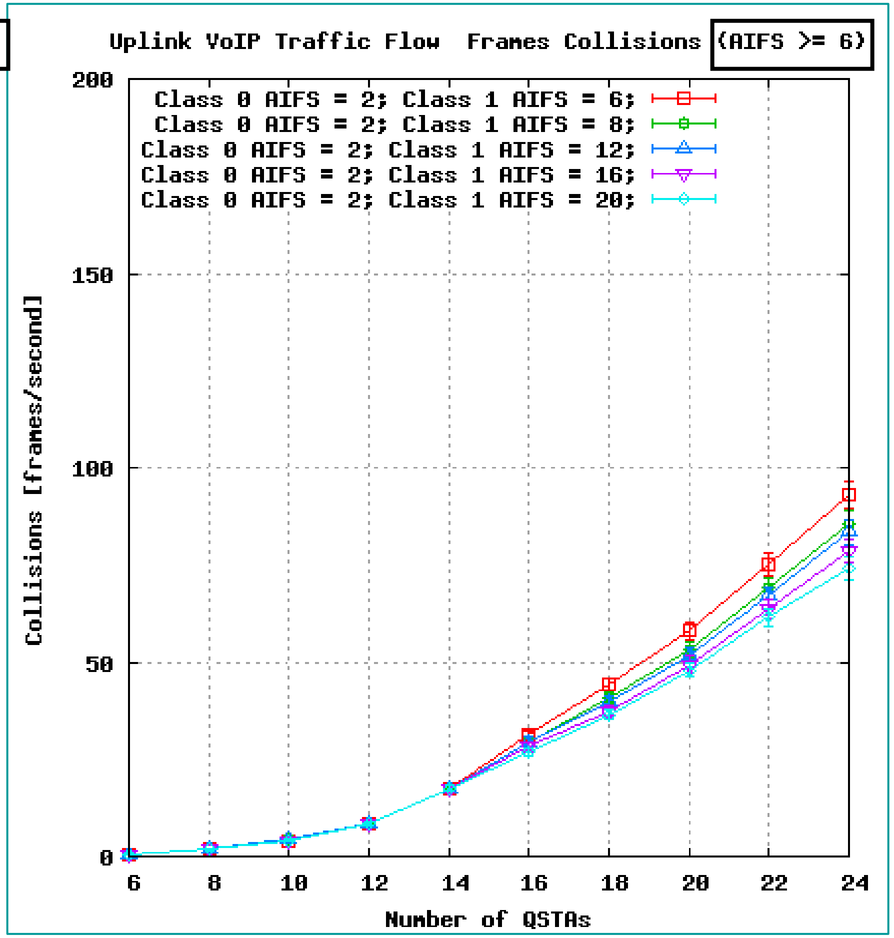




✓VoIP flows' Packet Loss considerably improves up to AIFS =6

Augmenting Class 1 AIFS: Uplink VoIP Frames Collisions

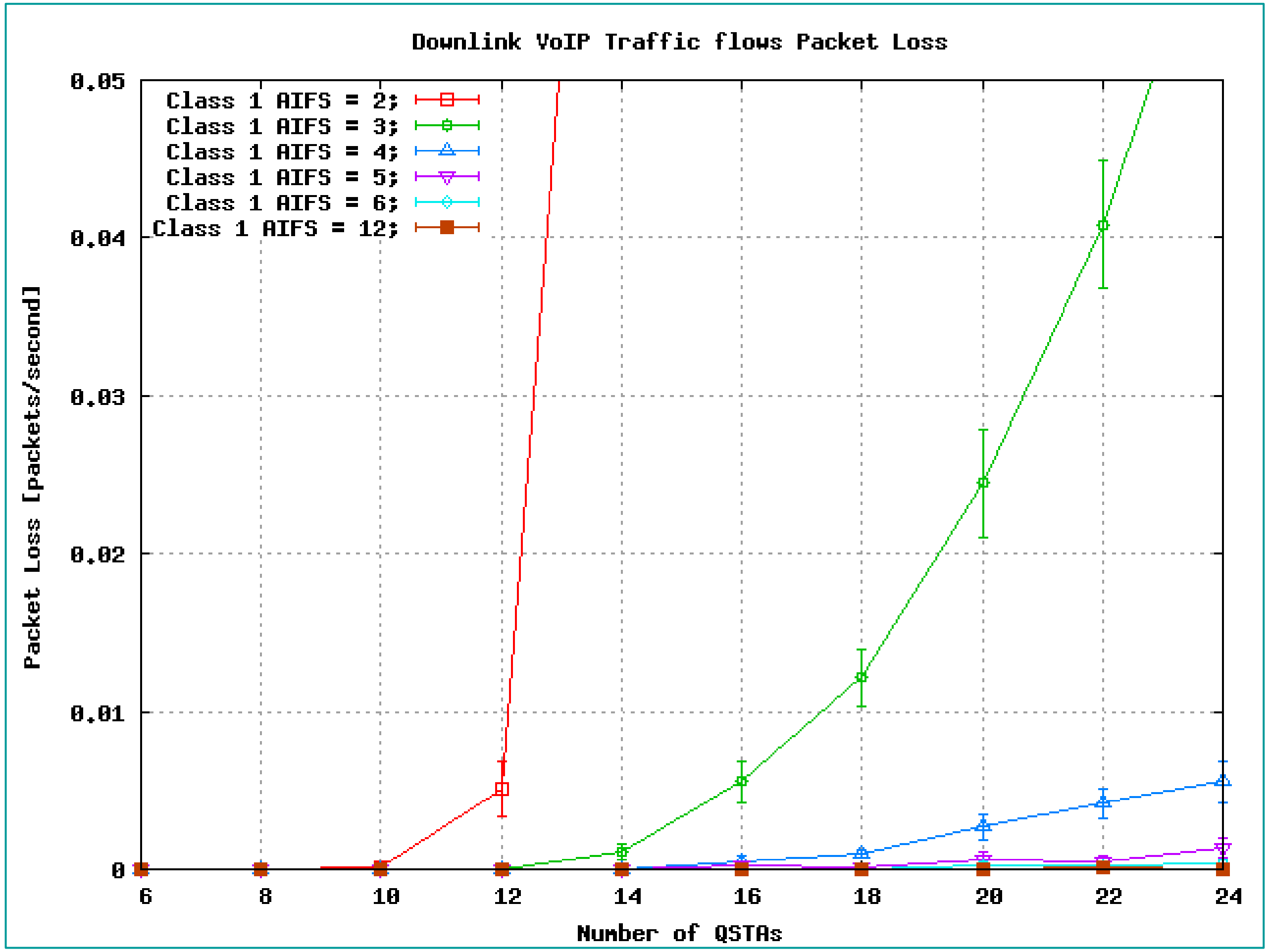




✓Improvements for VoIP flows' QoS parameters comes from greater isolation which considerably reduces collisions with Video traffic packets.

Augmenting Class 1 AIFS: Downlink VoIP Packet Loss

✓For downlink VoIP flows, QoS performance trend is about the same seen for uplink flows (mutatis mutandis).



Differentiating UL/DL AIFS

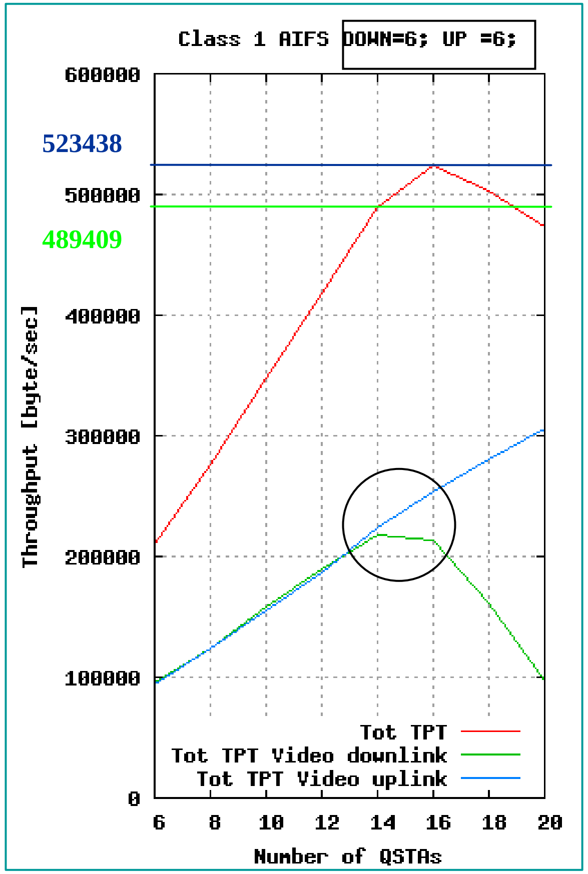
- ✓ In an infrastructure mode topology, problems come from IEEE 802.11e protocol not distinguish between QSTAs and QAP.
- ✓ To improves this issue, AIFS values could be differentiated according to flow direction (uplink, downlink).
- ✓ Differentiating AIFS it's possible to obtain more fair resources sharing (but no miracles).

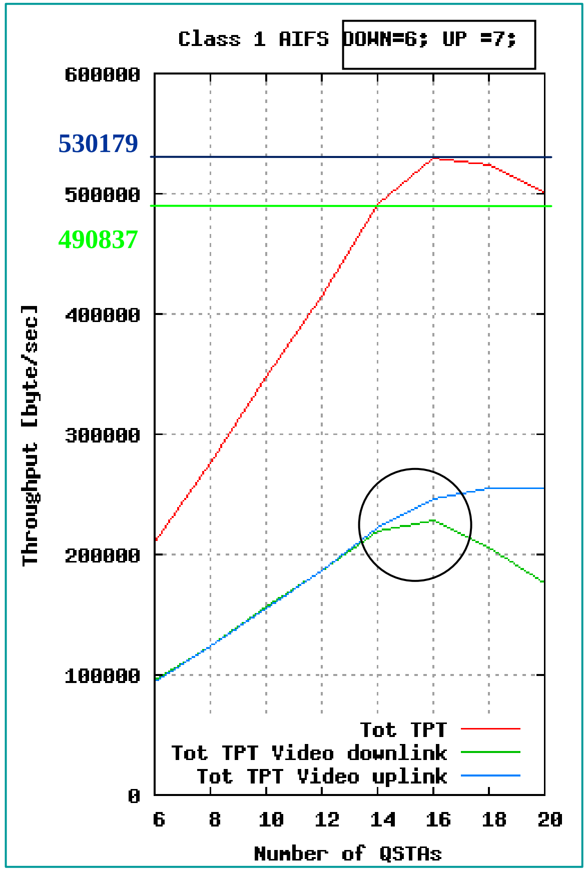
Class 0	(VoIP)	Class 1	(Video)
CWmin	3	Cwmin	7
CWmax	7	CWmax	15
		AIFS DOWN	**6**
AIFS	2	**AIFS UP**	**6**
TXOP	0.003264	TXOP	0.006016

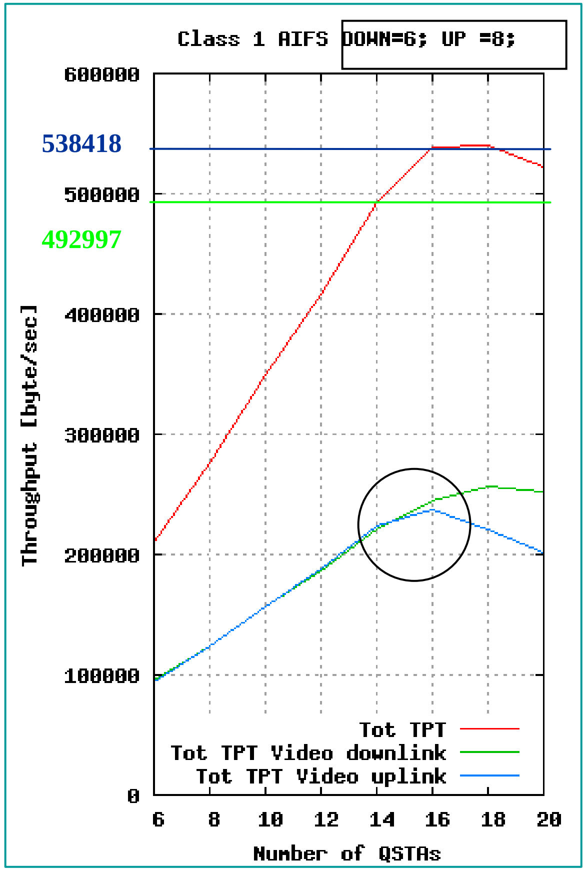
Class 0	(VoIP)	Class 1	(Video)
CWmin	3	Cwmin	7
CWmax	7	CWmax	15
		AIFS DOWN	**6**
AIFS	2	**AIFS UP**	**7**
TXOP	0.003264	TXOP	0.006016

Class 0	(VoIP)	Class 1	(Video)
CWmin	3	Cwmin	7
CWmax	7	CWmax	15
		AIFS DOWN	**6**
AIFS	2	**AIFS UP**	**8**
TXOP	0.003264	TXOP	0.006016

Differentiating UL/DL AIFS: Total Throughput







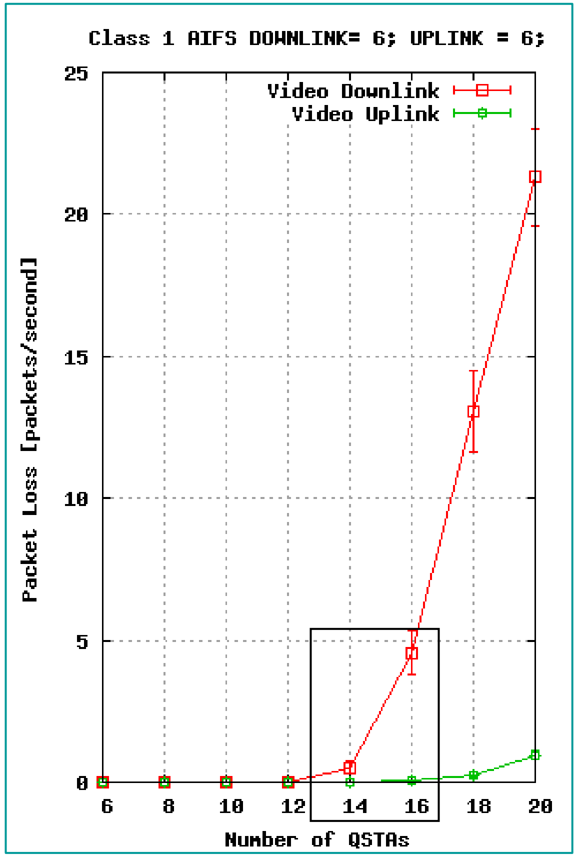
QSTAs	14	16
TOT TPT Video DL	217251	214097
TOT TPT Video UL	223338	253610

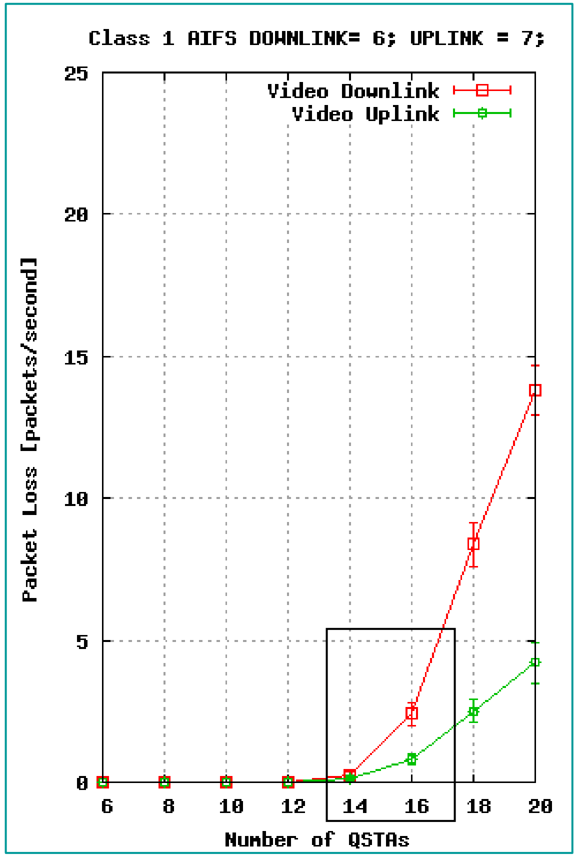
QSTAs	14	16
TOT TPT Video DL	219150	228635
TOT TPT Video UL	222867	245813

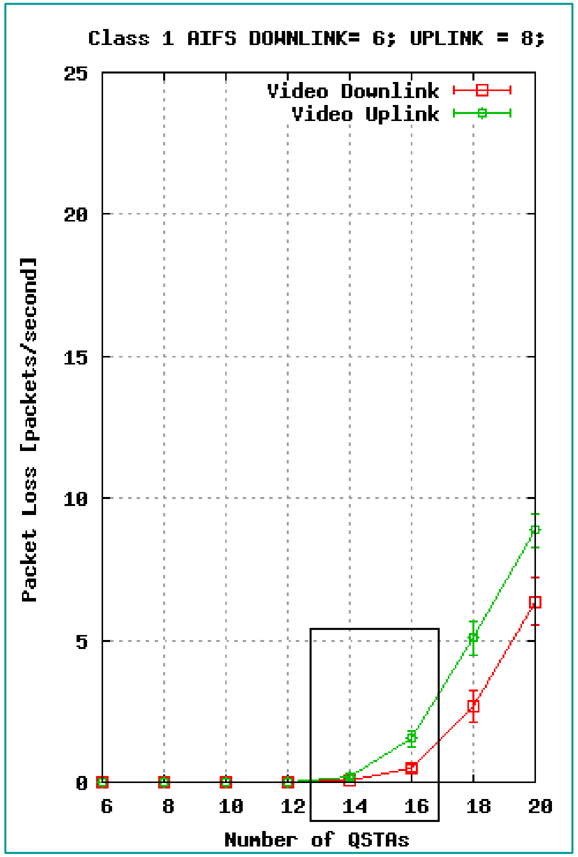
QSTAs	14	16
TOT TPT Video DL	220842	245159
TOT TPT Video UL	223336	237528

✓Throughput is shared more fairly between uplink and downlink flows. Total throughput augments not much.

Differentiating UL/DL AIFS: Video Packet Loss





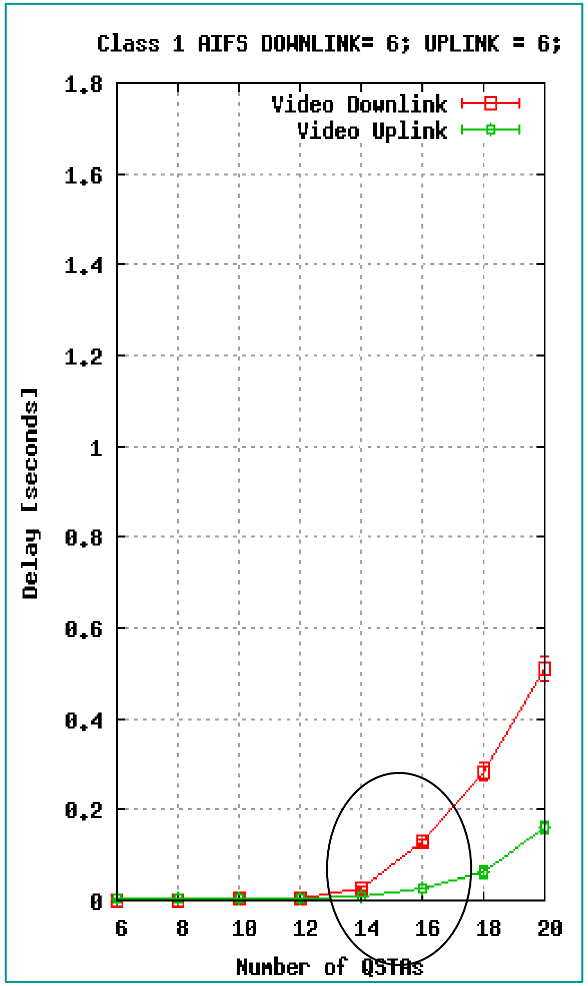


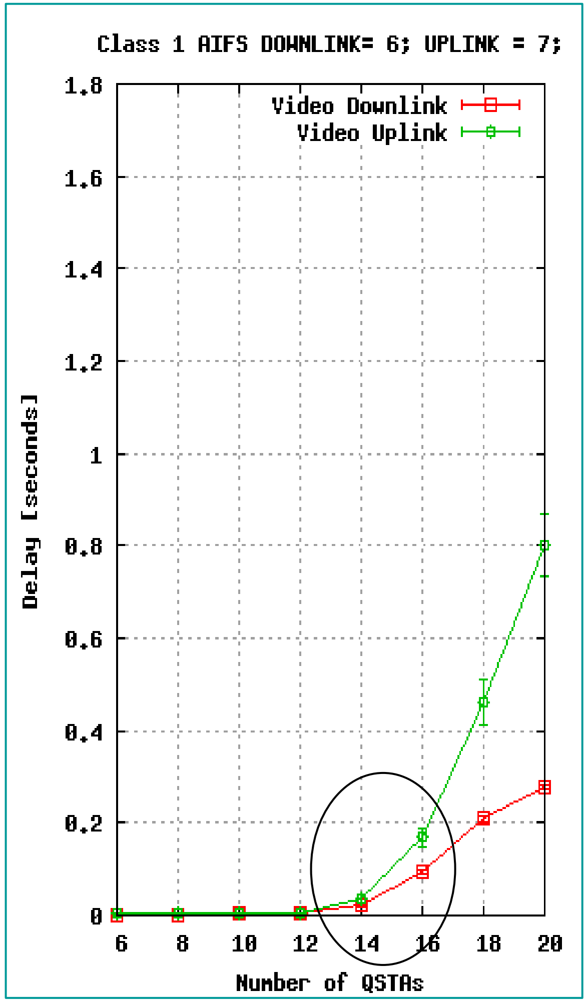
QSTAs	14	16
Packet Loss DL [P/s]	0.513	4.548
Packet Loss UL [P/s]	0.006	0.055
Gap	0.507	4.493

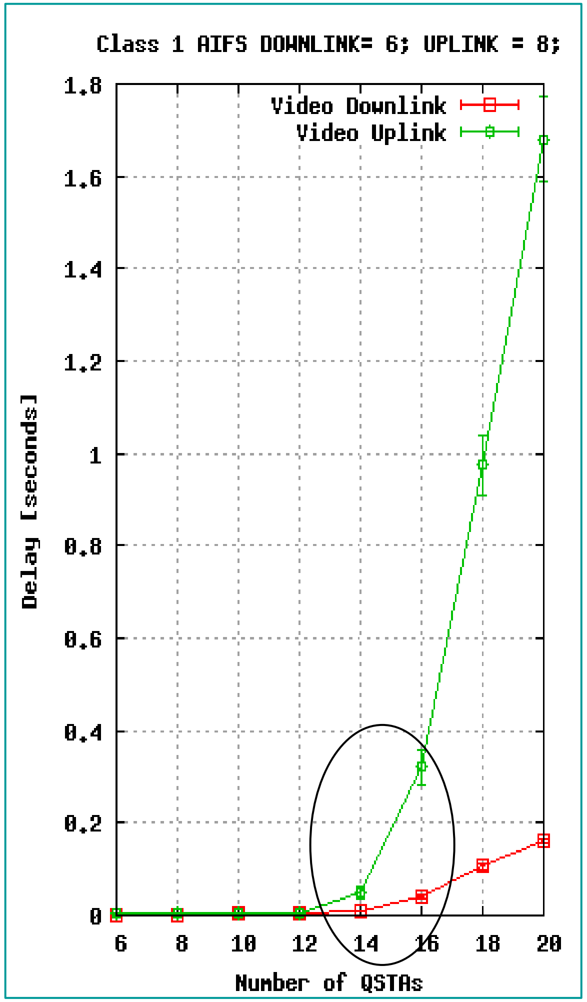
QSTAs	14	16
Packet Loss DL [P/s]	0.255	2.407
Packet Loss UL [P/s]	0.128	0.796
Gap	0.127	1.611

QSTAs	14	16
Packet Loss DL [P/s]	0.035	0.491
Packet Loss UL [P/s]	0.197	1.528
Gap	(-)0.162	(-)1.037

Differentiating UL/DL AIFS: Video Average Delay





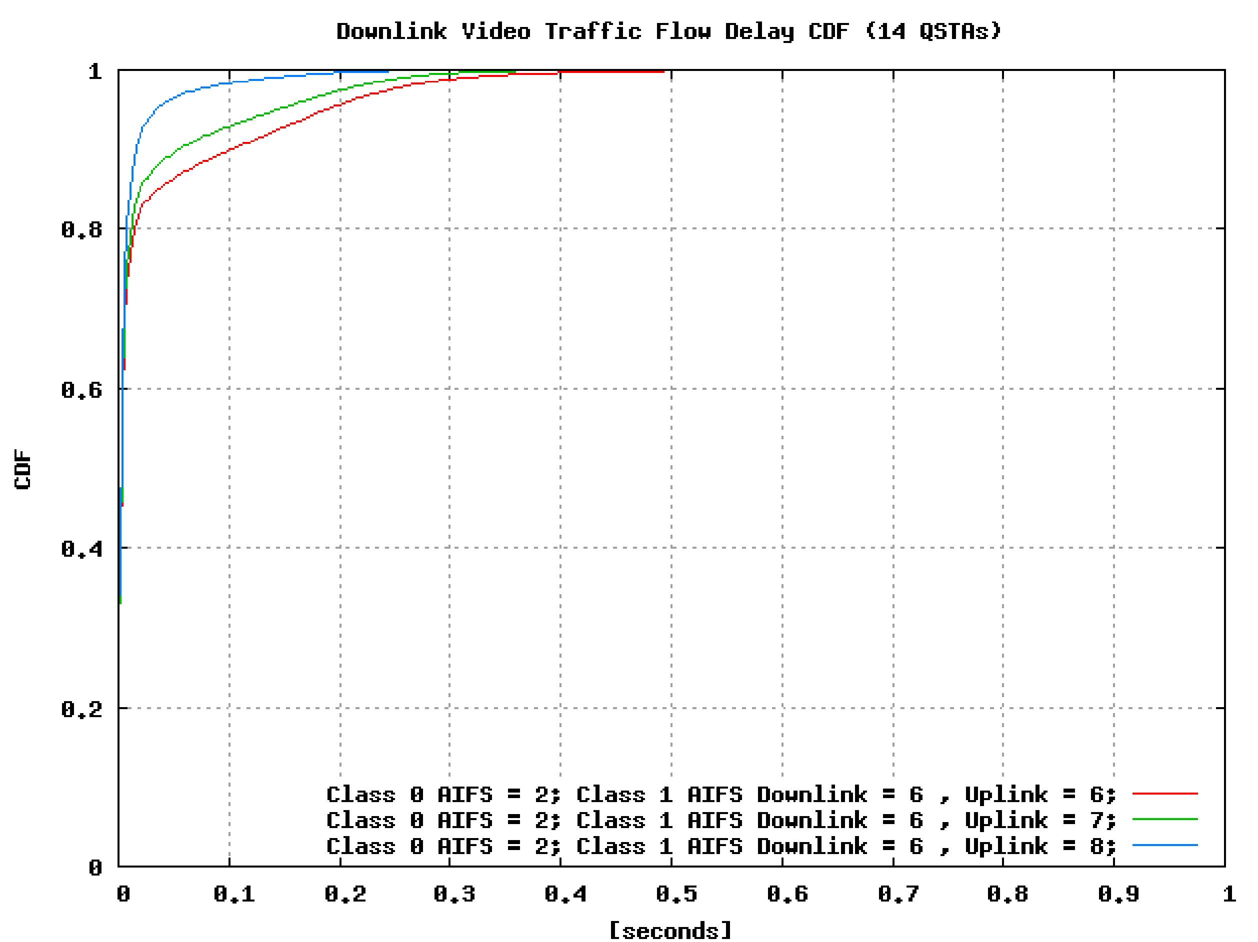


✓There are improvements also on delay, but it's not possible to obtain a fine grained regulation.

Differentiating UL/DL AIFS: CDF Delay for Downlink video Traffic Flow

✓Average delay cumulative distribution function of video downlink flow considerably improves.

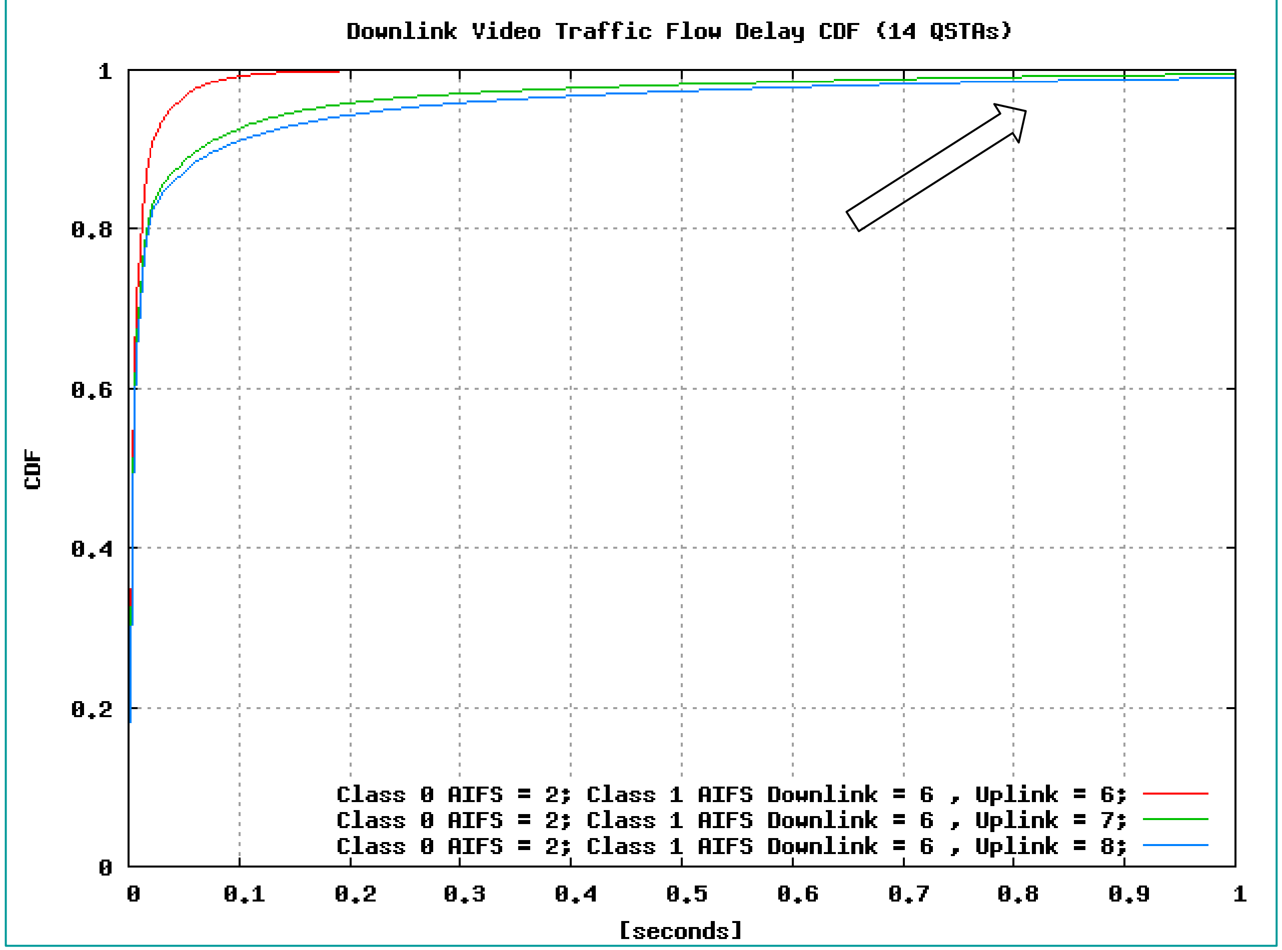
	0,1 sec	0,2 sec
DL = 6, UL = 6	**0.899**	**0.956**
DL = 6, UL = 7	**0.929**	**0.974**
DL = 6, UL = 8	**0.983**	**0.996**



Differentiating UL/DL AIFS: CDF Delay for Uplink video Traffic Flow

✓For Uplink flows, CDF Delay gets worse. Moreover, "the tail" aims to extend excessively.

	0,1 sec	0,2 sec
DL = 6, UL = 6	0.991	0.998
DL = 6, UL = 7	0.926	0.958
DL = 6, UL = 8	0.910	0.943



AIFS Analysis: conclusions

- ✓ To obtain the best performances, it's advisable to choose the minimum Class 1 AIFS value guarantying greater isolation between traffic classes.
- ✓ It's better to not exceed the minimum AIFS value offering the best isolation, since video traffic flows would be excessively damaged.
- ✓ It's possible to use different AIFS values for uplink and downlink flows to share resource more fairly. However improvements are limited and only a summary regulation is applicable.

Contention Window Variation for VoIP Flows

802.11e Mac Layer

Type of Wireless Mac Connection: Infrastructure

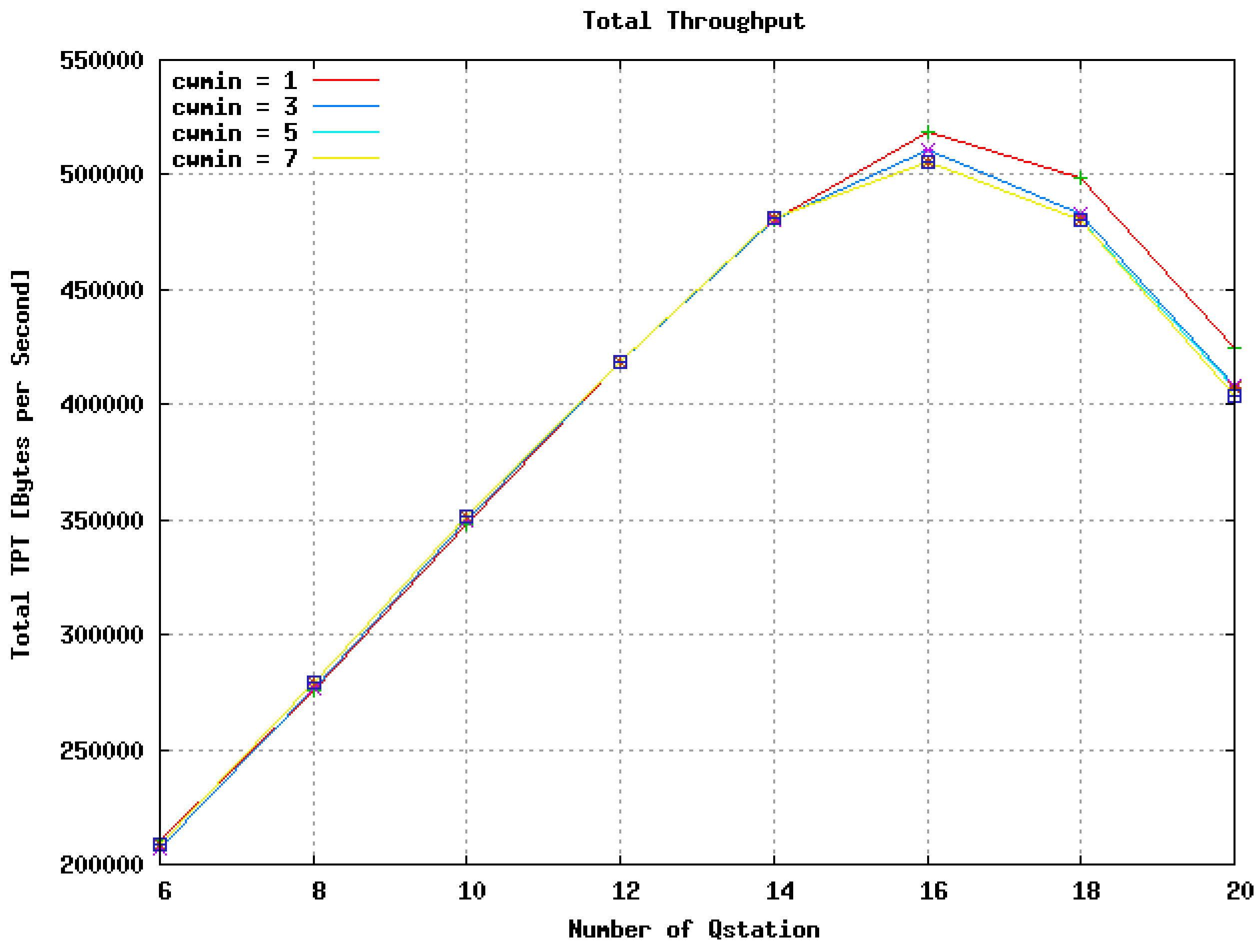
In every simulation an equal number of Up/Downlink VoIP and Video flows were used (ex. 2 QSta = 1 VoIP Up, 1 VoIP Down, 1 Video Up, 1 Video Down)

Video Flows: VBR MPEG4 With Medium Compression

Only CWmin parameter of VoIP flows has been modified

Class 0	(VoIP)
Cwmin	1 – 3 – 5 – 7
CWmax	7
AIFS	2
TXOP	0.003264
Class 1	(Video)
Cwmin	7
CWmax	15
AIFS	4
TXOP	0.006016
Number of QSTAs	6-20

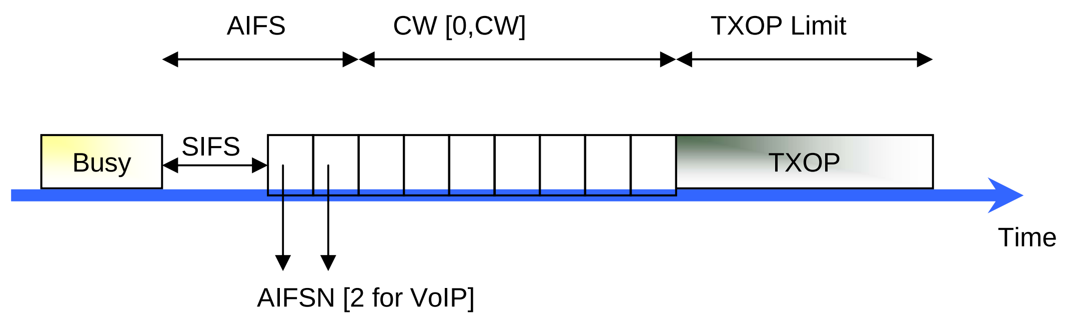
Total Throughput Variation



As expected reducing to ‘1’ CWmin parameter cause an increment of Throughput for 2 reasons

- The [0,CWmin] choosing window is smaller and have less values to choose from
- For reason number 1, VoIP flows are prioritized respect to the video flows and gets much less collisions so they can use a little more bandwidth

Structure of the 802.11e MAC protocol

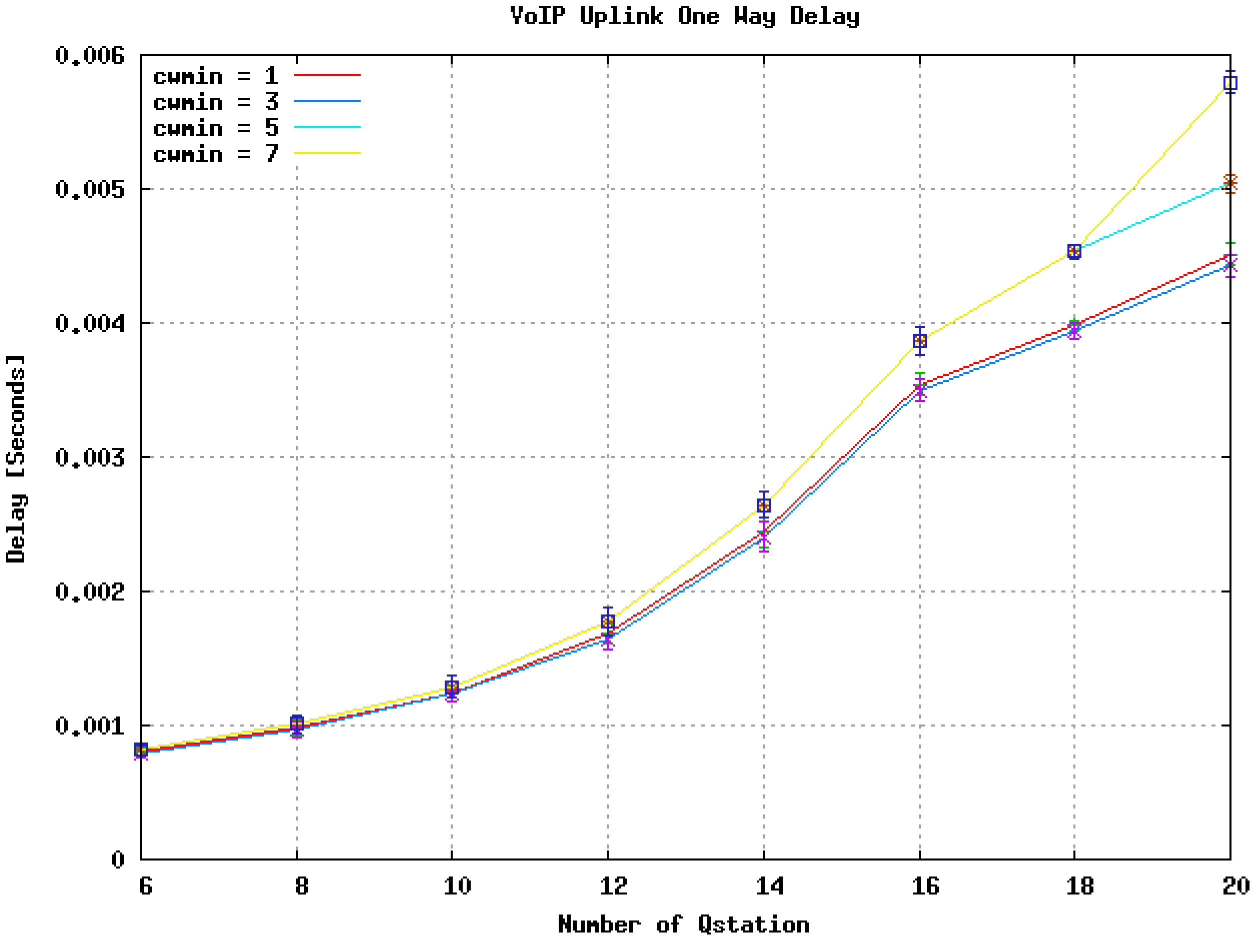


Using a smaller cwmin value for VoIP flows reduces the probability of collision with a video flow on the second try to access the medium

Ex:

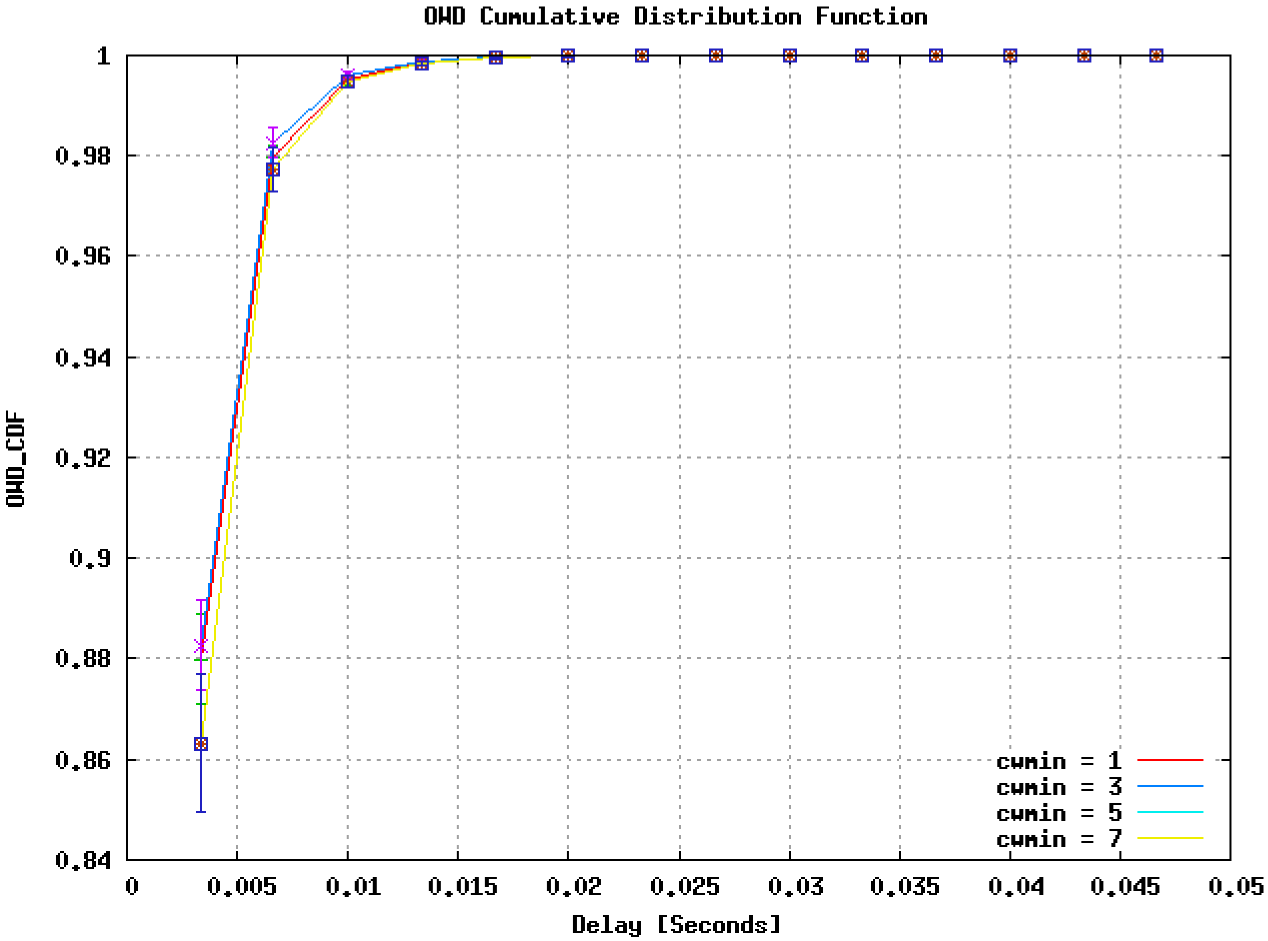
	VoIP	Video
CW First Collision	**0-1**	**0-7**
CW Second Collision	**1-3**	**1-15**

VoIP Uplink Delay



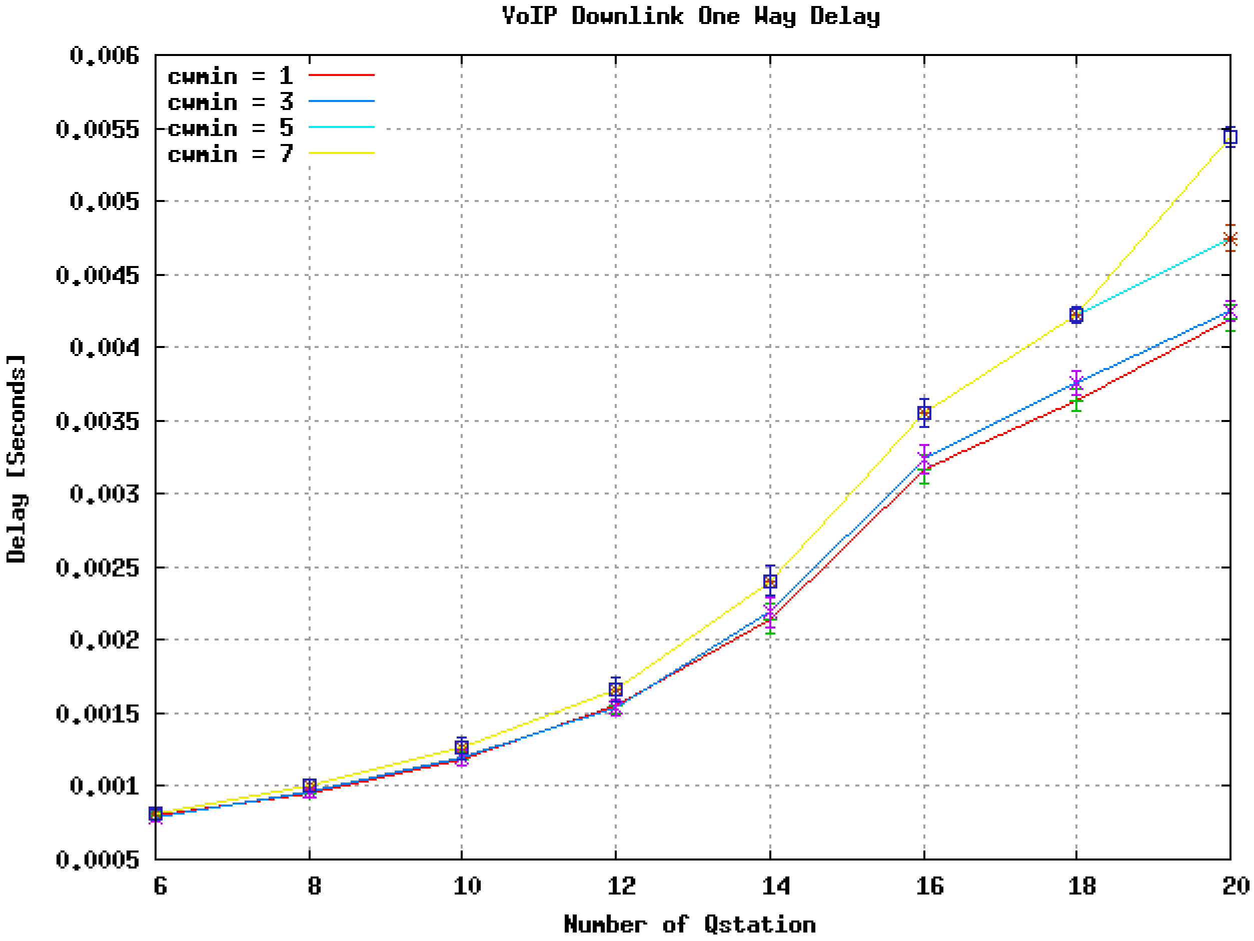
Tendence inversione due to a too much small cwmin with a consequential increase of collision with the other VoIP flows

VoIP Delay Cumulative Distribution Function



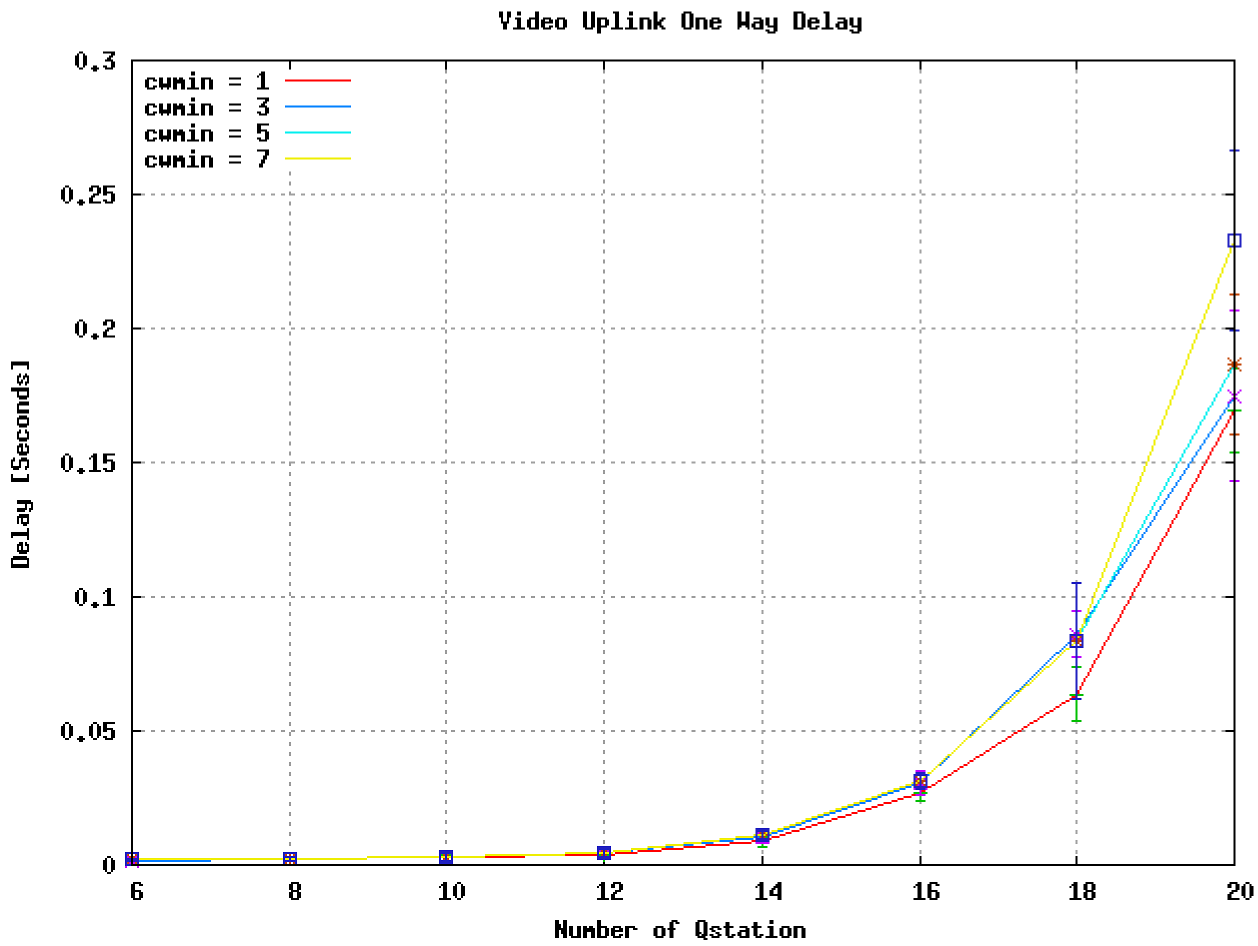
In this graph we can see that the delay is almost the same for every cwmin

VoIP Downlink Delay



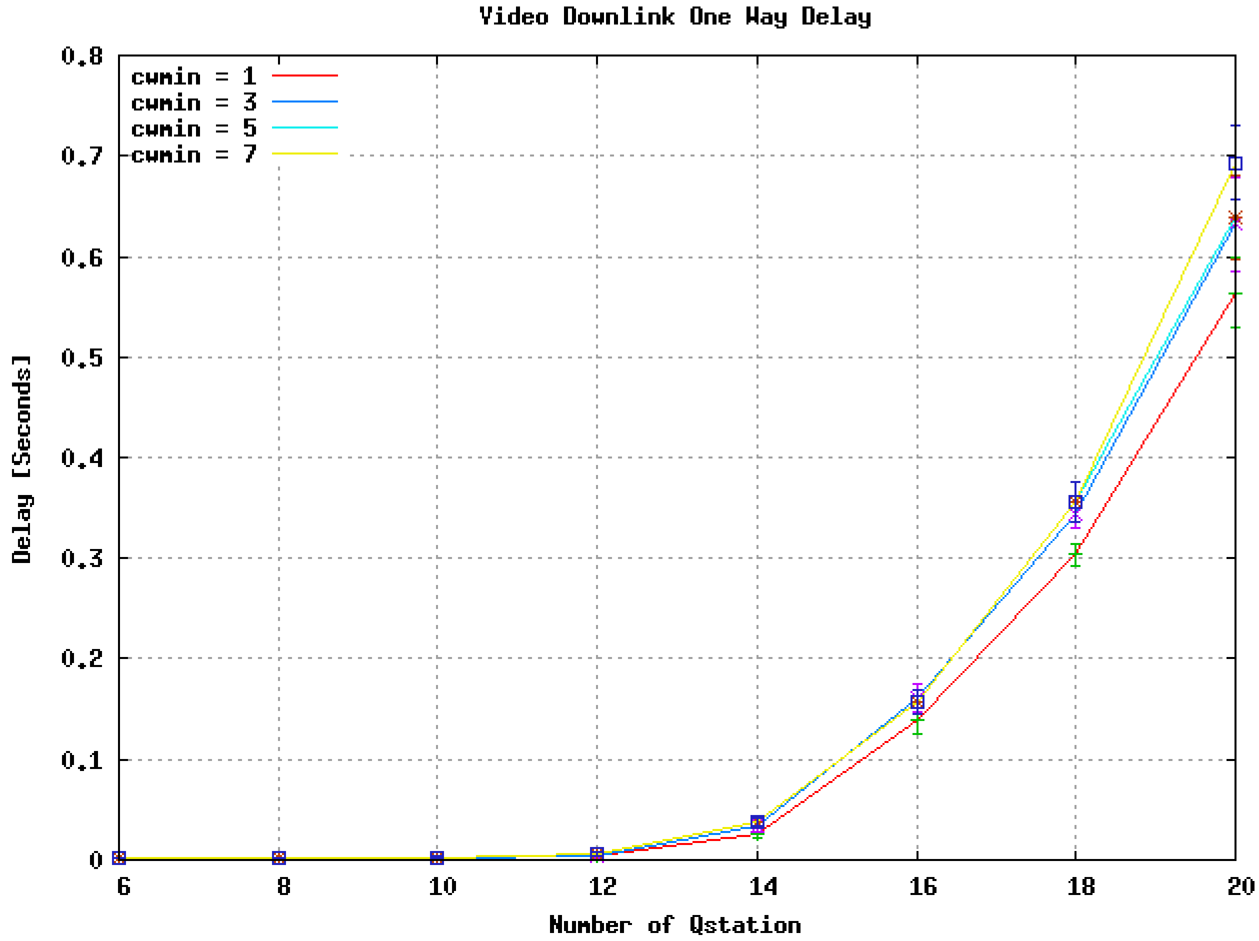
There isn't tendence inversion in downlink case decreasing cwmin

Video Uplink Delay

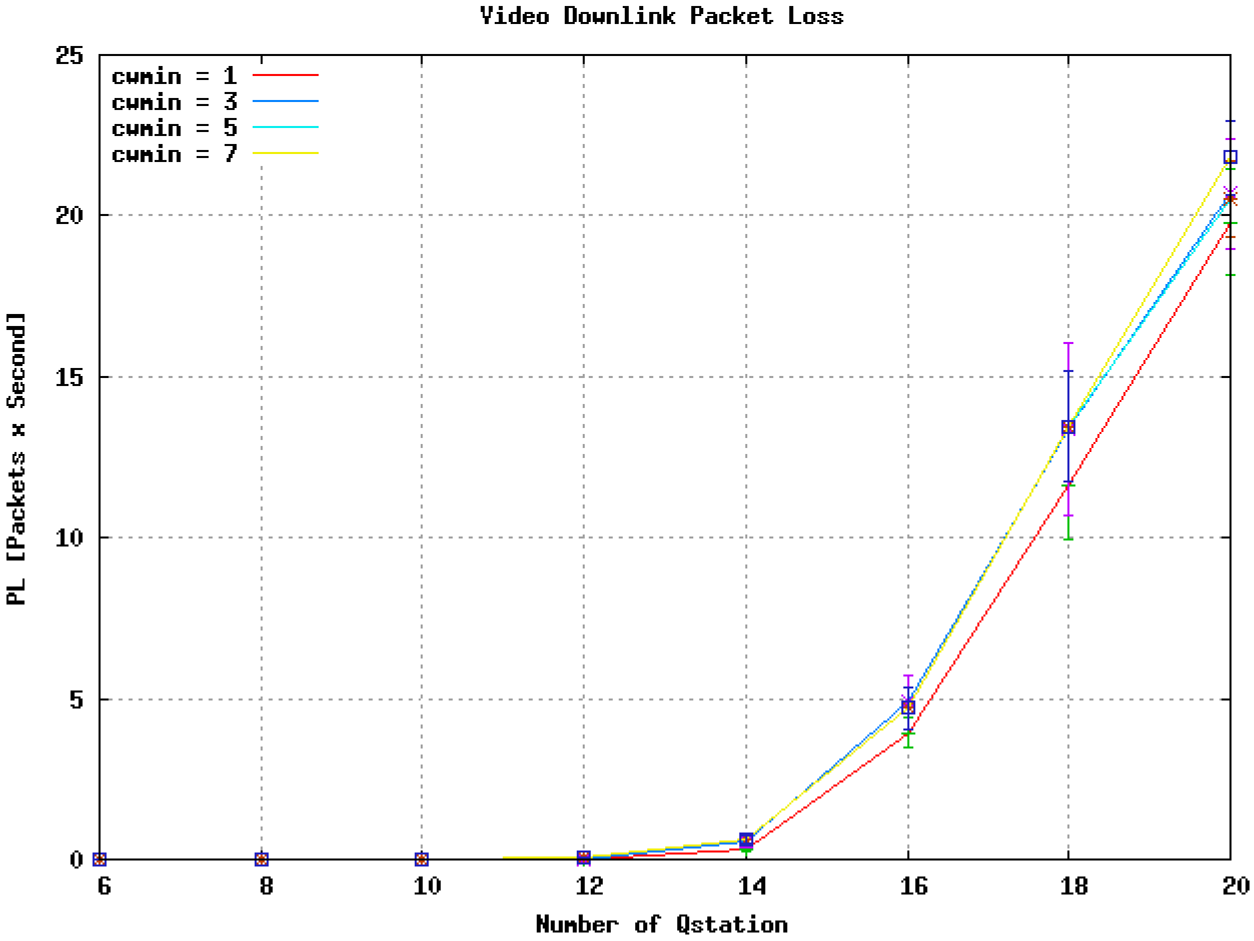


Video flows are almost untouched by the VoIP cwmin variation; such smaller flows (it's about ten times smaller) doesn't affect video flows performances.

Video Downlink Delay



Video Downlink Packet Loss



The same thing happens for packet loss

Conclusions

From this analisys we can see that increasing VoIP cwmin (leaving untouched parameters for video flows) is counterproductive; this can be expected as previously explained, cause increasing VoIP cwmin leaving the same standard cwmin for video flows raises the probability of collisions with Video Flows

Must be remarked that AIFS parameters for Service Class 1 isn’t optimal so Cwmin changes in VoIP Service Class involves a different behavior for Video Flows.

Choosing “7” as AIFS parameter for Video Flows may separate almost completely the two service classes making Cwmin parameter less important for global behavior

TXOP Analysis

802.11e Mac Layer

Type of Wireless Mac Connection: Infrastructure

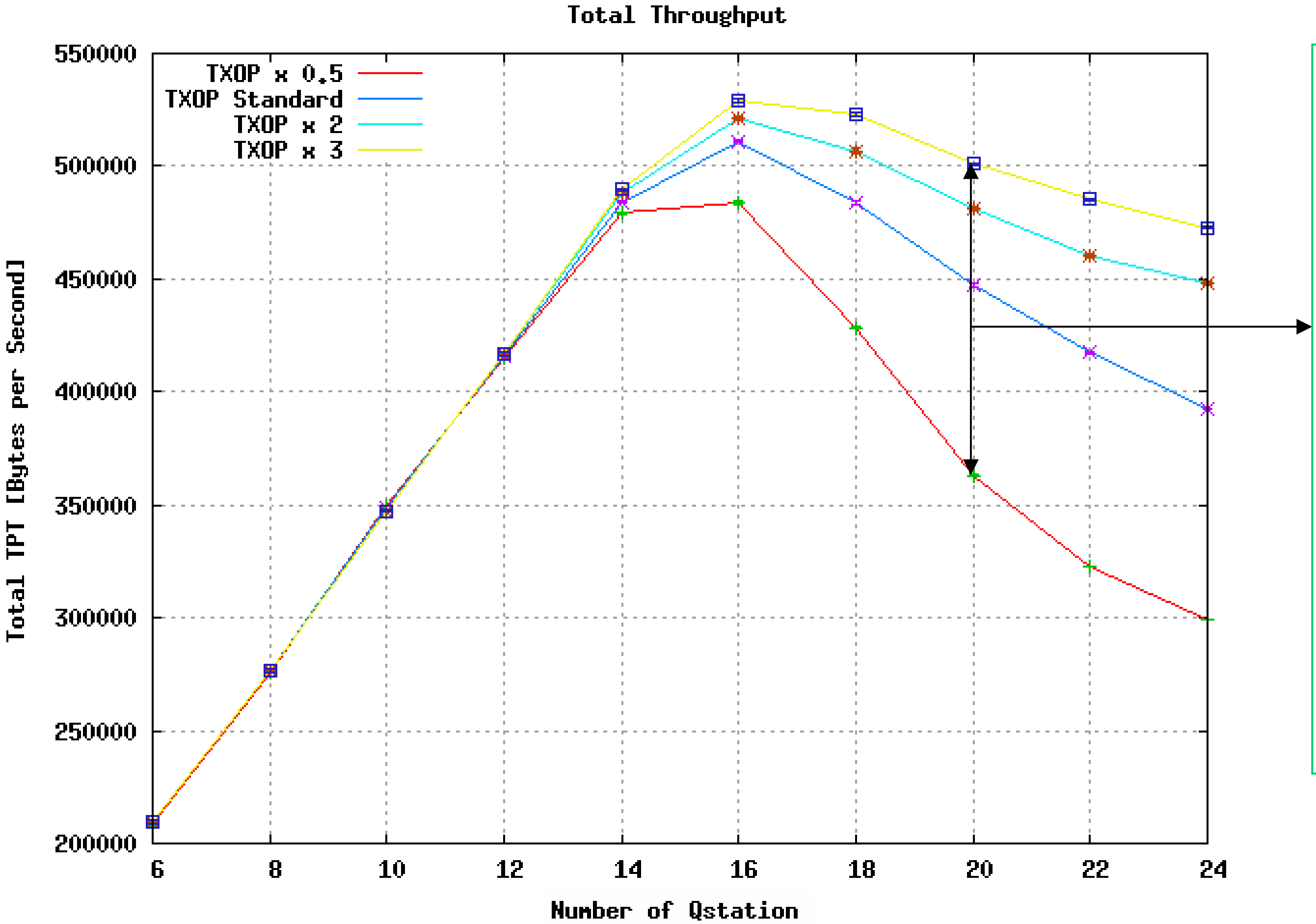
In every simulation an equal number of Up/Downlink VoIP and Video flows were used (ex. 2 QSta = 1 VoIP Up, 1 VoIP Down, 1 Video Up, 1 Video Down)

Video Flows: VBR MPEG4 With Medium Compression

Only TXOP parameter of VoIP flows has been modified

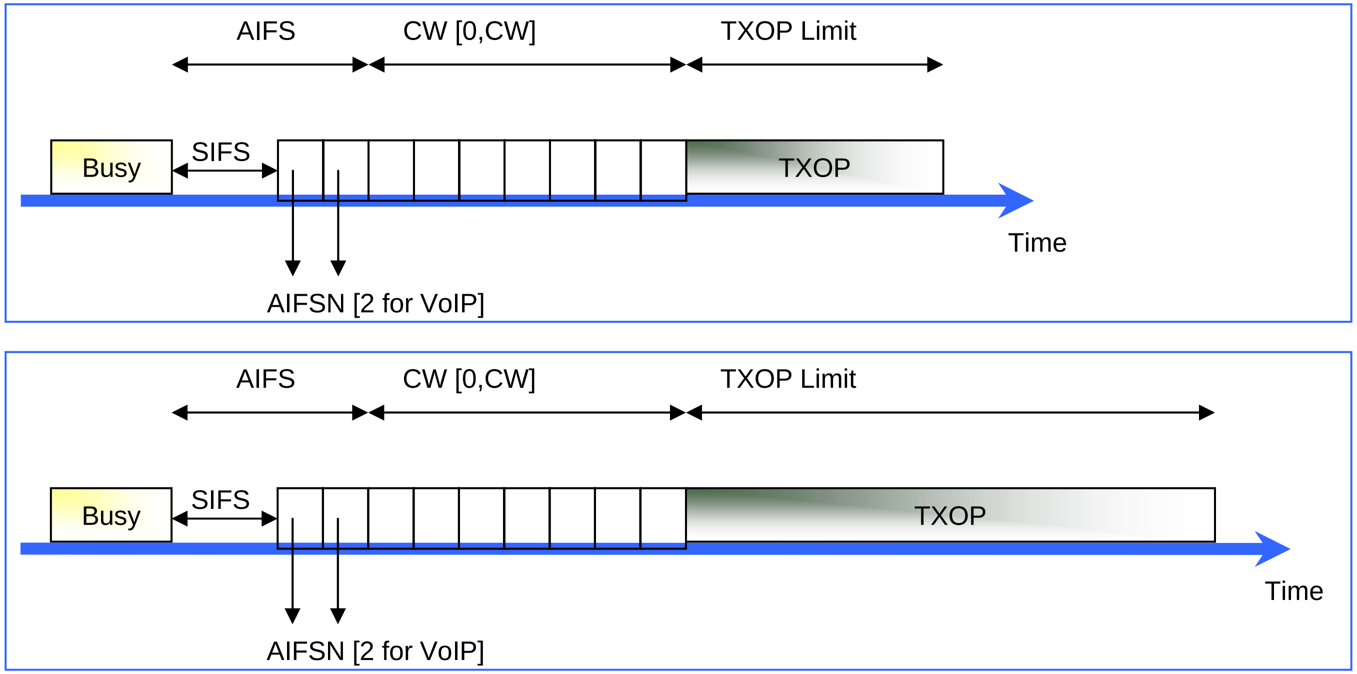
Class 0	(VoIP)
Cwmin	3
Cwmax	7
AIFS	2
TXOP	0.003264 (x0.5 – x1 – x2 – x3)
Class 1	(Video)
Cwmin	7
Cwmax	15
AIFS	4
TXOP	0.006016
Number of QSTAs	6-20

Total Throughput 1/2



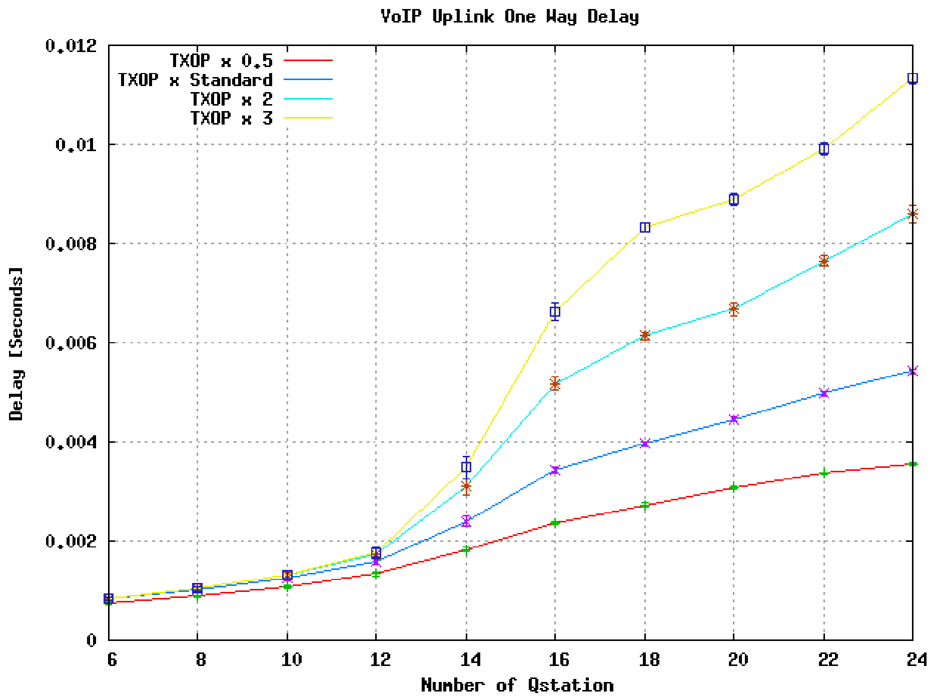
- Throughput is decreasing because using a smaller TXOP value video flows can send less packets in a single burst
- Another cause is the increasing number of collisions caused by the greater number of tries made to access the shared media

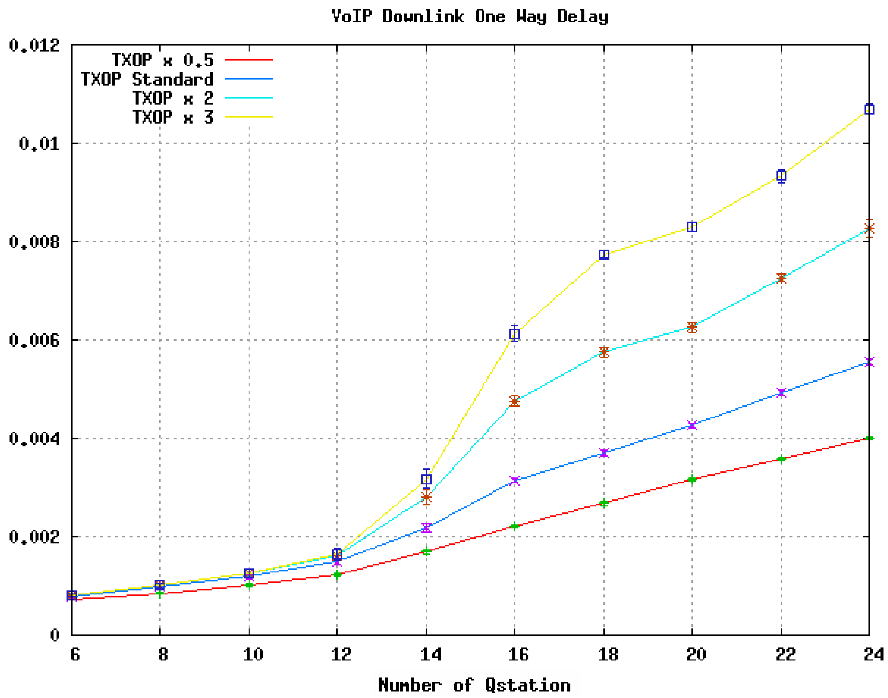
Total Throughput 2/2



Increasing TXOP makes video flows use too much transmission time respect to VoIP flows

VoIP Up/Downlink Delay

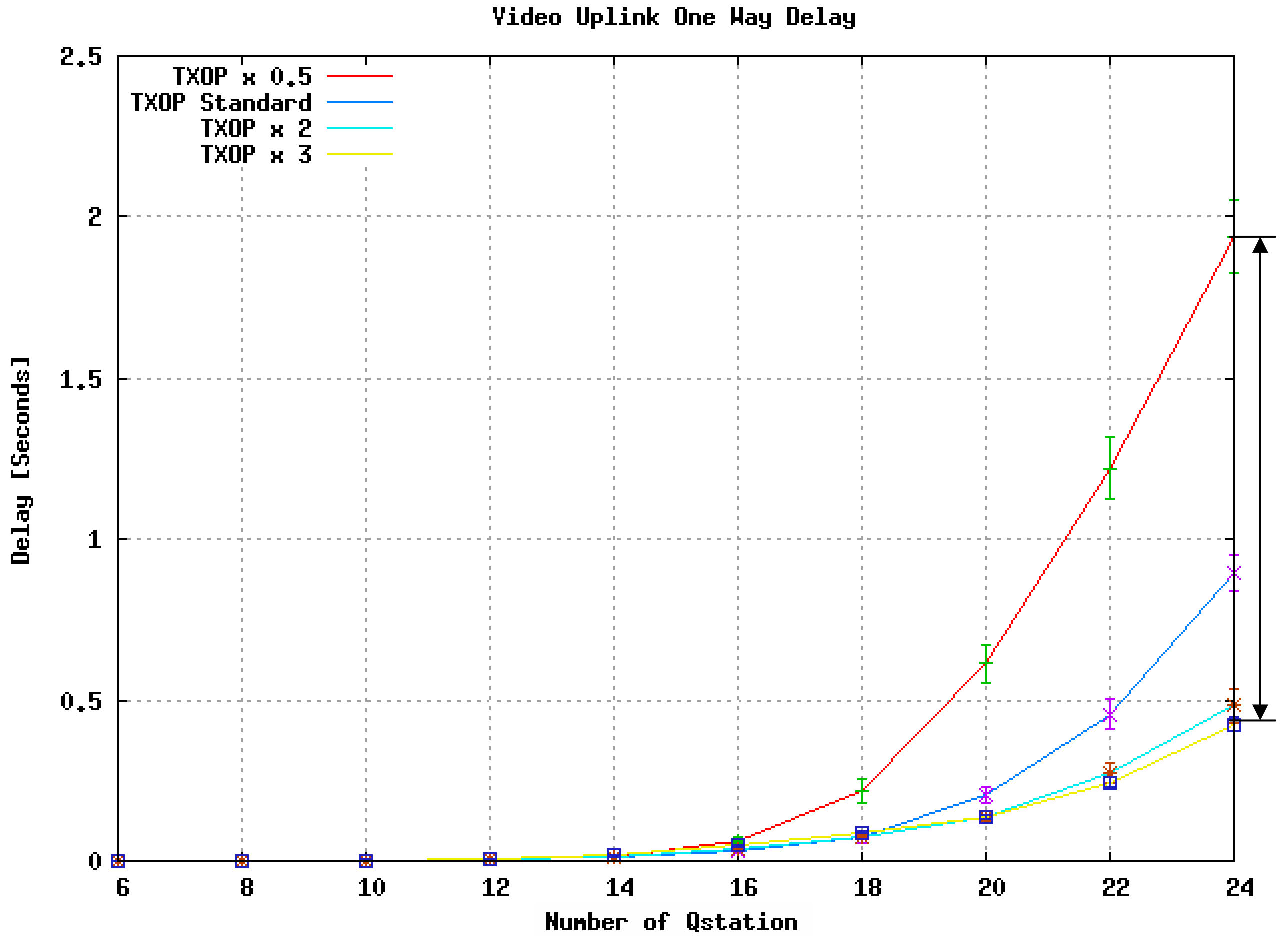




On the other hand of the increasing throughput we can observe a decrease of delay performances for the VoIP flows

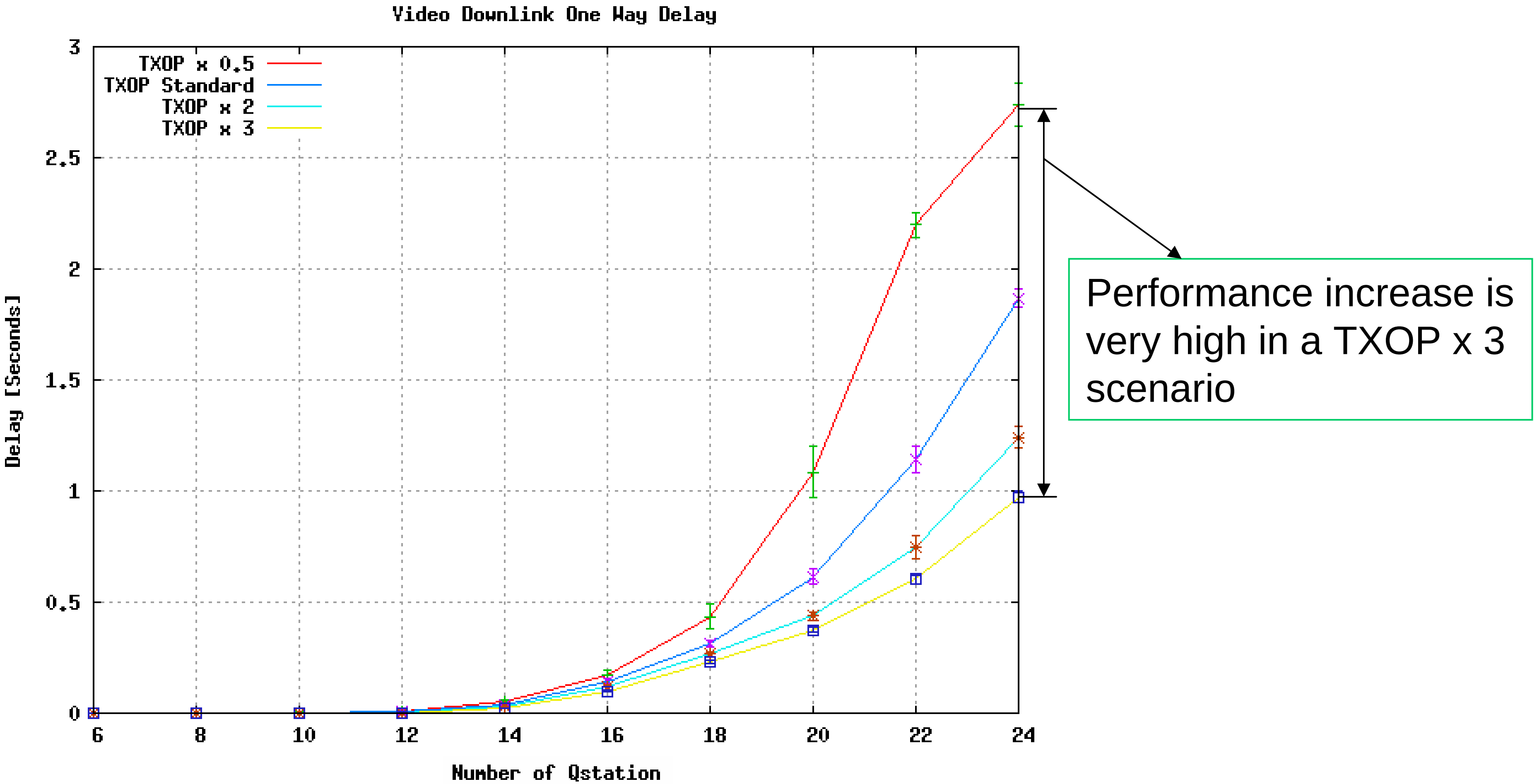
This trend is caused by video flows gettings an higher use of the available bandwidth respect to VoIP flows

Video Uplink delay

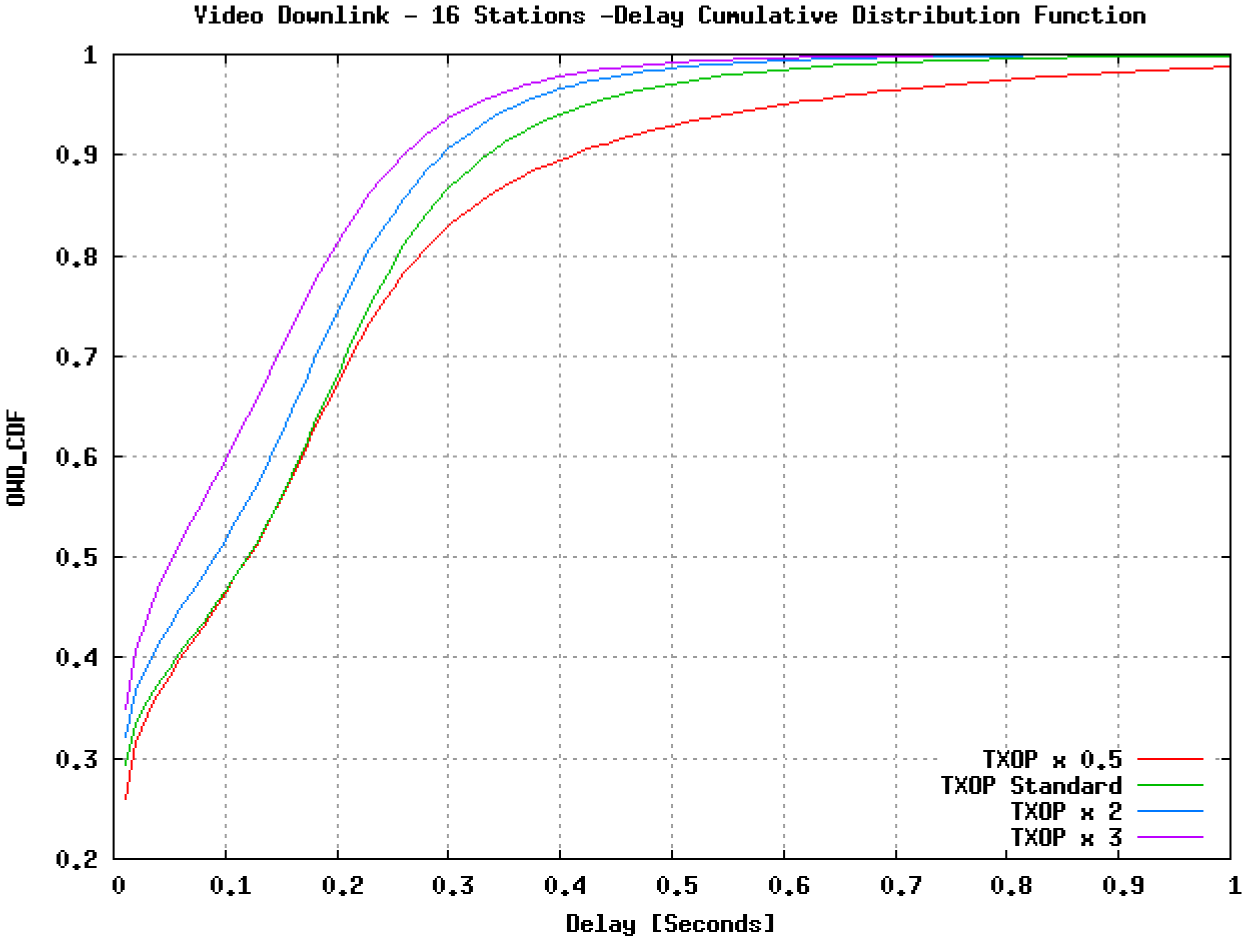


In opposition, delay performances of Video flows are much more better in the increased TXOP scenario

Video Downlink delay

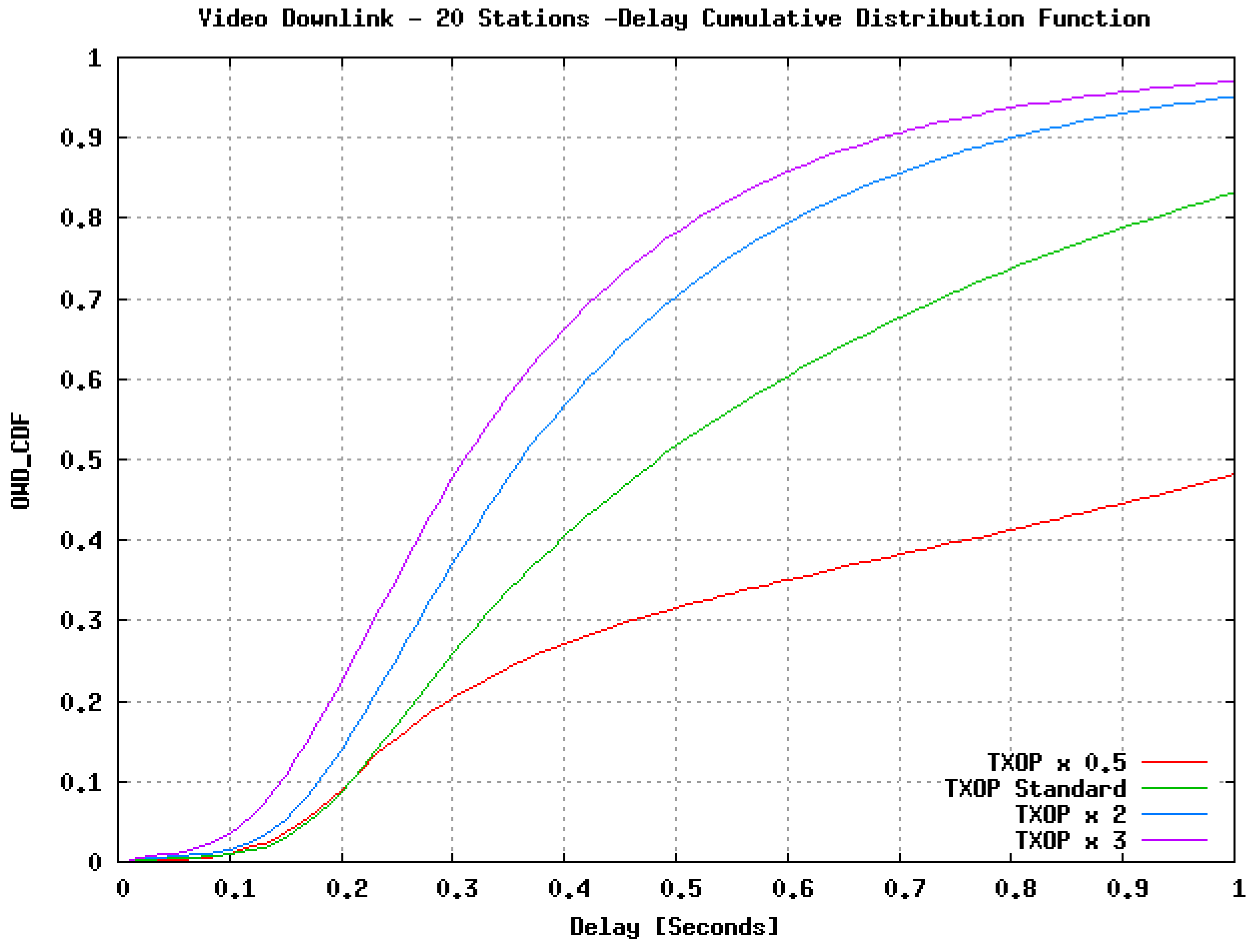


Delay Distribution Function – 16 QStations



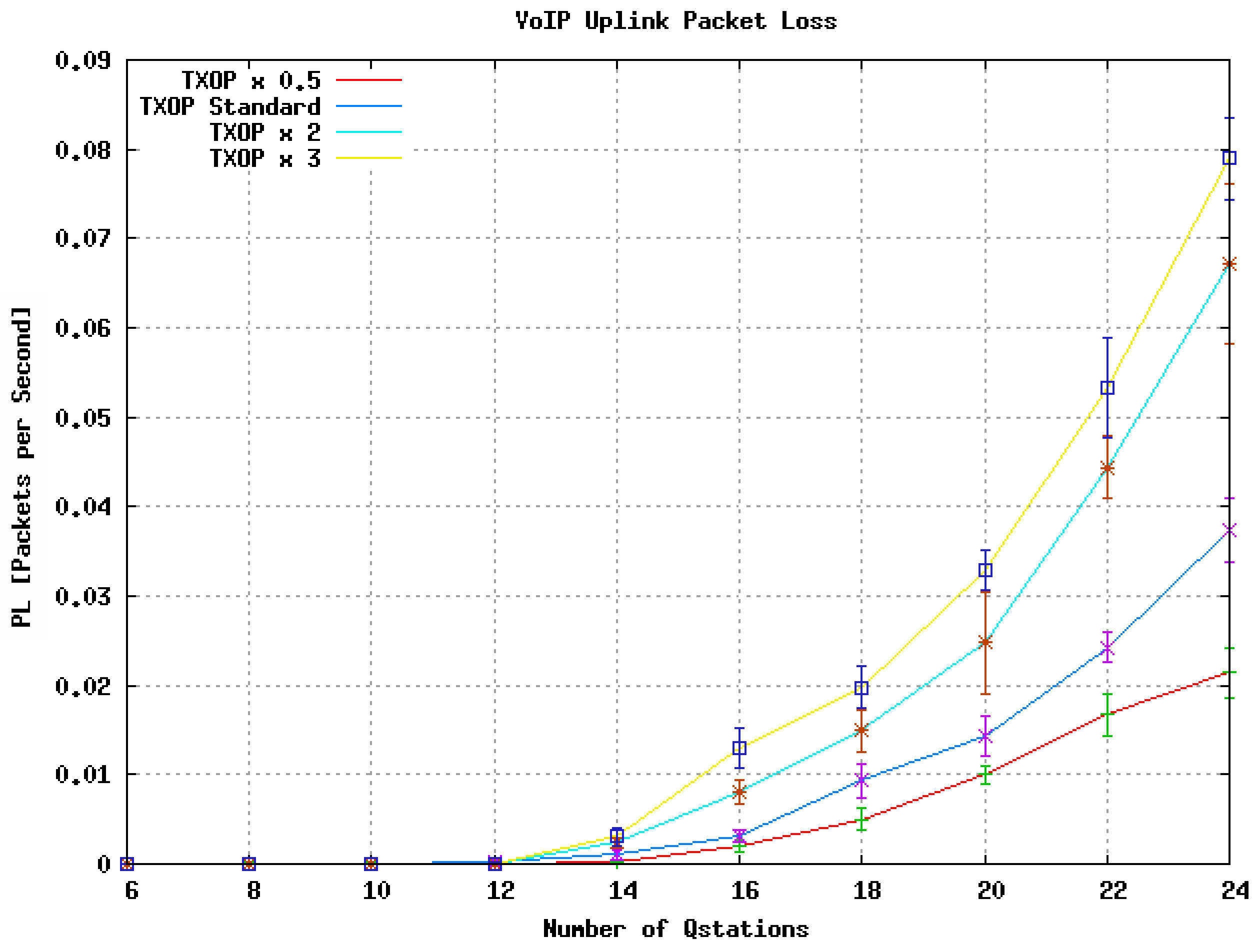
Flows's behavior is almost the same

Delay Distribution Function – 20 QStations



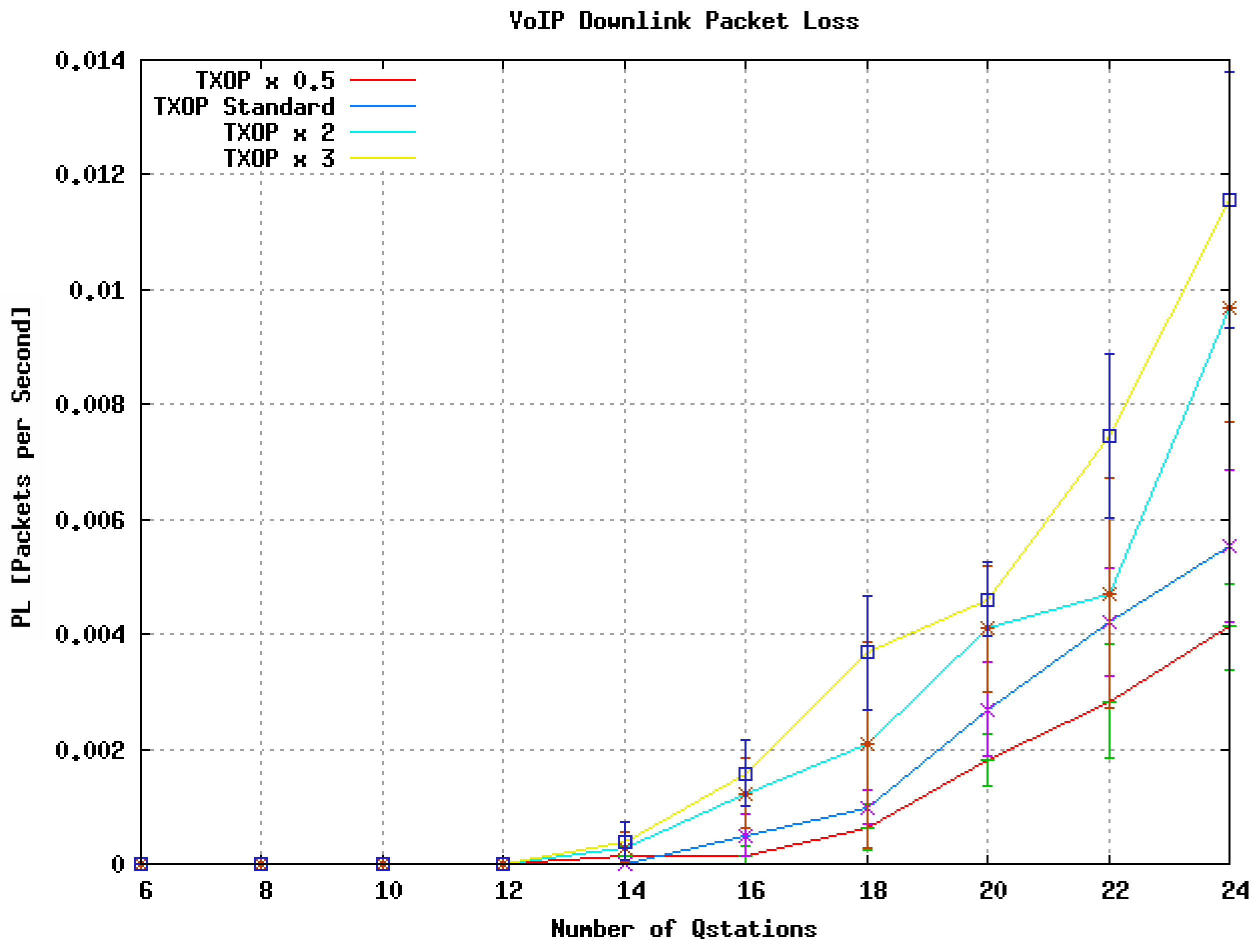
Even in an highly congested network a simulation scenario with TXOP (x 2) or (x 3) parameter is able to keep a stable delay longer than standard TXOP

VoIP Uplink Packet Loss



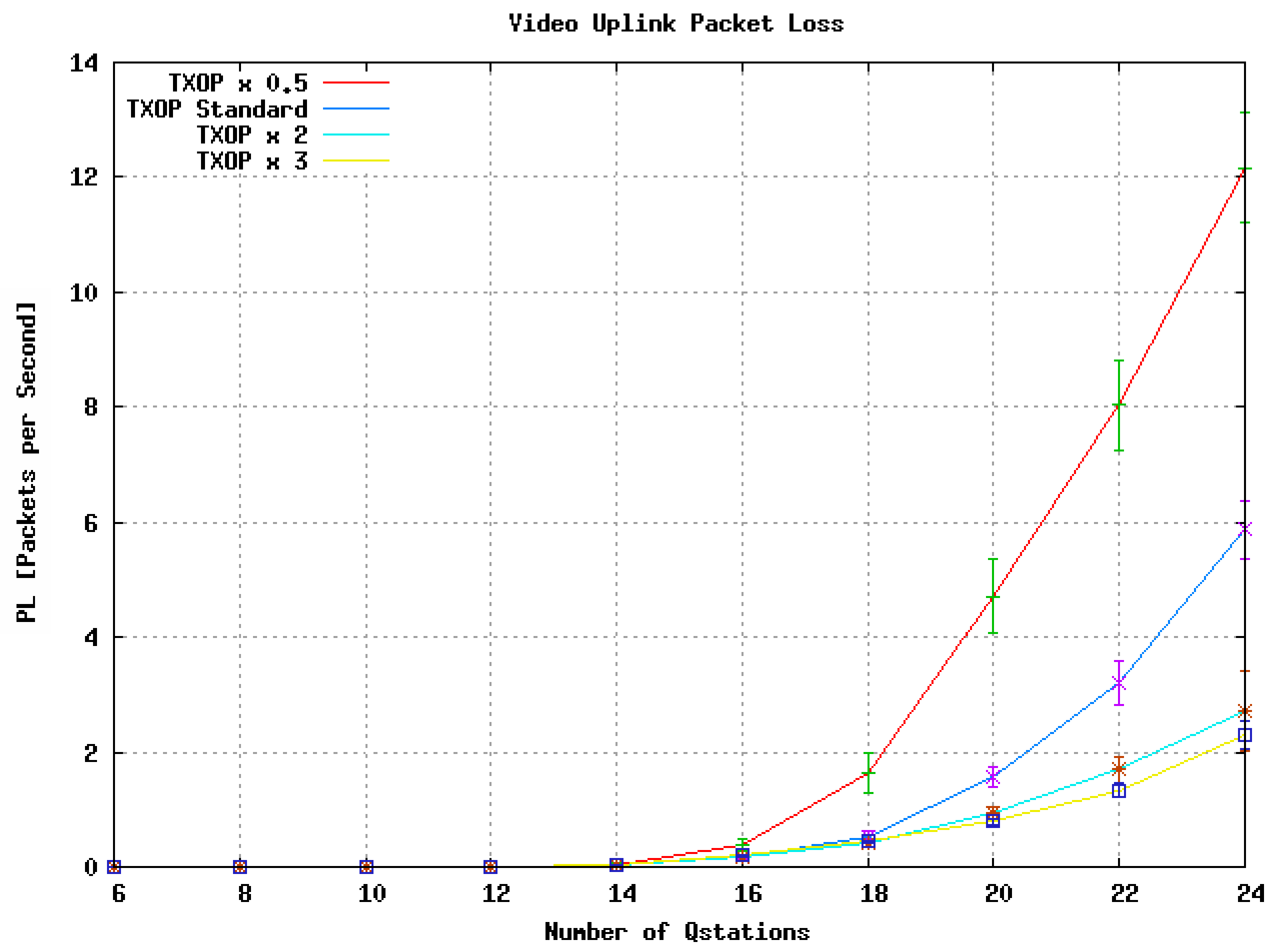
Packet Loss growth isn't so significant, from 0.02 packets per second to 0.08 (about 0.1% to 0.4% of packets per second loss)

VoIP Downlink Packet Loss



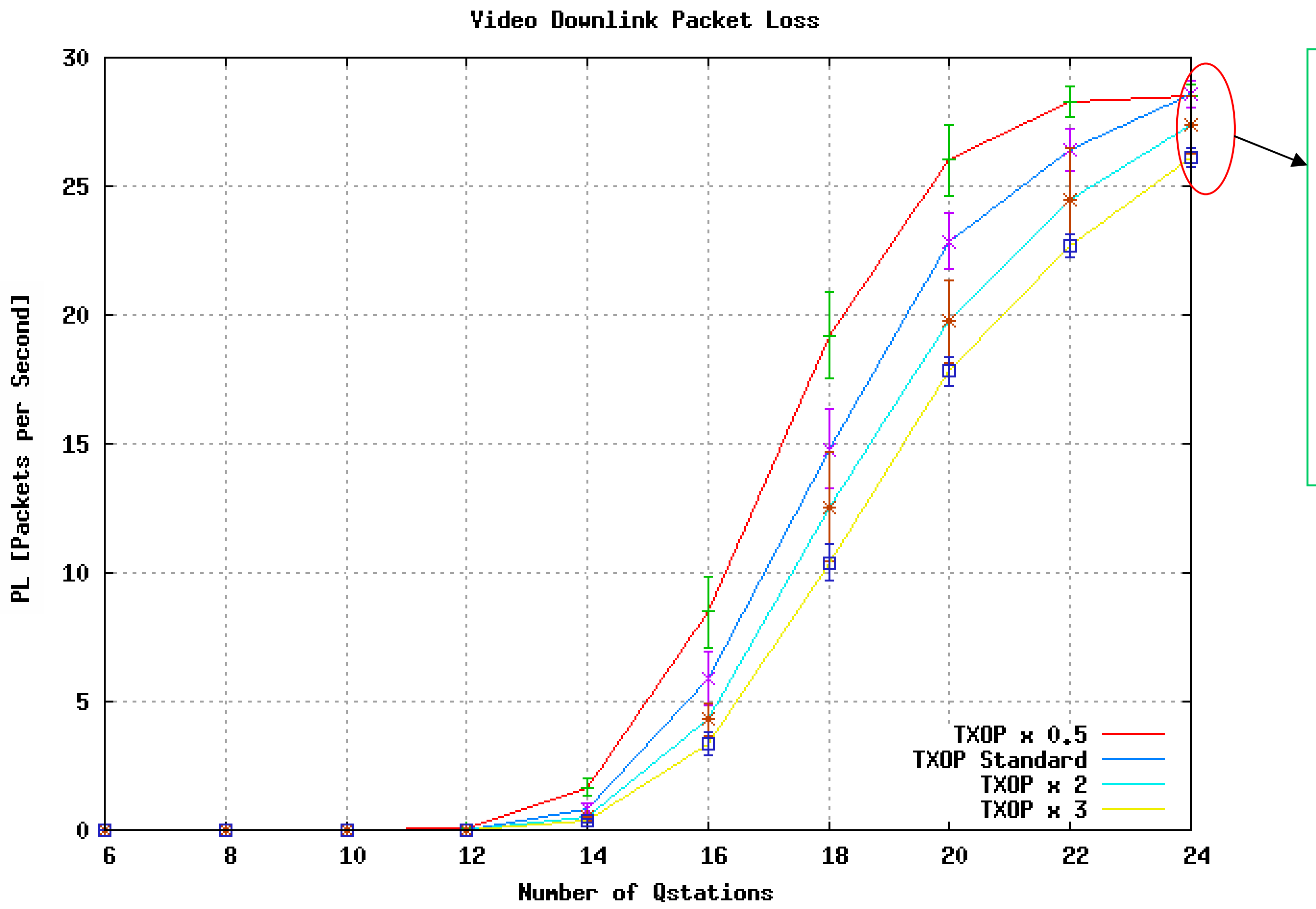
The same remarks are valid for Packet Loss

Video Uplink Packet Loss



As delay, Packet Loss for uplink flows is consistently reduced even in an highly congested system (from 42.8% to 7.1% decrease)

Video Downlink Packet Loss



Remember that the Video Flows we use sends about 28 packet per second.

This behavior is almost caused by the small queue on the QAP

Conclusions

We can say that increasing TXOP can largely optimize bandwidth utilization for flows with larger packet, but decrease performance of other flows, such as VoIP flows, even if they've got an higher priority.

The choose can only be made with a trade-off of performance between types of flows used in the considered network

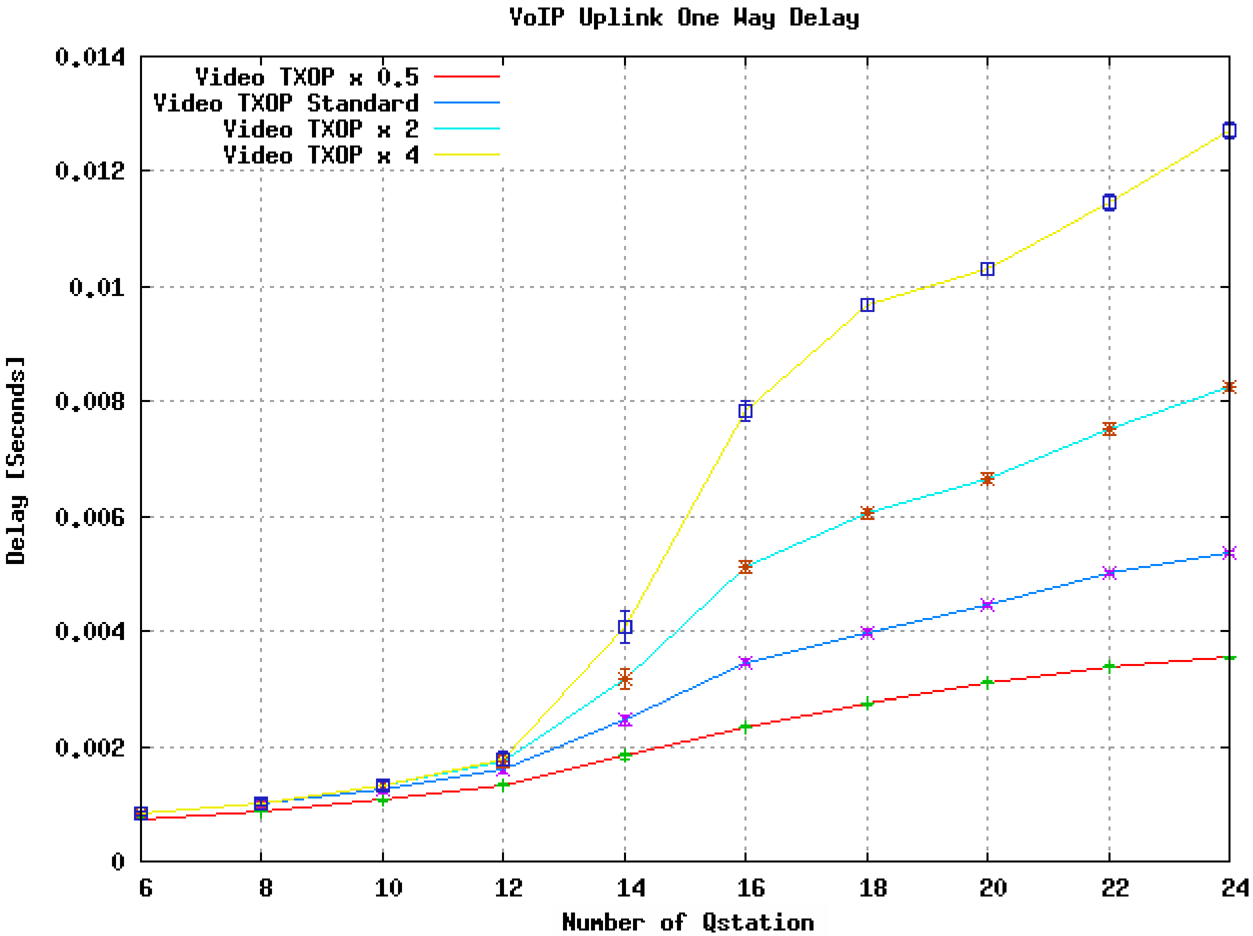
Further analisys shows that increasing too much TXOP values makes the network almost unusable by small packets flows and tends to decrease the general performances of the entire network

Scenario with VoIP TXOP Disabled

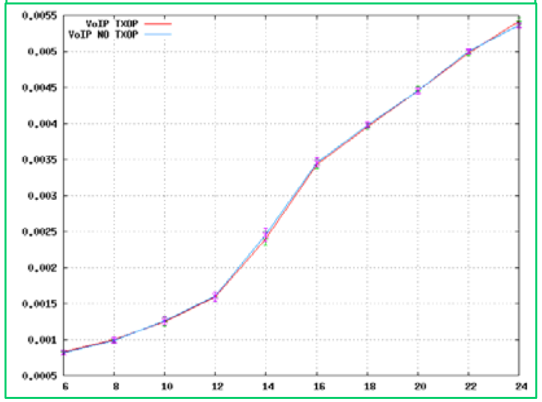
Doing this, VoIP flows can send only one packet for every contention won

Class 0	(VoIP)
Cwmin	3
Cwmax	7
AIFS	2
TXOP	0
Class 1	(Video)
Cwmin	7
Cwmax	15
AIFS	4
TXOP	0.006016
Number of QSTAs	6-20

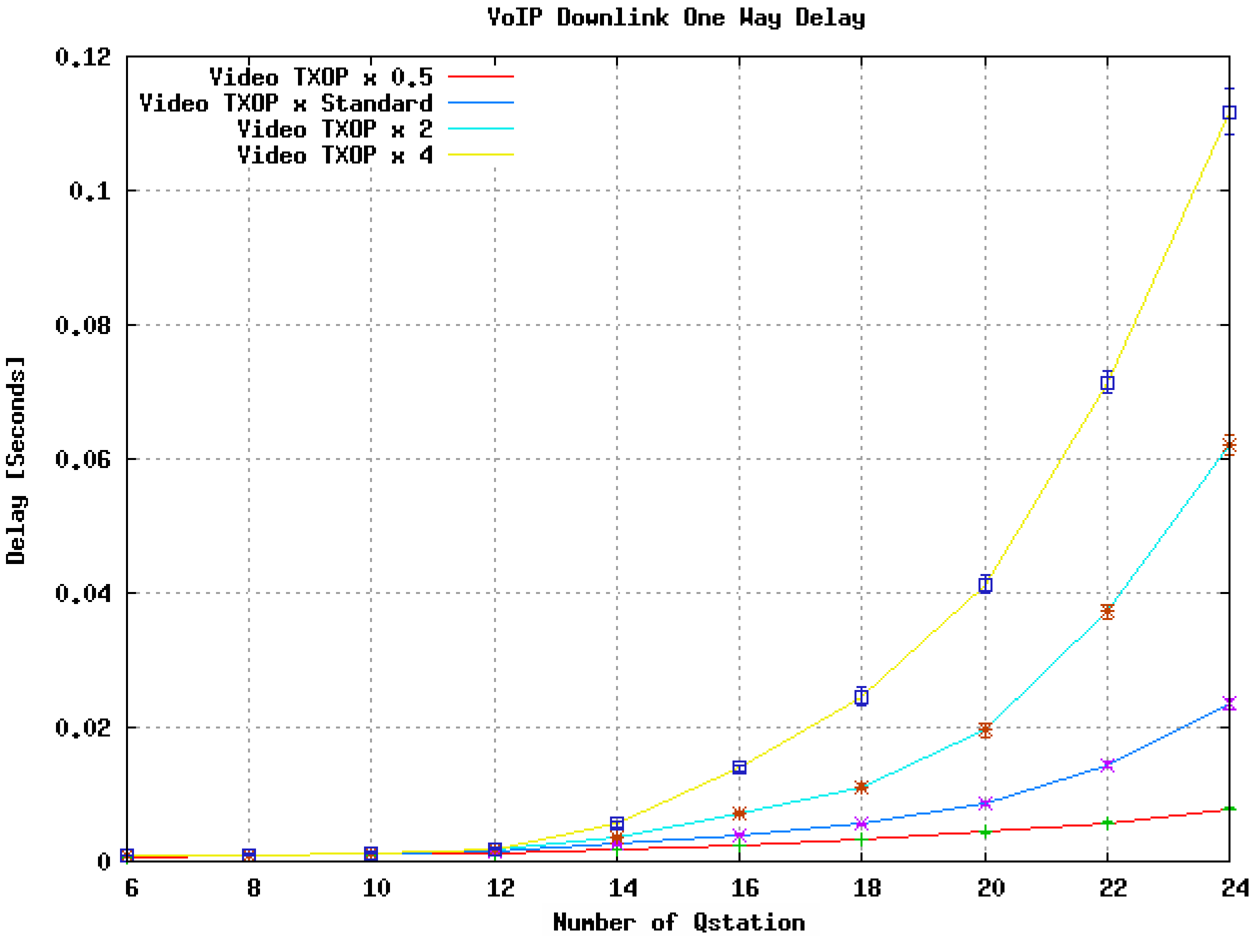
VoIP Uplink Delay



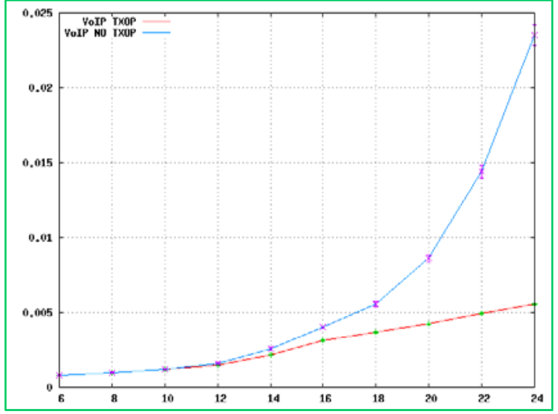
Uplink case is similar to the VoIP with Enabled TXOP; this is explainable because the uplink station has only one type of flow to send and so is able to keep the TXOP lack as ininfluent



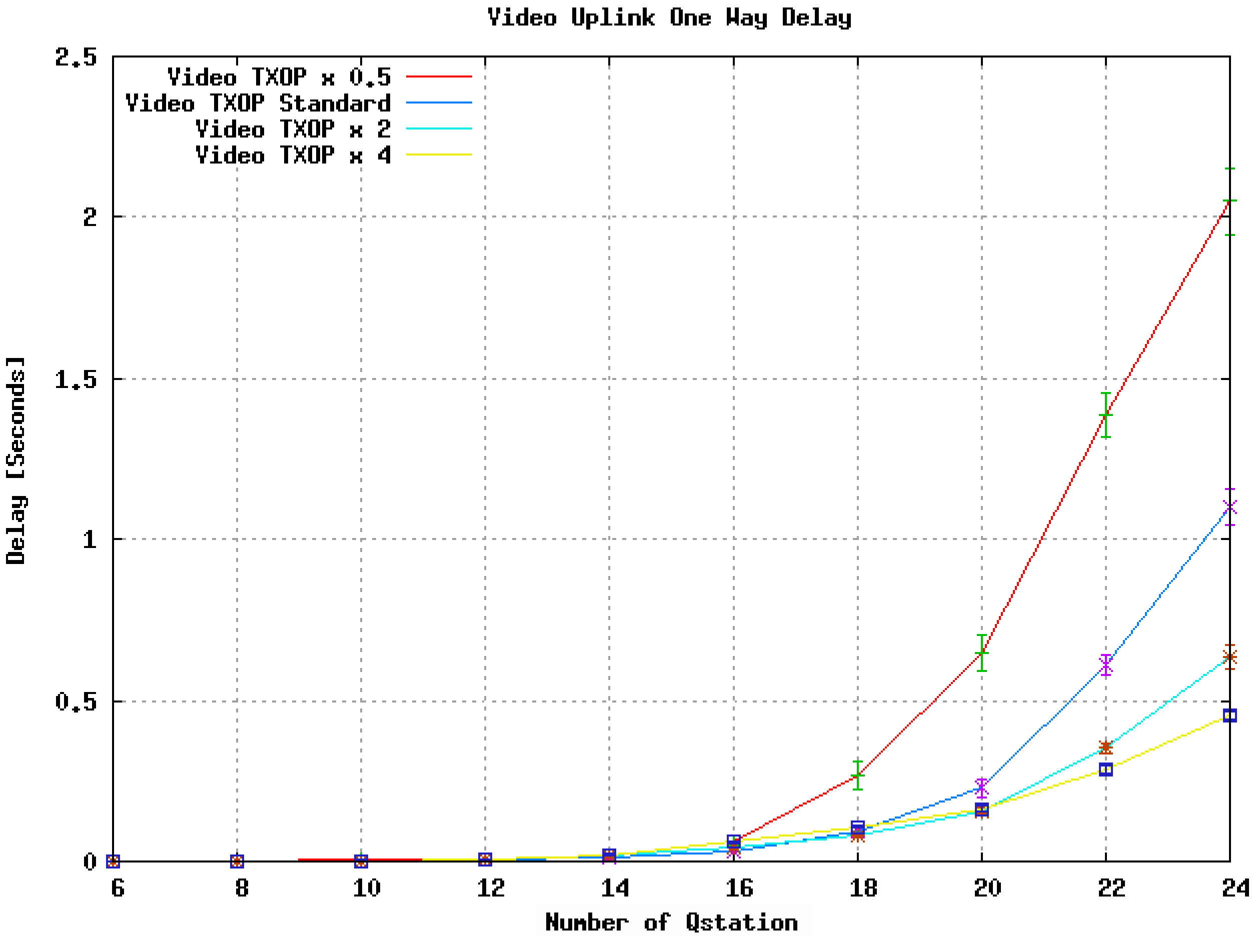
VoIP Downlink Delay



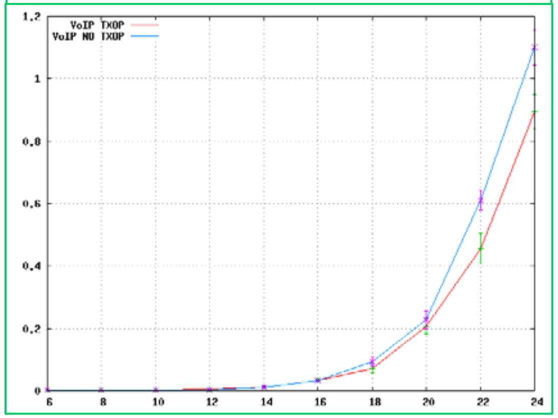
As video TXOP increase, different from previous scenario, VoIP flows increase exponentially their e2e delay instead of linearly



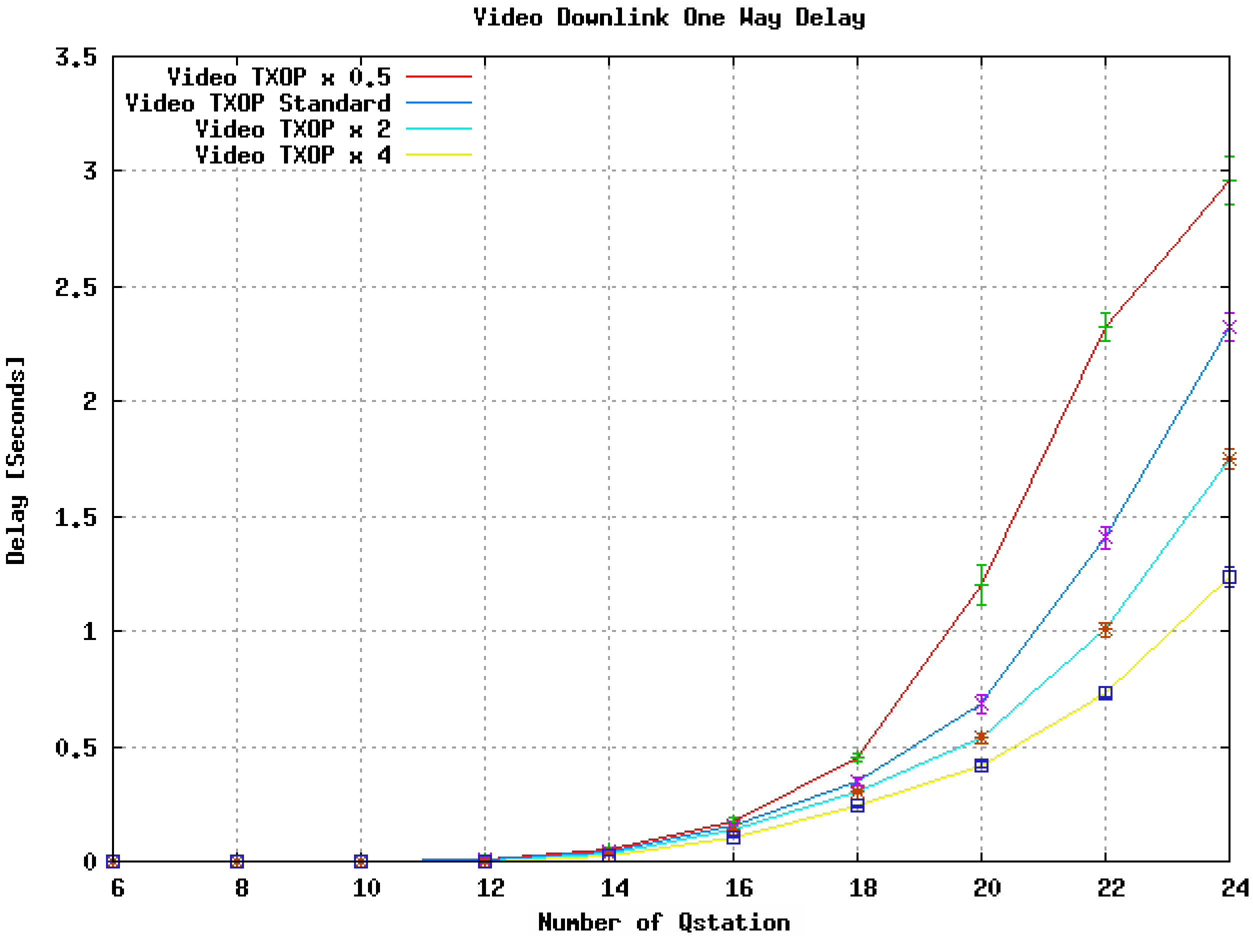
Video Uplink Delay



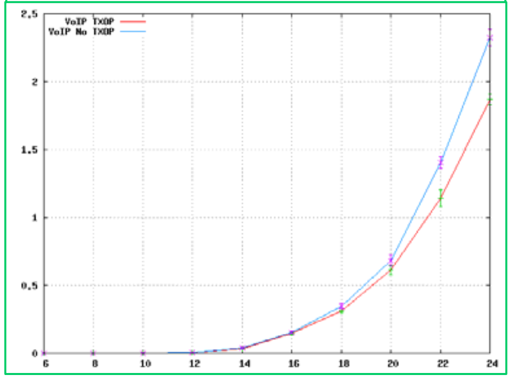
As previous, video flows advantage theirselves respect to VoIP flows as in uplink…



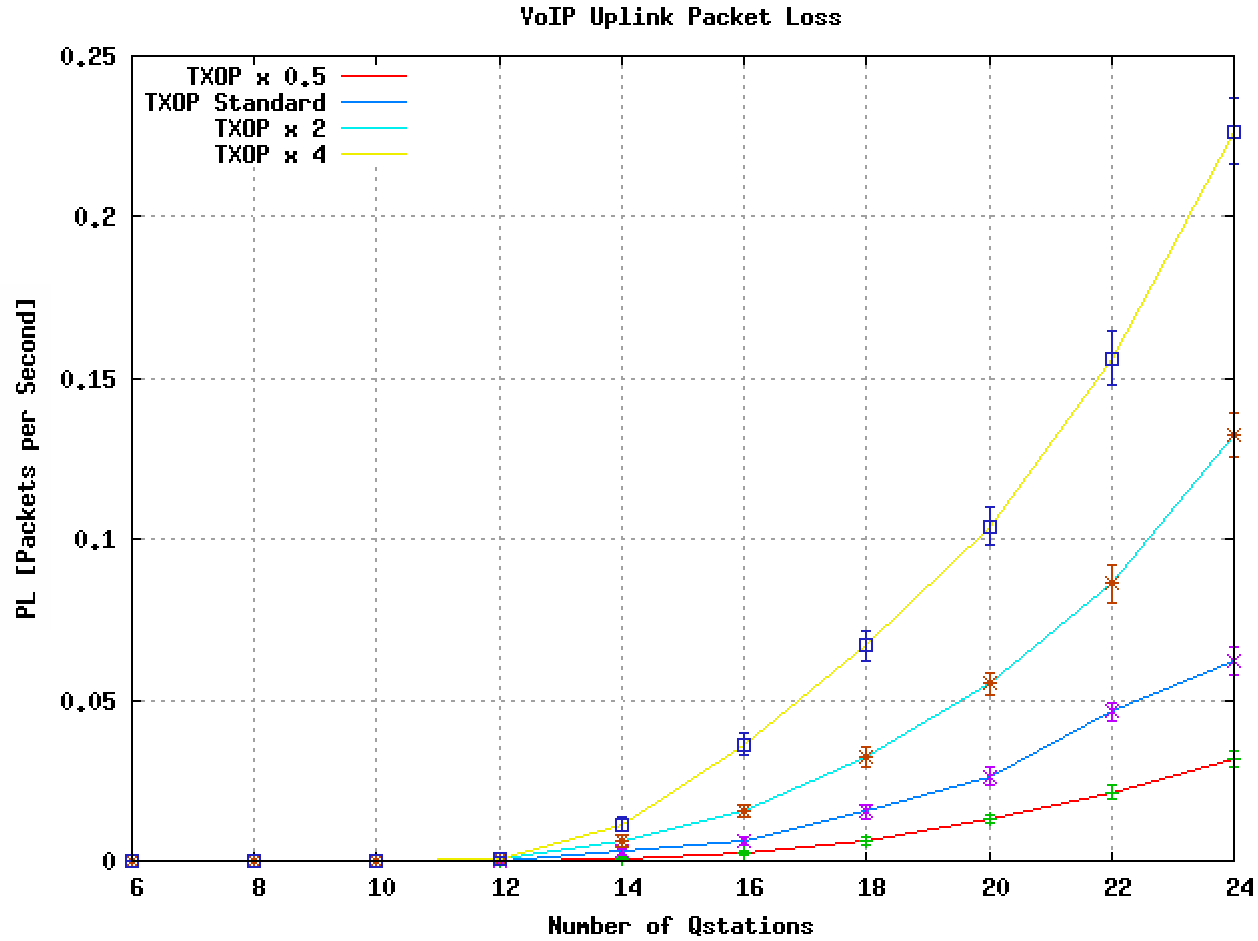
Video Downlink Delay



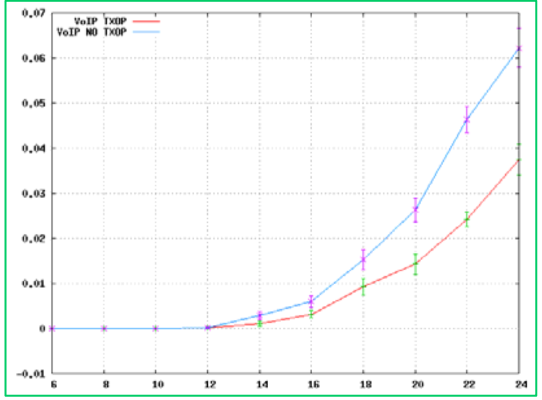
…as in downlink case



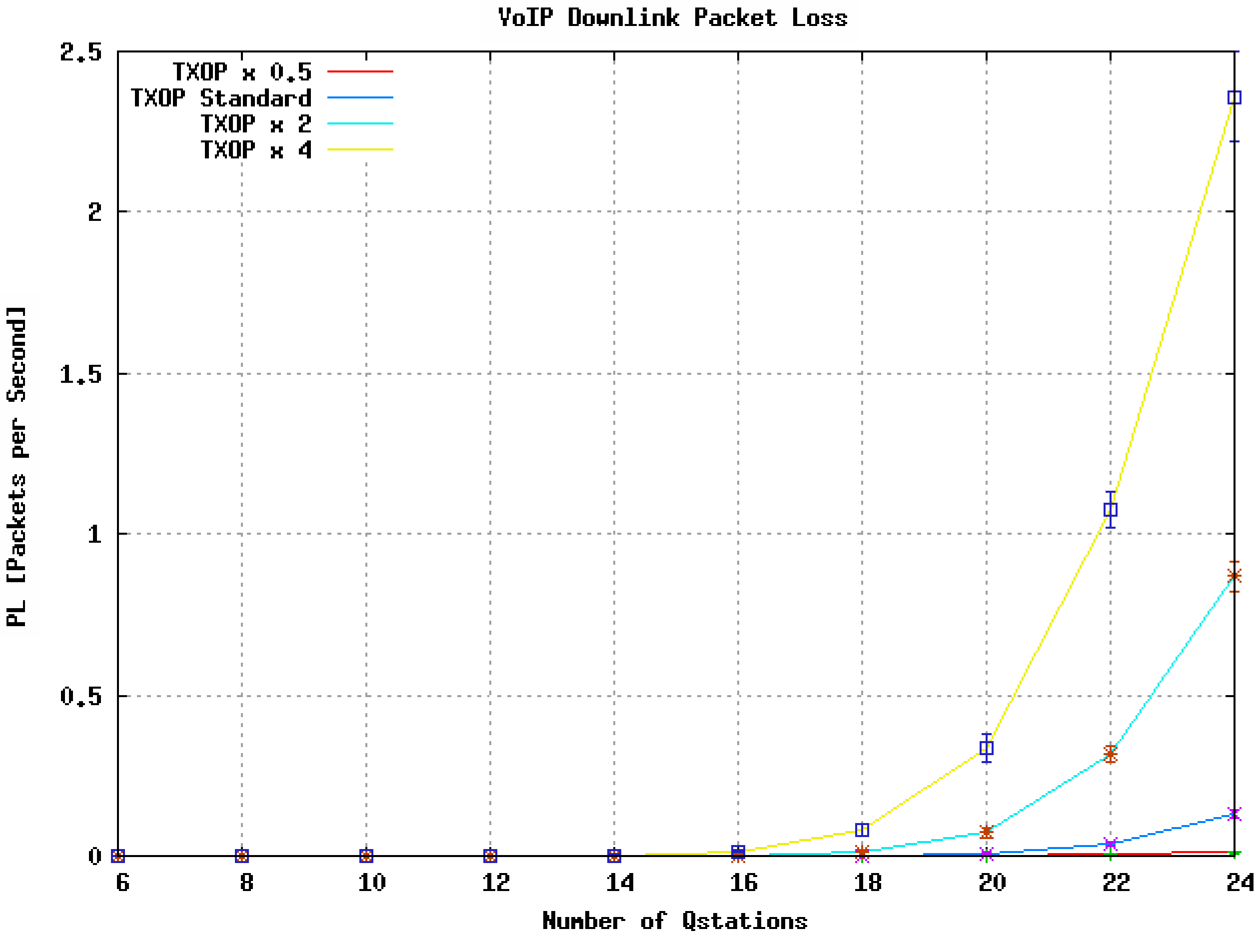
VoIP Uplink Packet Loss



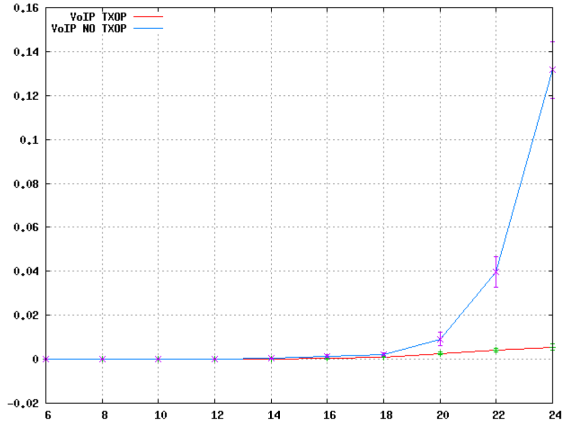
Keepin in mind results obtained in previous scenario, is obvious that, as Video TXOP increase, as whole VoIP performance, also in terms of packet loss, decrease



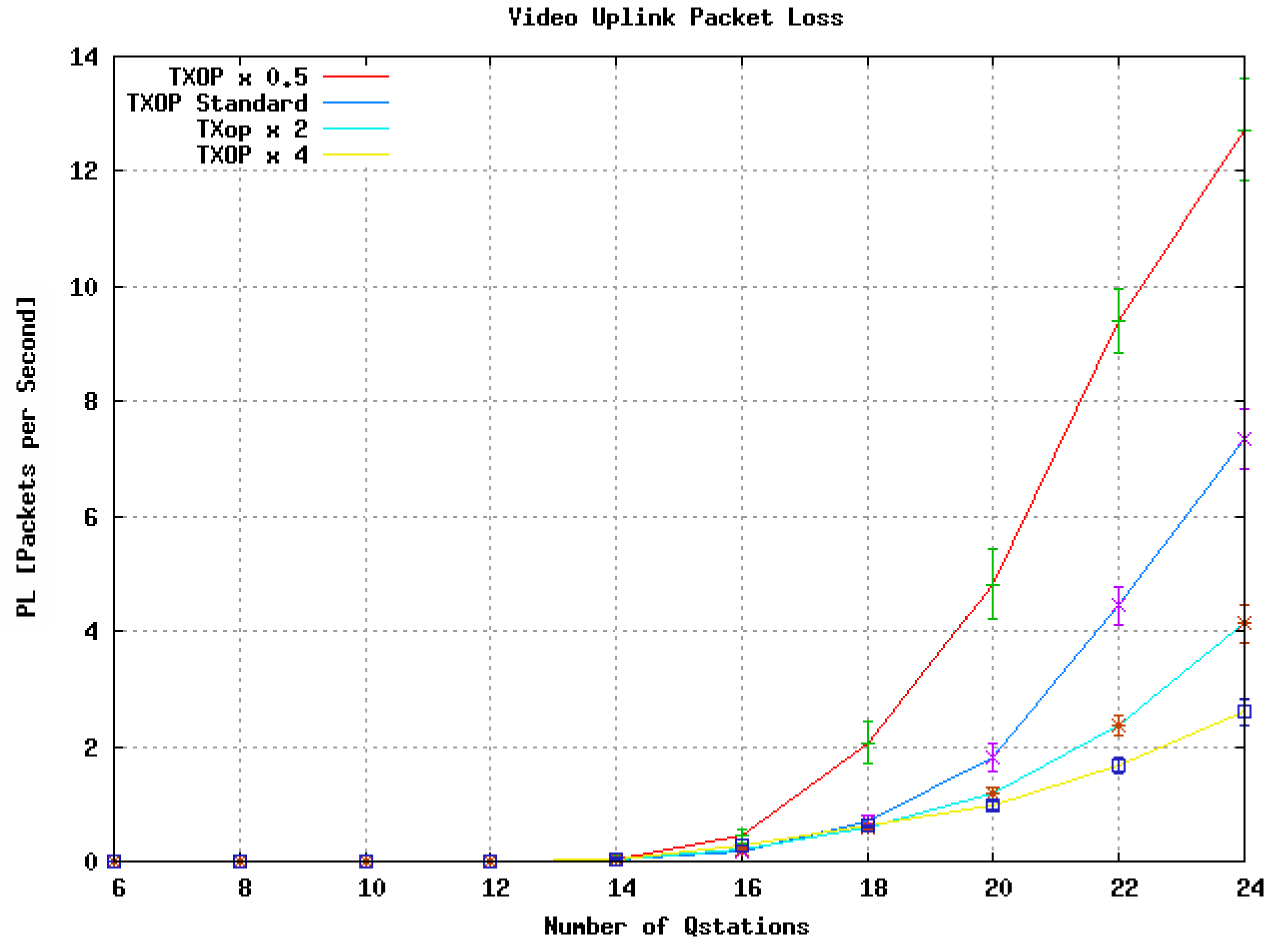
VoIP Downlink Packet Loss



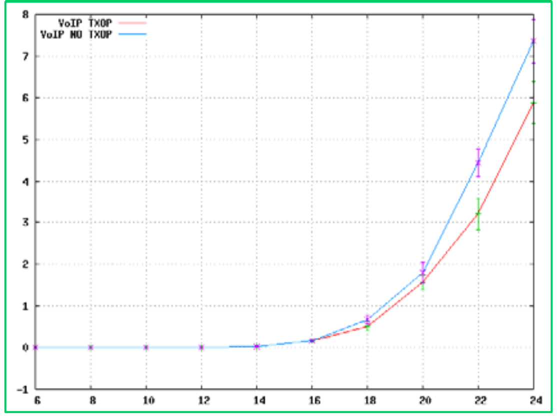
As delay case, Packet Loss in downlink flows exponentially increase with a linear increase of the TXOP parameter



Video Uplink Packet Loss



This remark is valid even for Video Downlink Packet Loss

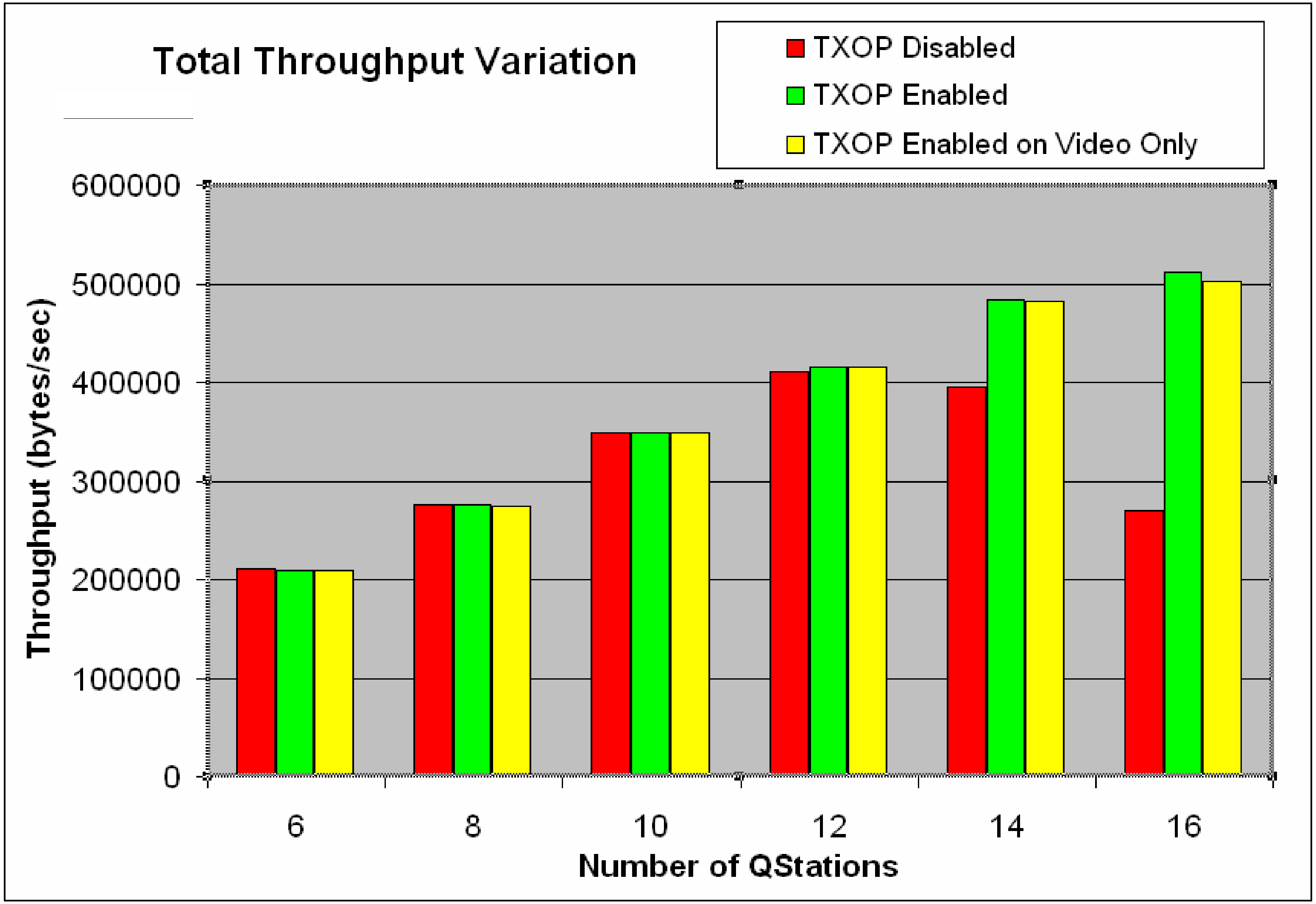


Conclusions

In addiction to conclusions obtained from previous scenario, last set of simulations are useful to understand that TXOP parameter on VoIP flows doesn't influence Video flows trends; even if VoIP has an higher priority respect to other classes and an higher probability of winning a contention with a lower service class due to the lower cwmin/cwmax/AIFS parameters

This may be due to the size of packets sent by VoIP Qstations, too small to interfere with video flows

A little comparison



Conclusions

This last two analisys shows that TXOP parameter is a very valuable resource to count on to make a network works better, but must be kept in mind that increasing too much that parameter can take the network to serve only the class with the higher TXOP without keep in considerations other parameters and getting the network to an unstable (or just a “one-only” class of service) situation

Contention Window in 802.11e

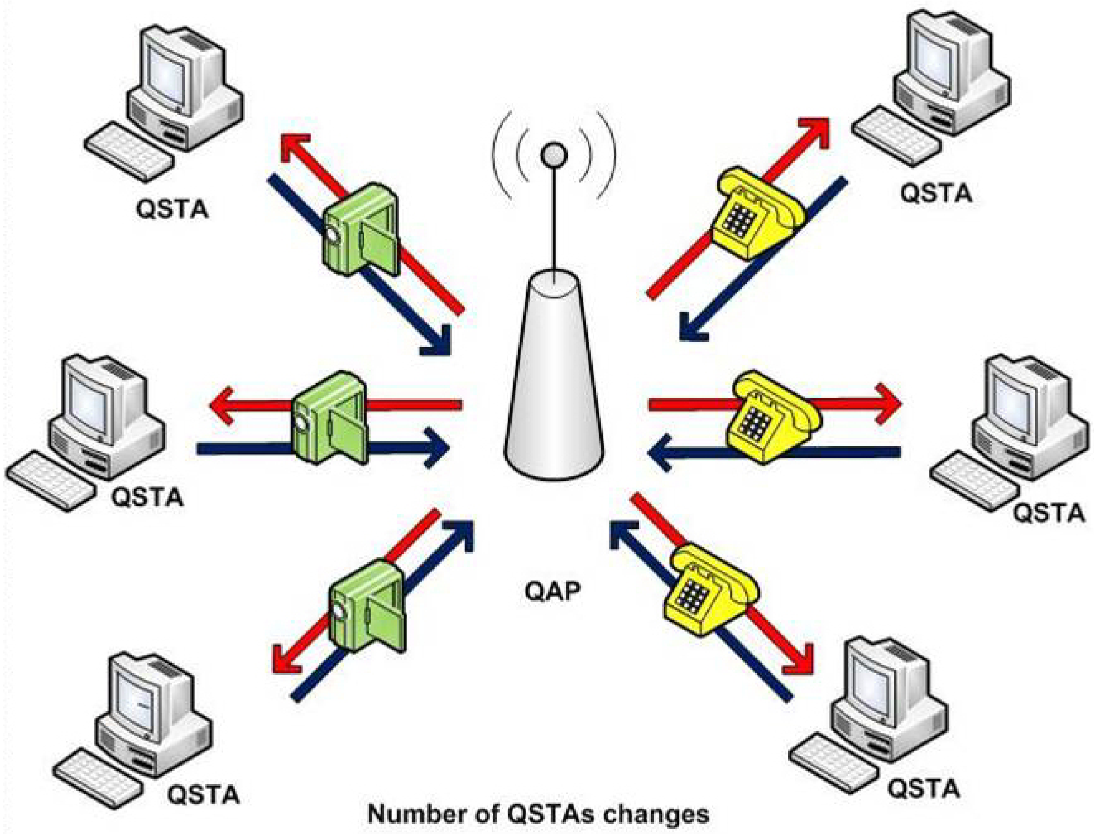
The purpose of using different
contention parameters for different queues is to give a low-priority class a longer waiting time than a high-priority class, so the high-priority class is likely to access the medium earlier than the low-priority

Contention Window variation for video traffic

Scenario Parameters

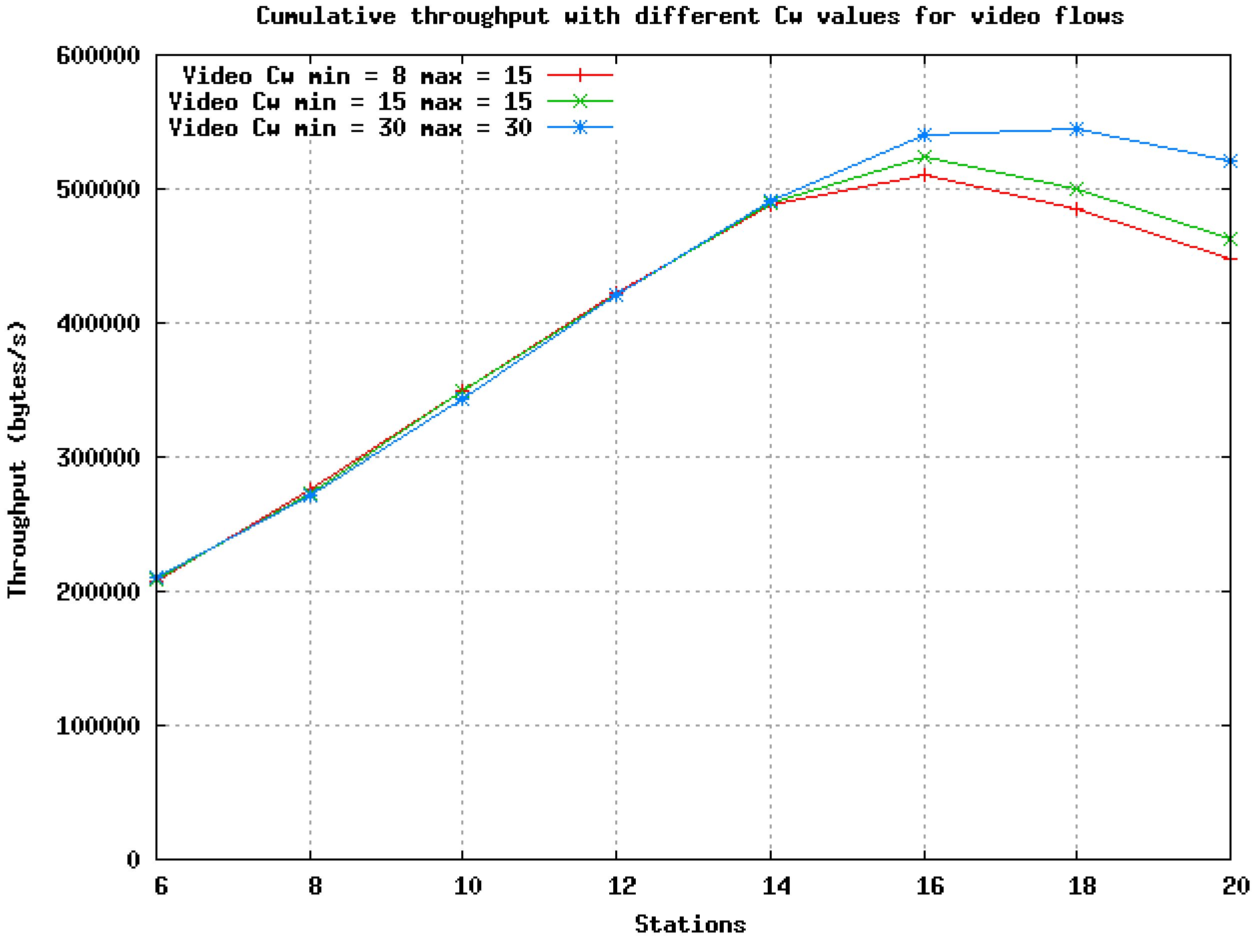
	Class 0 (voip)	Class 1 (video)
Cw Min	3	**8 – 15 - 30**
Cw Max	7	**15 – 15 - 30**
TxOP	0.003264	0.006016
AIFS	2	4

Scenario topology



Up to 20 QSTA

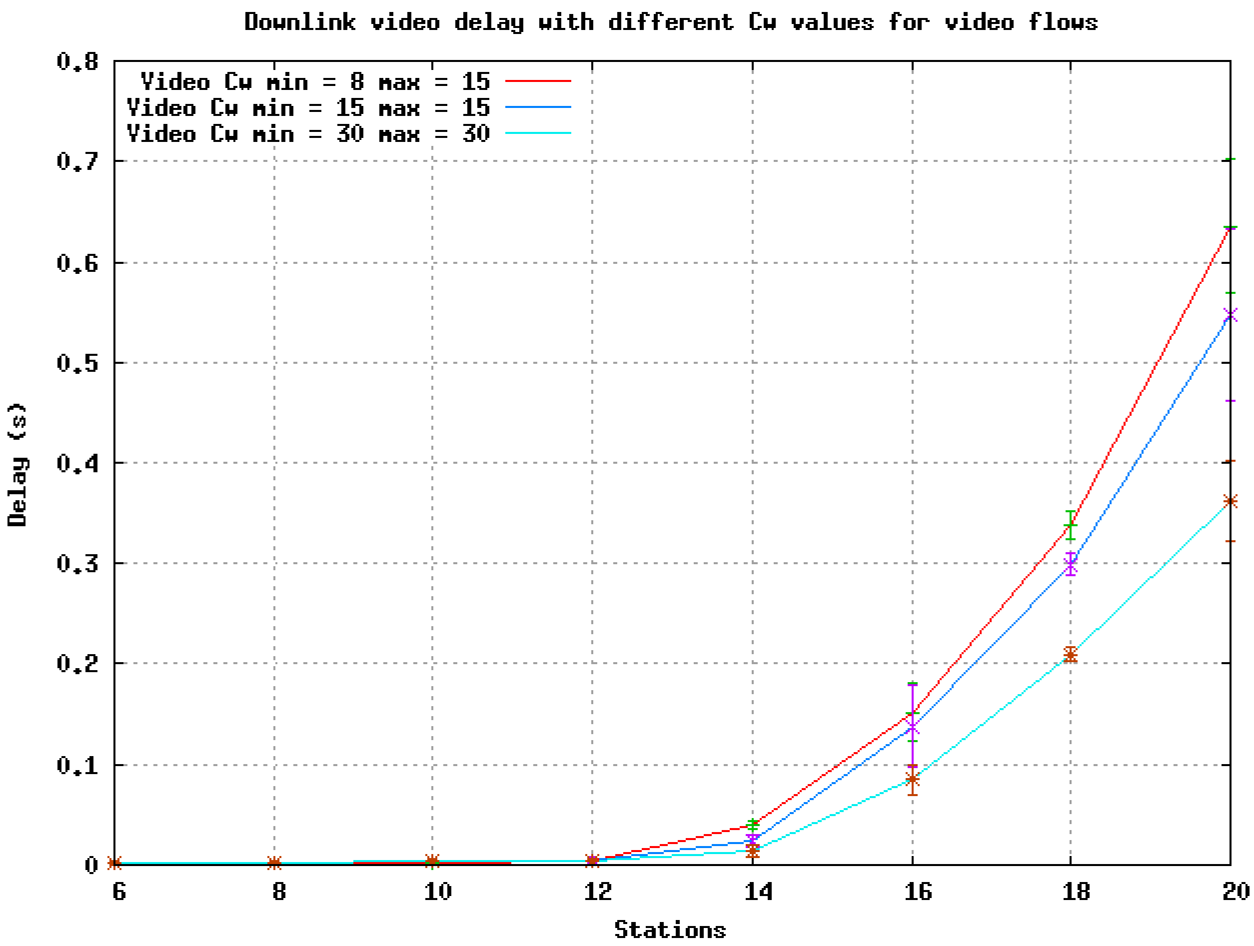
Cumulative Throughtput



Here we show how Cumulative Throughtput varies as we change the cw min parameter for class 1 traffic. Cw values for voip is fixed.

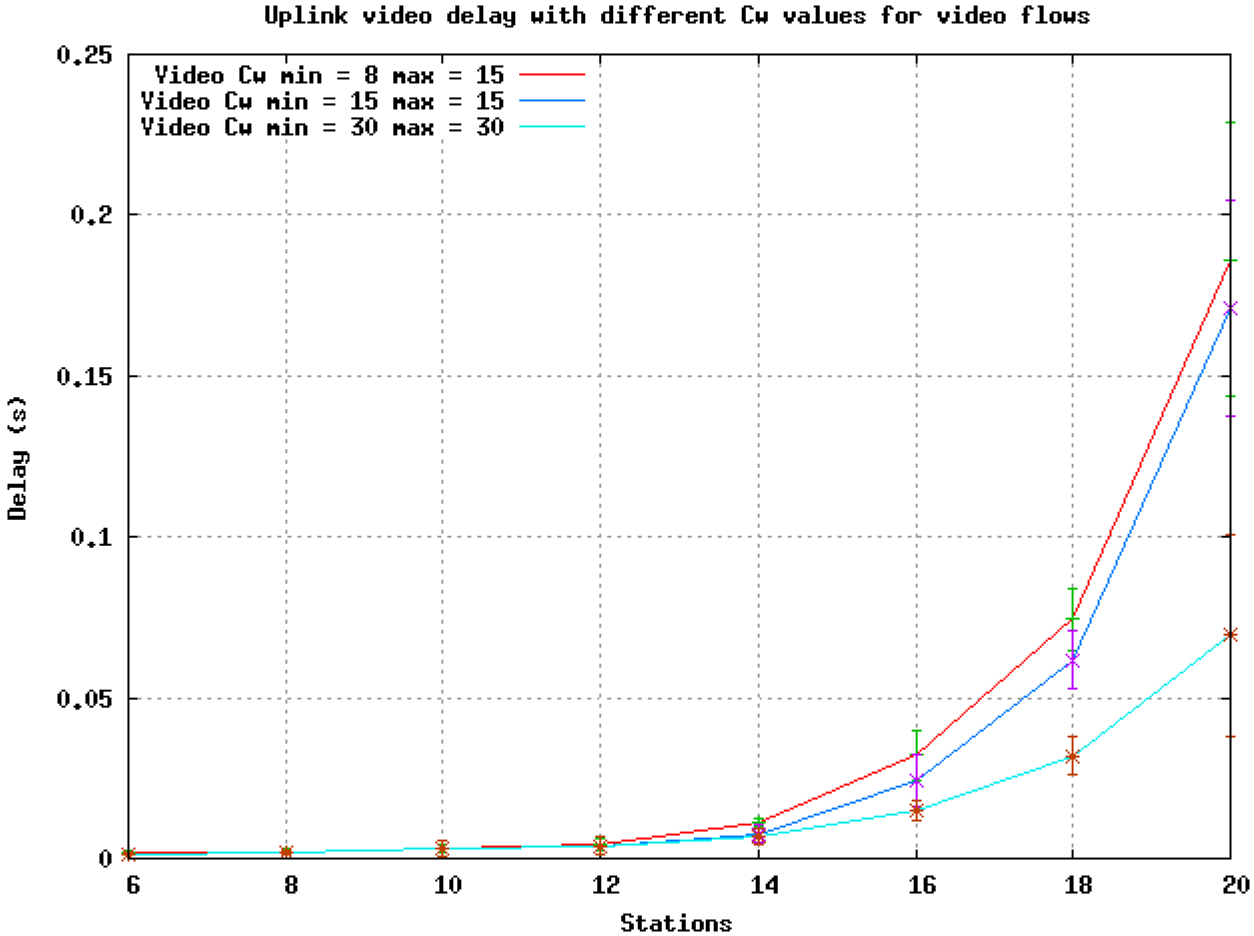
System's throughput decreases with lower Cw min value

Video Delay (Downlink)



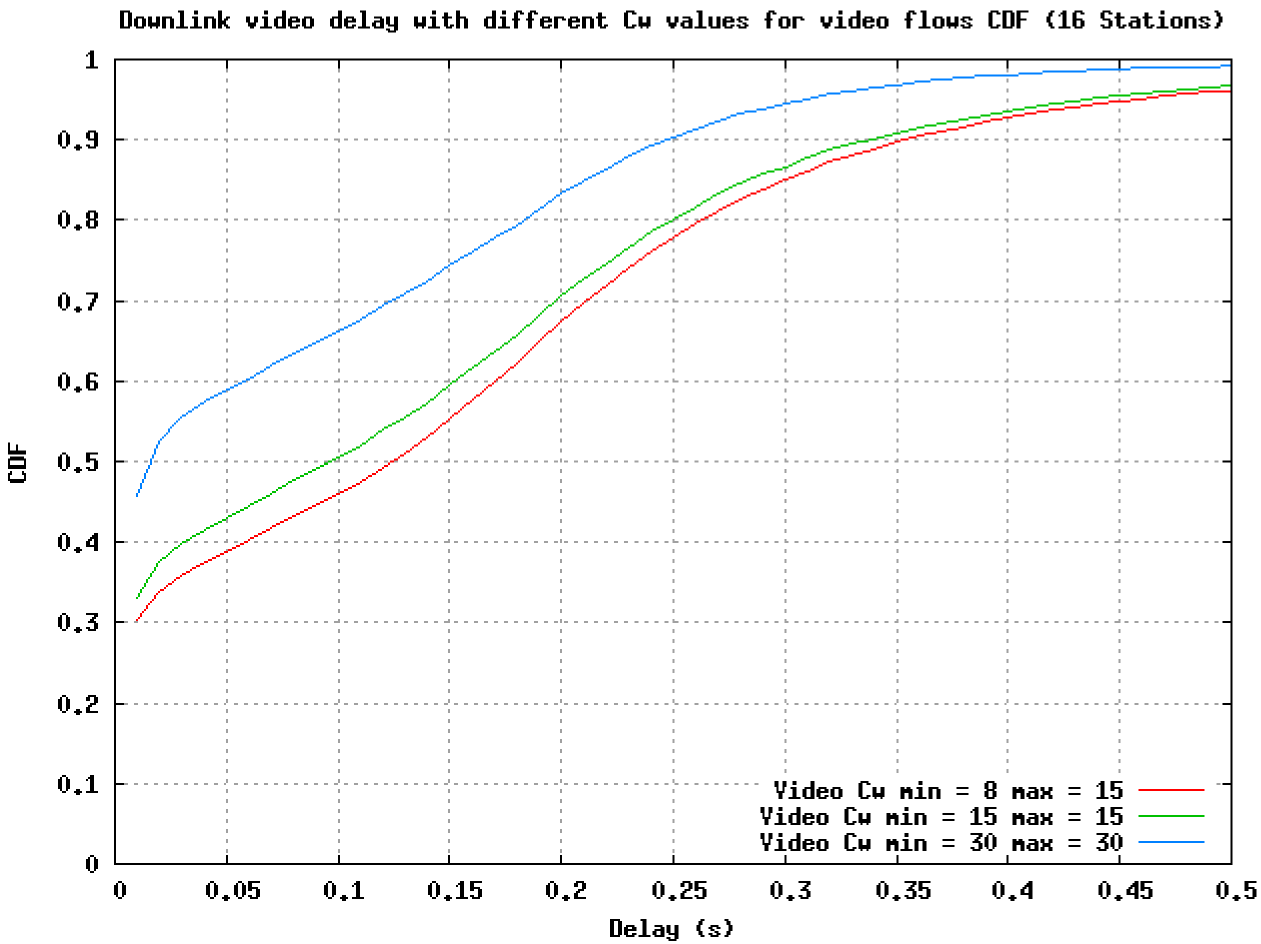
Increasing Cw Min we deeply reduce mean delay for video traffic.

Video Delay (uplink)



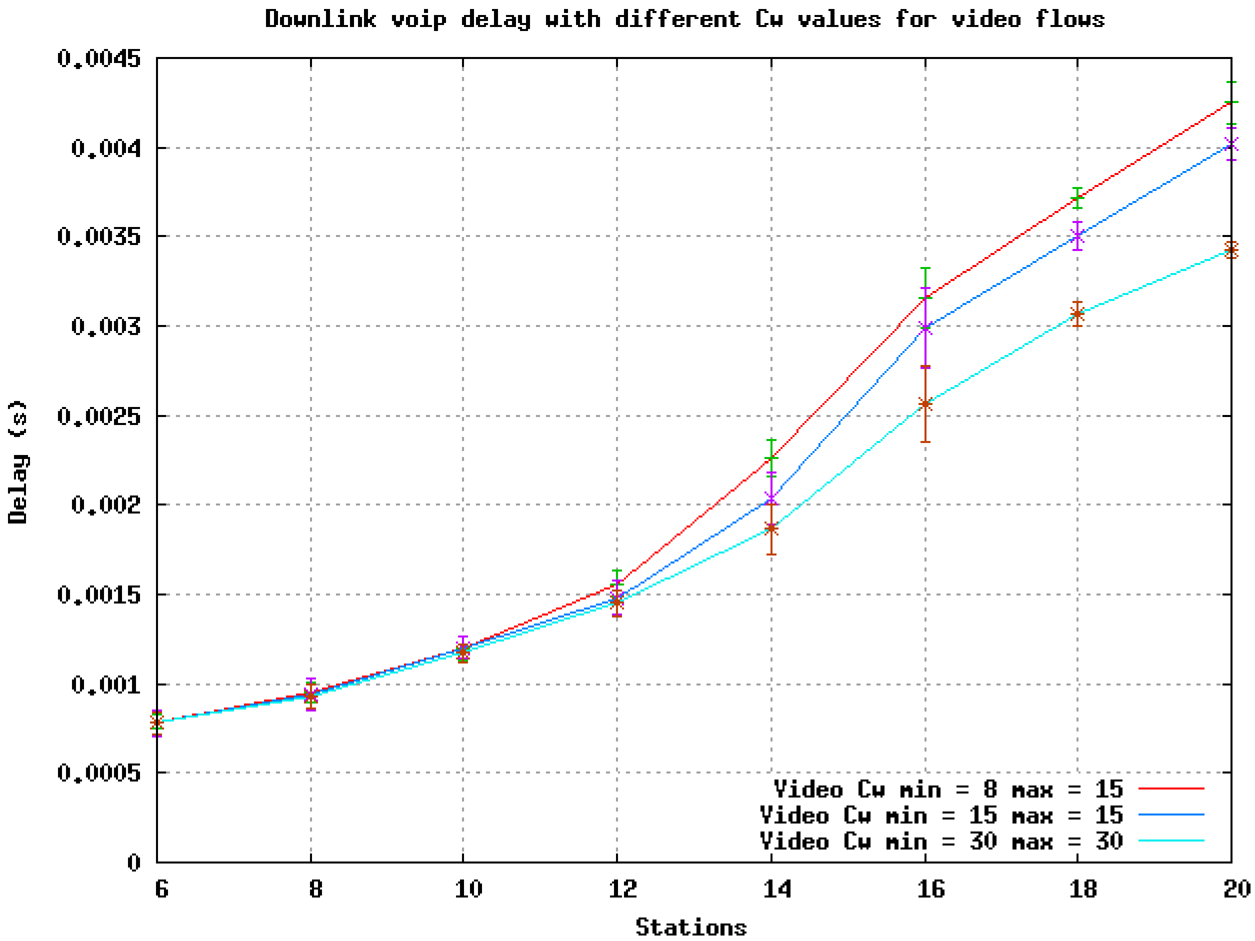
This effect is even more clear for uplink traffic

Video Delay (downlink) – CDF



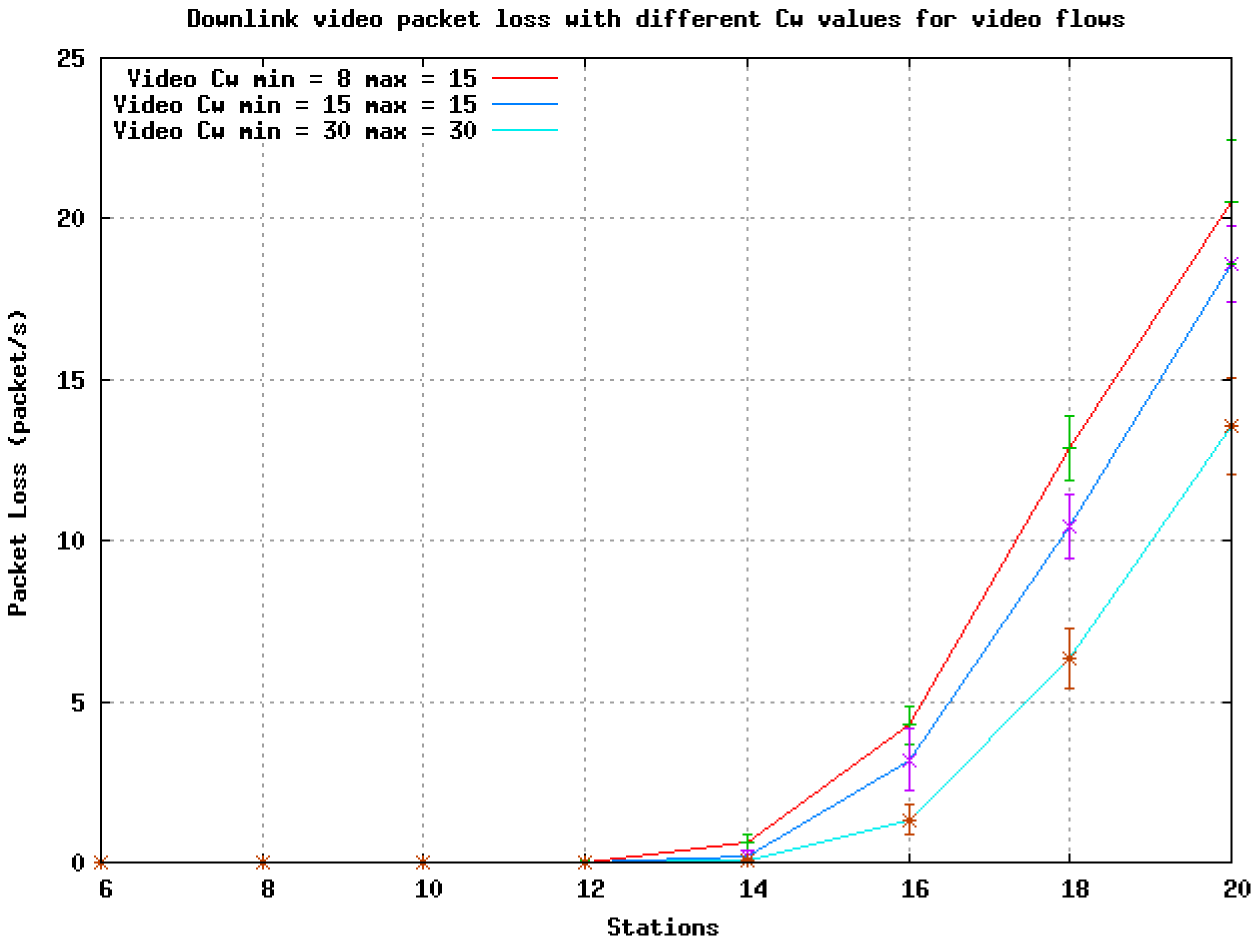
This graph shows a detail of the situation with 14 stations

Influence on Voip traffic (Uplink)



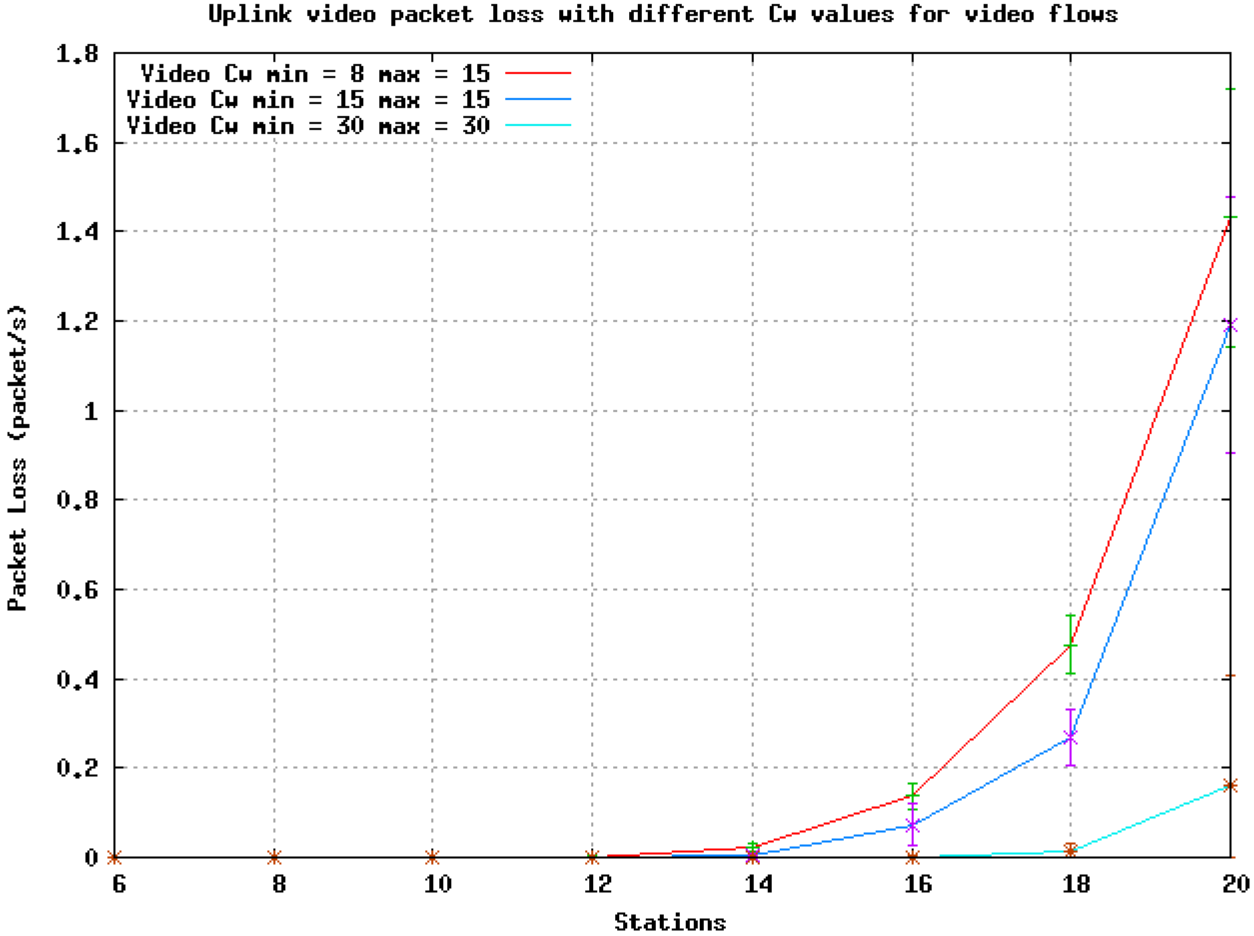
Variation on Class 1 Contention window influences Class 0 delay in a similar way. The advantage is particularly noticeable for downlink traffic.

Video Packet Loss



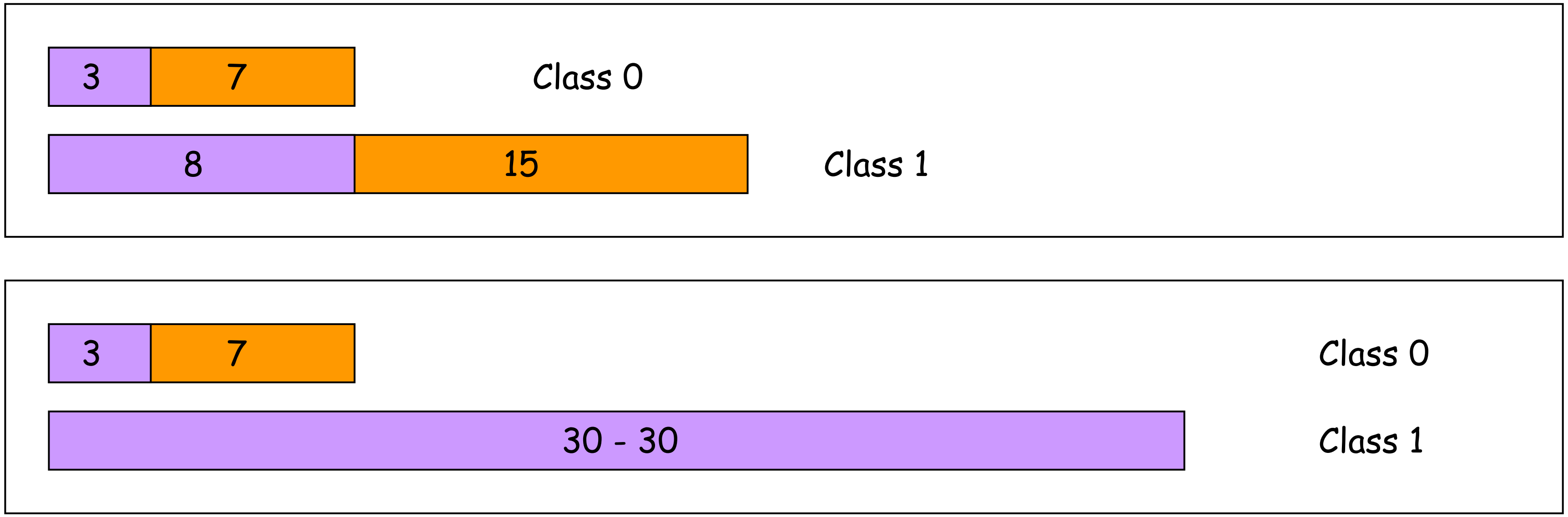
In this slide we can see how packet loss grows as we lower cw min for video, i.e. as we put voip and video contention windows closer.

Video Packet Loss

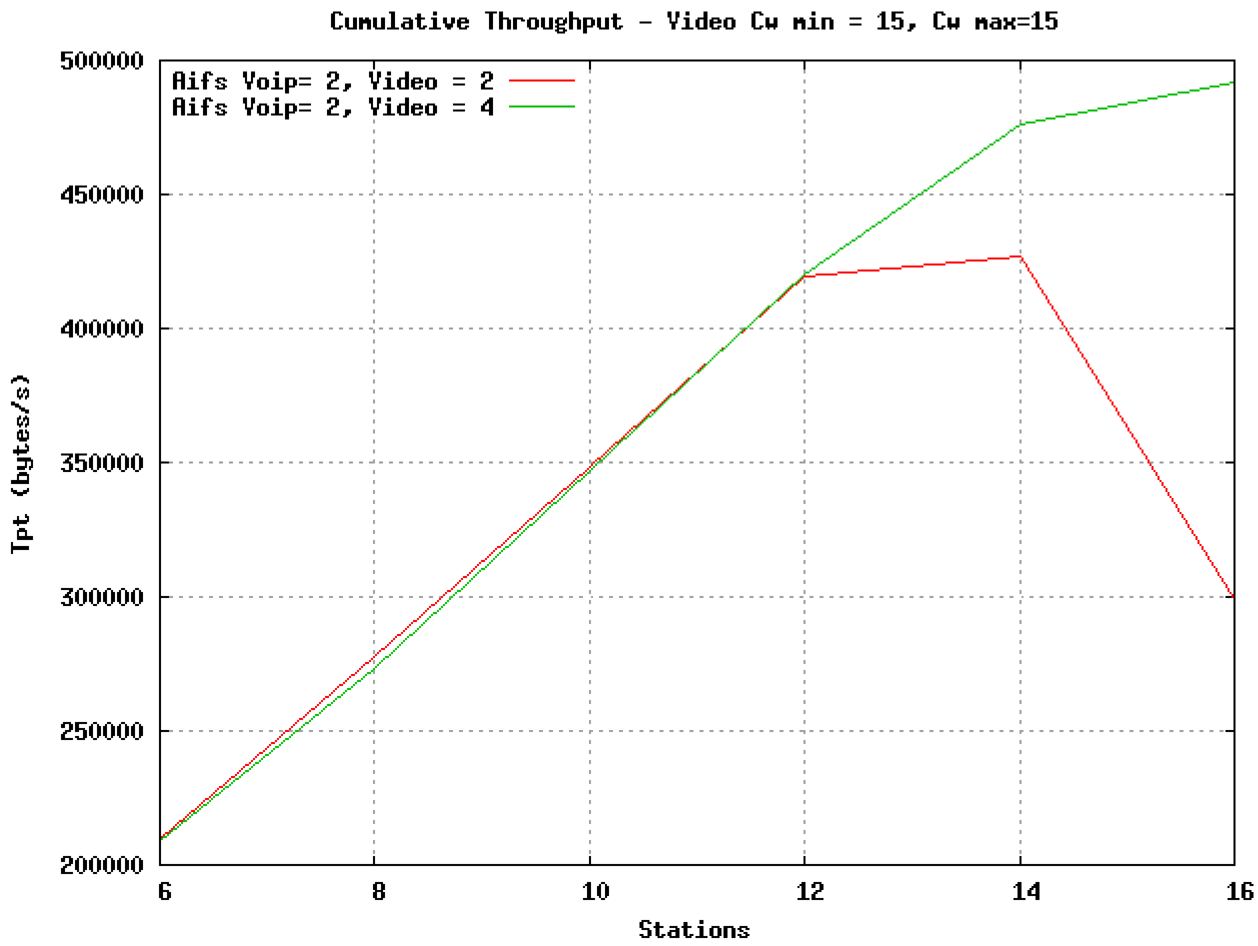


The difference is even more clear as we look at uplink flows. With higher cw values packet loss remains close to 0.

Low Cw values for video traffic determine a rise of collision probability since windows for voip and video become mostly overlapped.



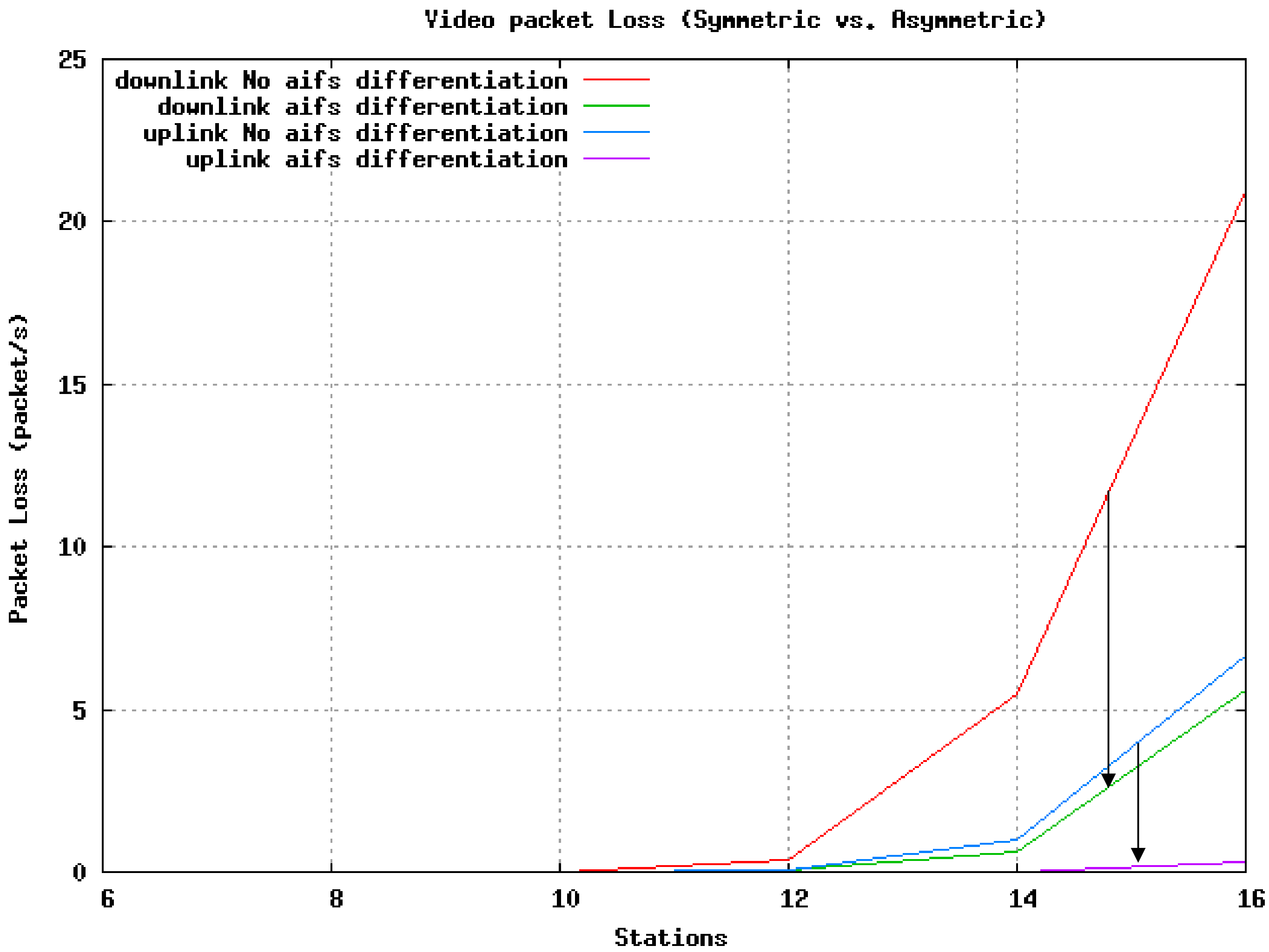
Analogy w.r.t. AIFS



We can observe a similar behavior in this graph. With no-aifs-differentiation performance degrades quickly.

The reason is the loss of isolation between the flows and the consequent raise of collisions.

Analogy w.r.t. AIFS …



The difference in number of collisions is more clear in this graph.

The arrows remark the gain obtained with aifs differentiation.

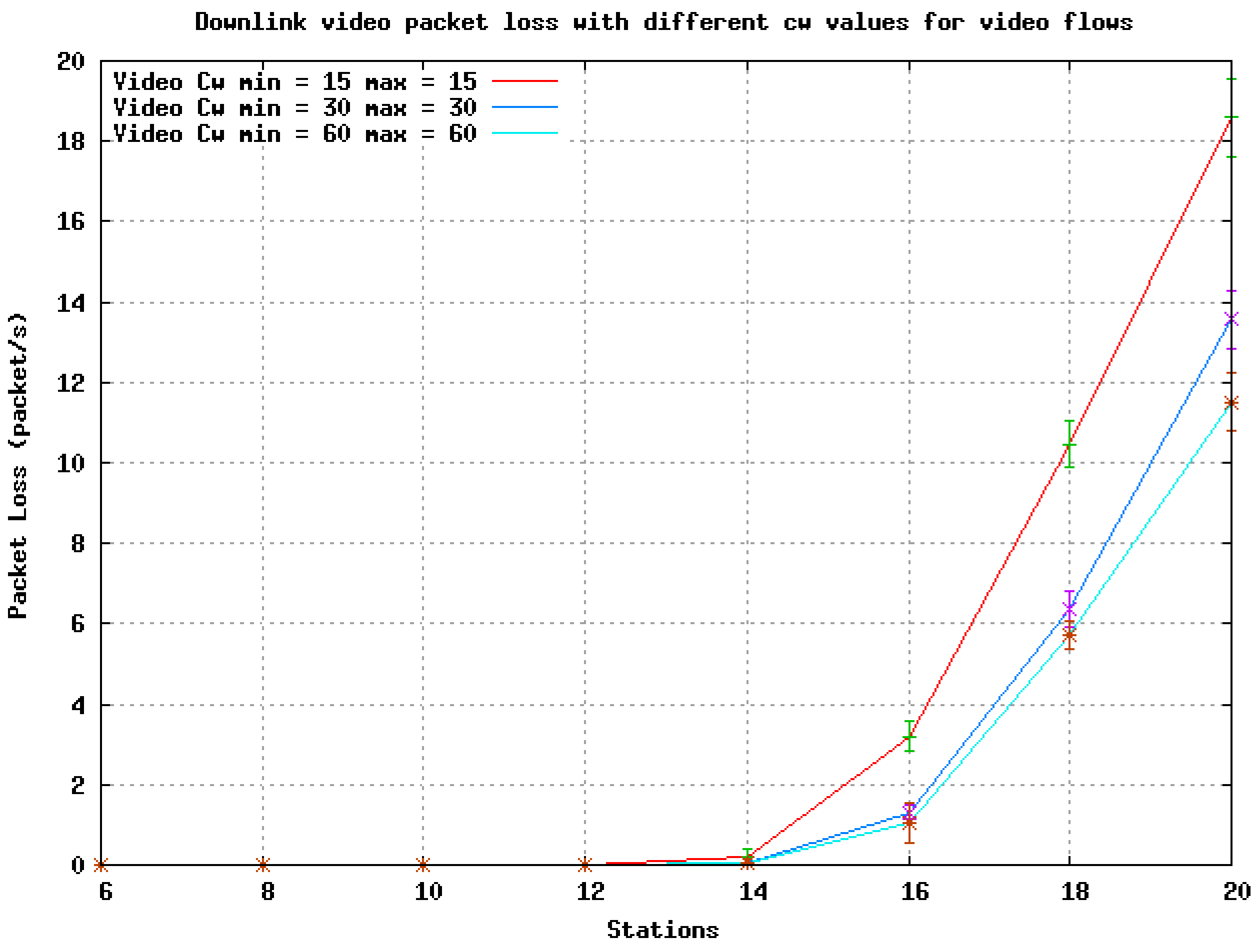
In the following we examine the performance obtained increasing cw values for class 1 traffic,

(thus reducing the overlapping part of voip and video retransmission windows.)

Scenario Parameters

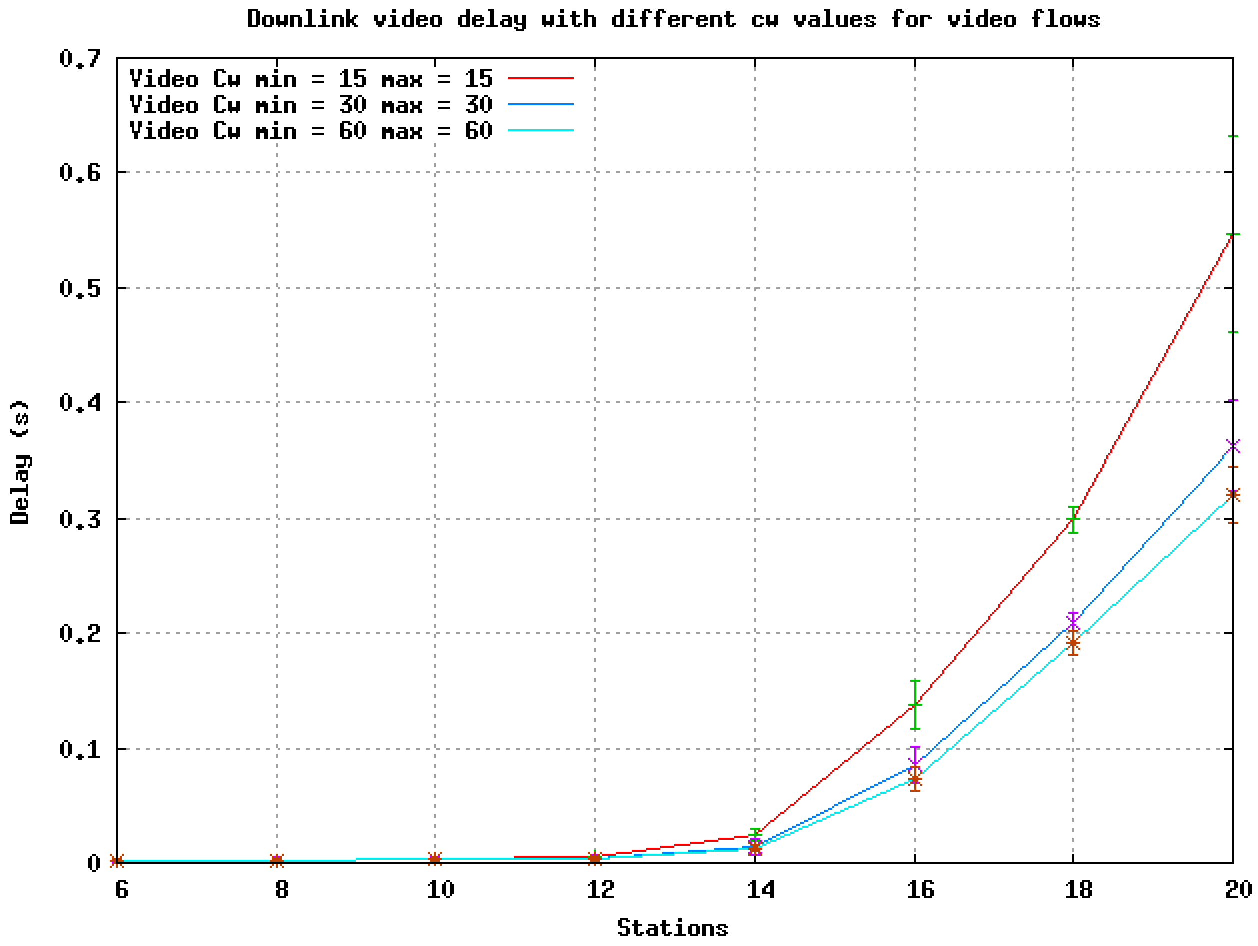
	Class 0 (voip)	Class 1 (video)
Cw Min	3	**15** - **30** - **60**
Cw Max	7	**15** - **30** - **60**
TxOP	0.003264	0.006016
AIFS	2	4
PF	2	2

Downlink Packet Loss



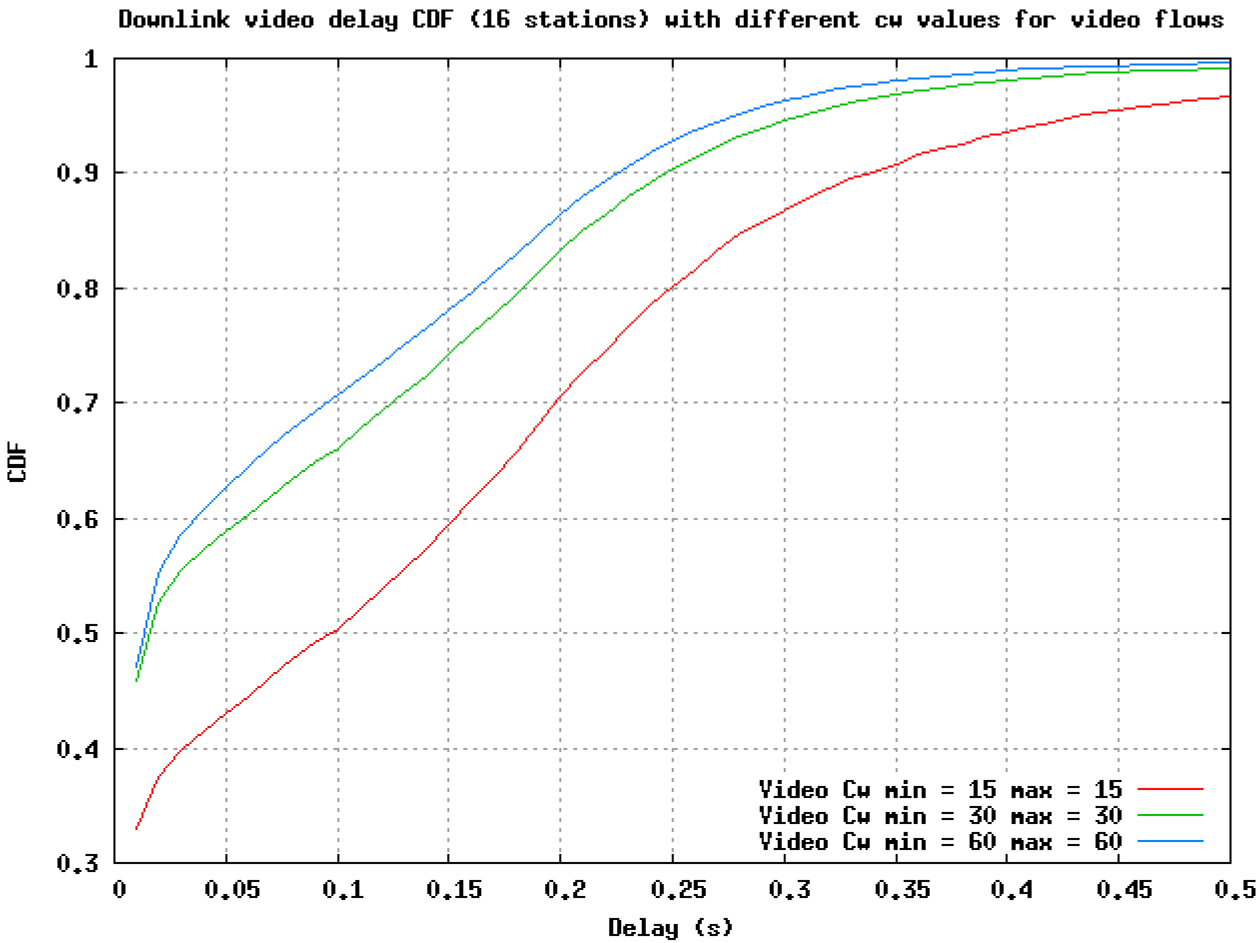
As expected higher Cw values bring a further overall improvement in packet loss stat.

Video Delay (Downlink)



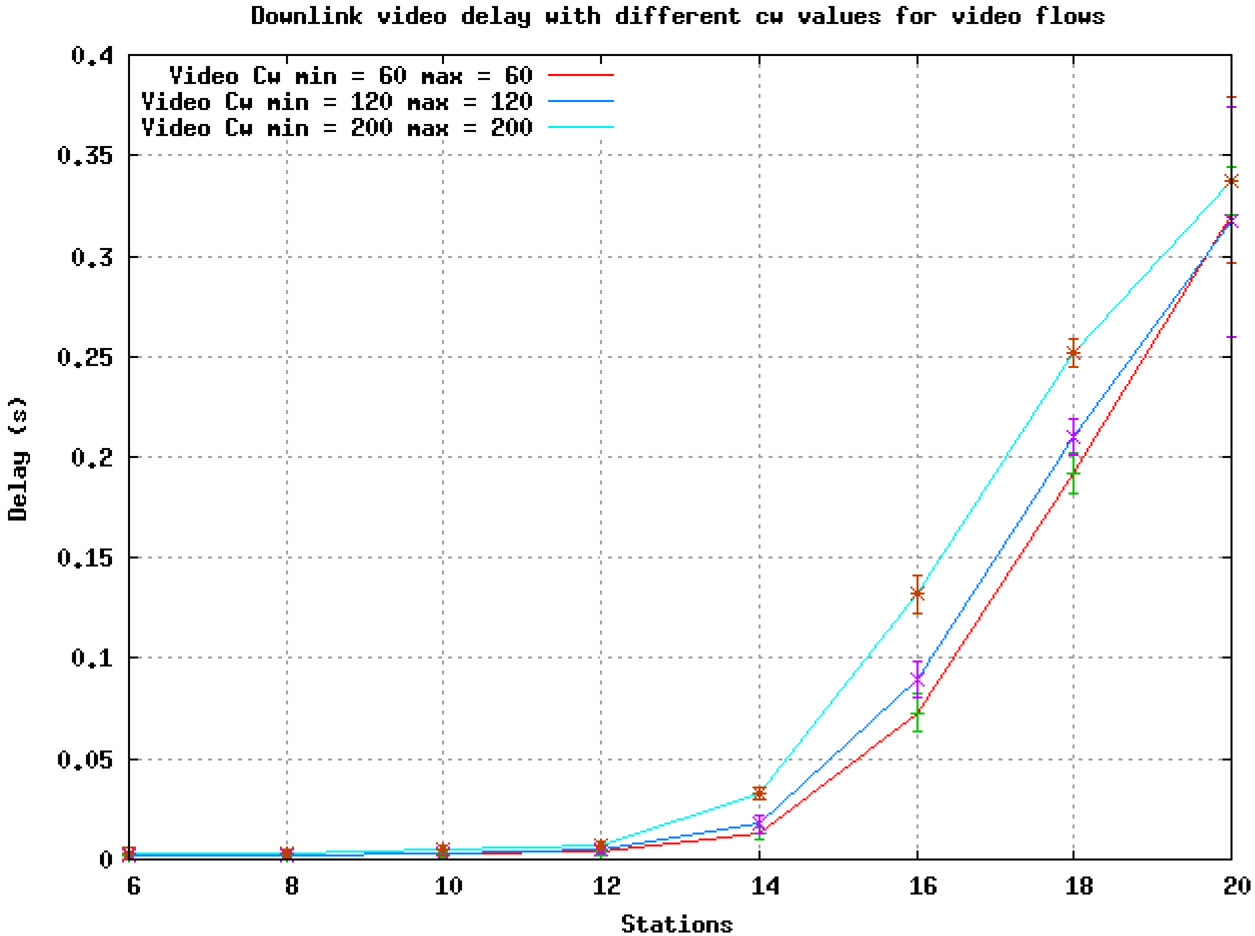
Similarly the delay decreases as we boost Cw values.

Video Delay (Downlink)



Focus on 16-stations state

Video Delay (Downlink)



Further growth of cw values brings to a turnaround in performance.

Conclusions

In the first step of backoff procedure each QSTA computes its backoff time randomly

backoff = rand [0,CW] x Slot Time

(Slot time = 20 μs)

Let's suppose a random choice of Cw=100 for a video station backoff procedure. The backoff time becomes 2 ms, which is a time noticeably smaller than the mean delay we experiment.

With greater values for CW we introduce a little variable delay while we lower the probability of collisions, boosting overall performances and improving flows isolation, which is a primary goal to provide QoS.

We start to see a degradation in delay with values of Cw greater than 100.

Differentiating UL/DL Contention Window

As previously said every QStation (voip or video) manages two flows: uplink and downlink. QAP handles up to 40 flows (20 stations scenario).
This overload brings to a great difference between the performance of uplink and downlink flows.

In the following simulation we try to compensate this behavior by lowering cw values for downlink flows.

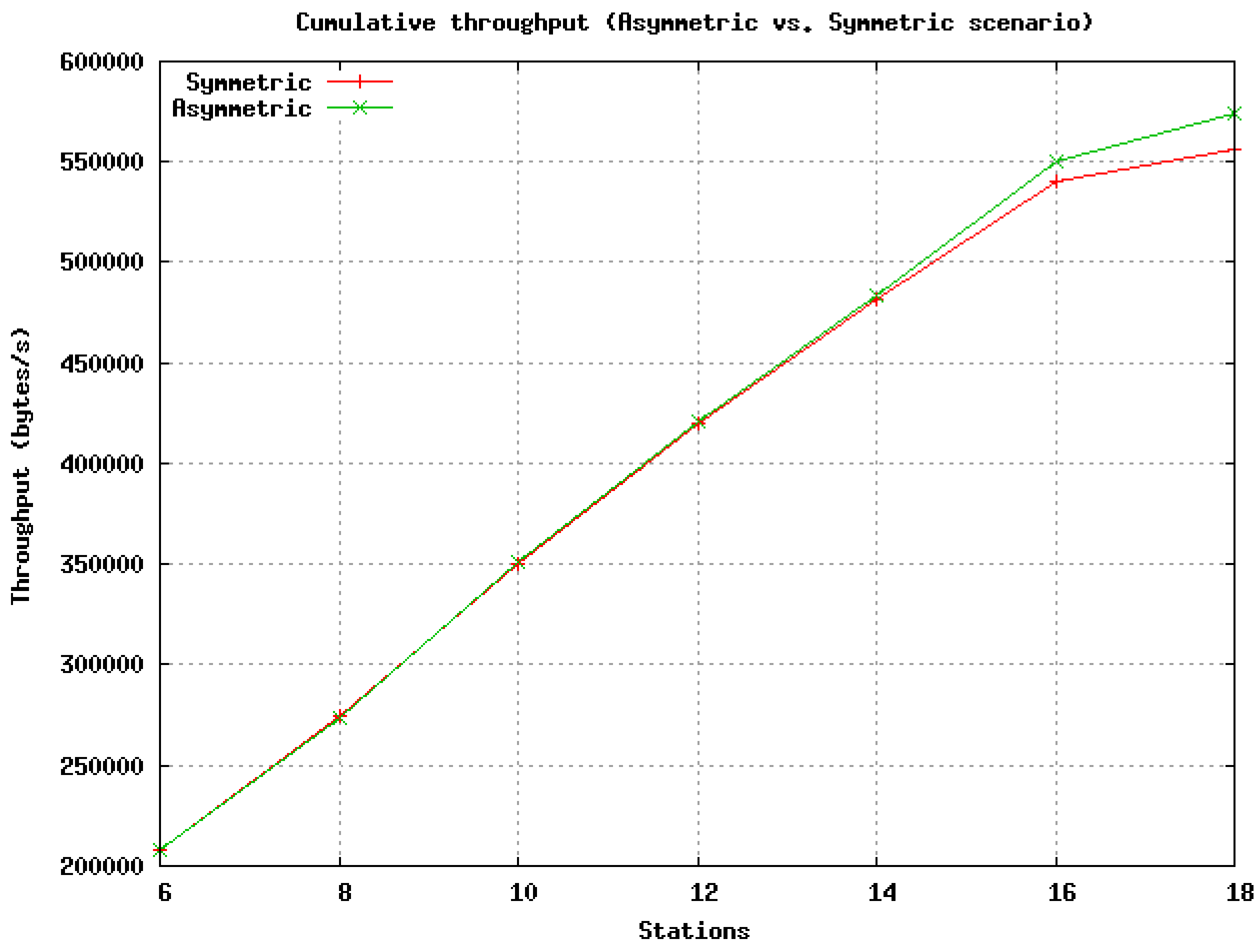
We choose to apply this differentiation only to video flows because voip flows (both uplink and downlink) already have good and balanced performances.

Scenario Parameters

We choose high values for uplink Cw, thus reducing the influence of the isolation problem with respect to voip flows. Then we consider smaller values for downlink video flows trying to give them some benefits

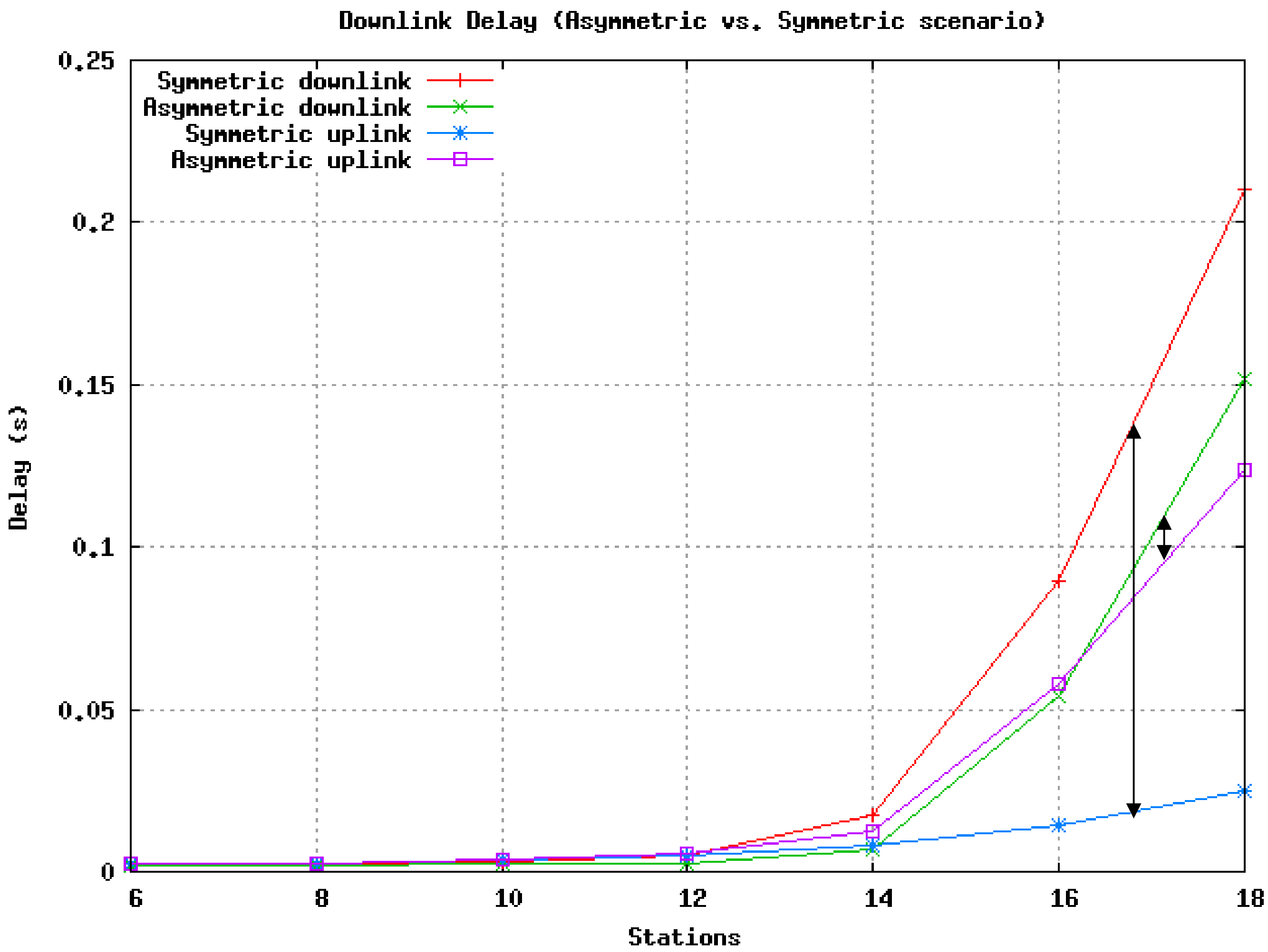
	Class 0 (voip)	Class 1 (video uplink)	Class 2 (video downlink)
Cw Min	3	**120**	**30**
Cw Max	7	**120**	**60**
TxOP	0.003264	0.006016	0.006016
AIFS	2	4	4
PF	2	2	2

General Performance



Overall throughtput of the symmetric and asymmetric system are almost similar.

What changes. Delay

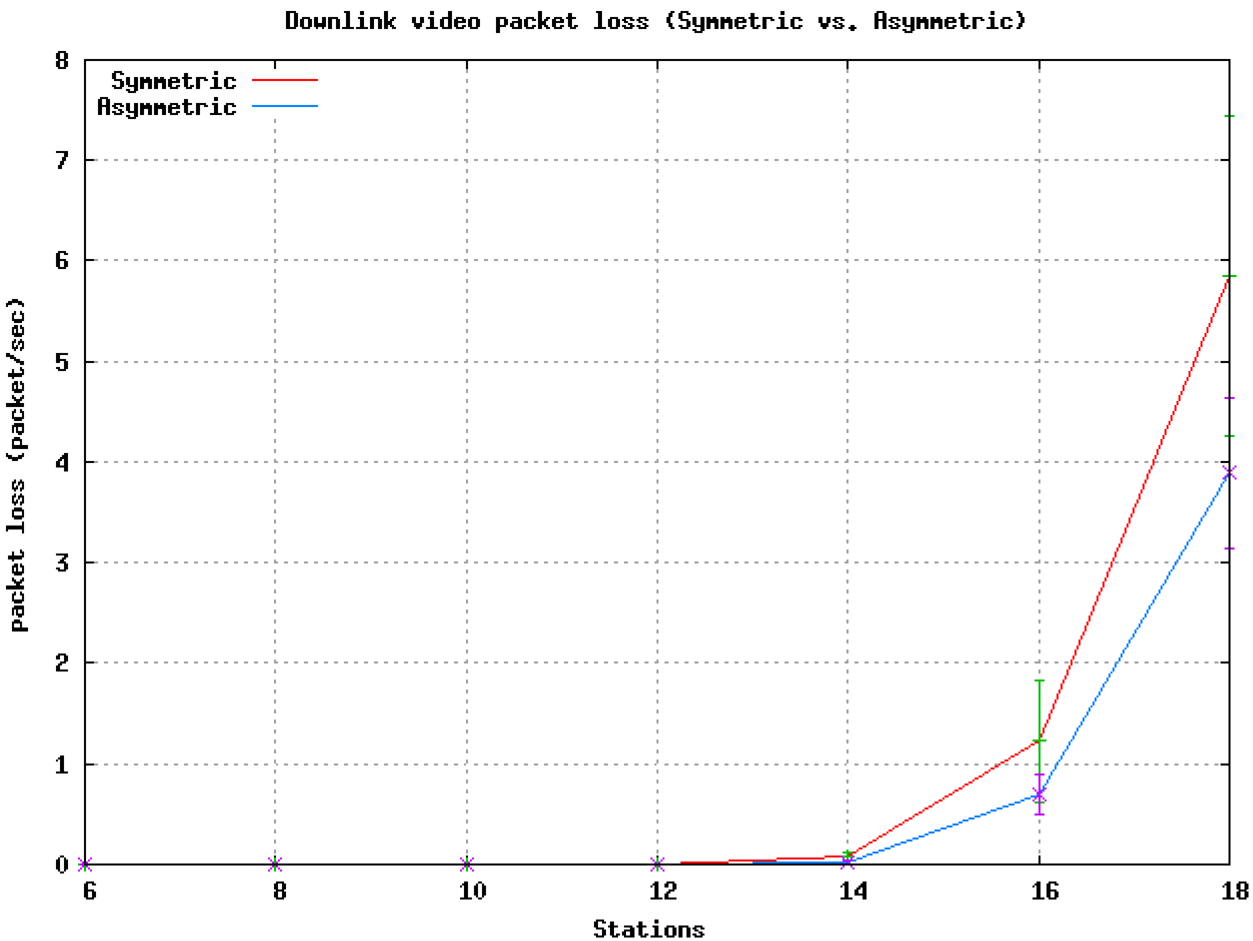


With Asymmetric scenario we reduce the difference between uplink and downlink delay.

The drawback is a worsening of uplink delay.

Influence on voip is irrelevant.

What changes. Packet Loss



Consistently packet loss for downlink video flows in the asymmetric scenario is up to 30% lower than the one we obtain with no differentiation.

Conclusions

Changing Cw windows parameters we can balance the innate disparity, due to topology, between uplink and downlink video flows.

Downlink flows with reduced Cw values gain an edge in contention with uplink flows to access the medium. Parameters must be changed paying attention at the isolation problem, trying to reduce the number of collisions.

If we keep class 1-2 parameters enough distant from those for class 0, voip class is not affected (it has little bandwith demands and shorter waiting time due to smaller AIFS and CW).

2 QAPs Scenario

QAPs working on ***non overlapping*** frequencies

- Doubled performances. Behavior can be argued by 1 QAP scenario.
- 802.11 physical layer specification allows up to 3 QAPs non overlapping.

QAPs working on ***overlapping*** frequencies

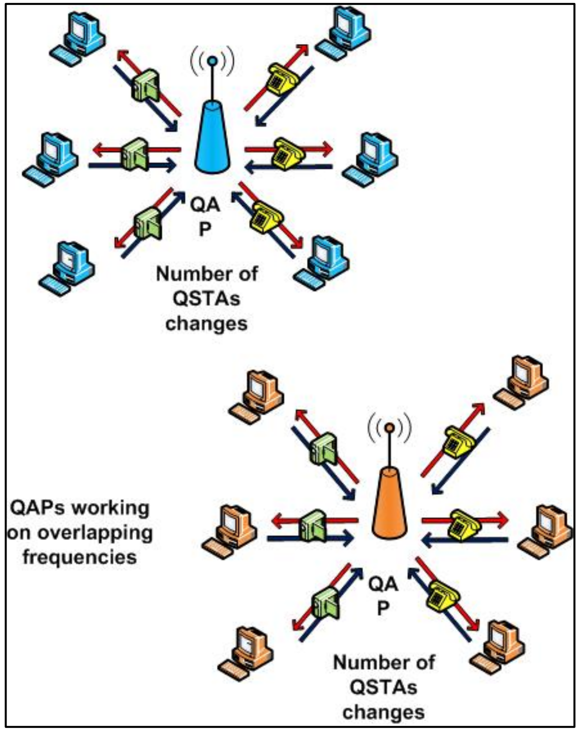
- There are two possible configuration:
  - Either QAPS accept both type of traffic (VoIP and Video)
    - For the same traffic, all Qos parameters deteriorate because of collisions' growth (there is STA more, the second QAP)
    - The sole benefit is an obvious increment of Infrastructure's fault tolerance
  - One QAP accepts Video Traffic only, the other accepts VoIP traffic only
    - Performances are similar. There is a little degradation because of collisions' growth. The latter augments because collision between VoIP downlink flows' packets and Video downlink flows' packets are not more virtual .
    - QSTA can't send both traffic type

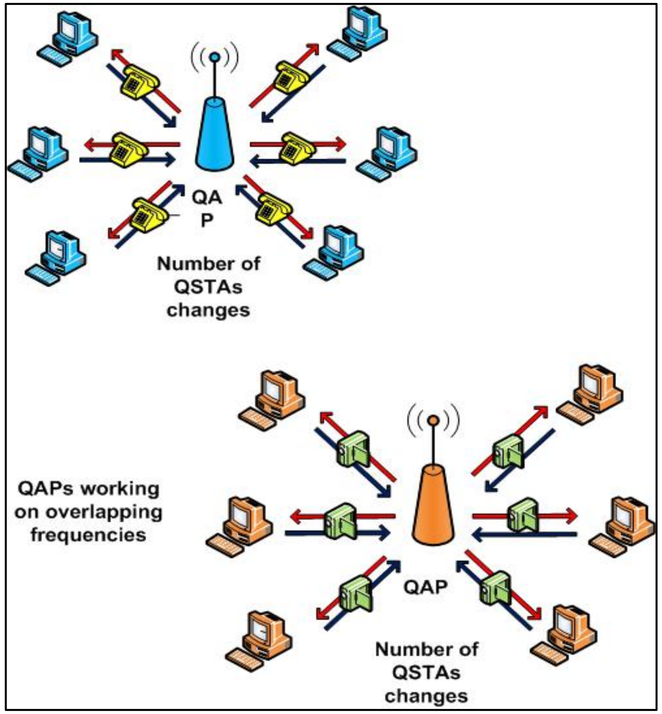
Because of everything just said, scenarios with 2 QAPs are not much meaningful. Next few slides will show as much as is necessary to draw the situation. Particularly, Video downlink traffic flows' Qos parameters will be compared.

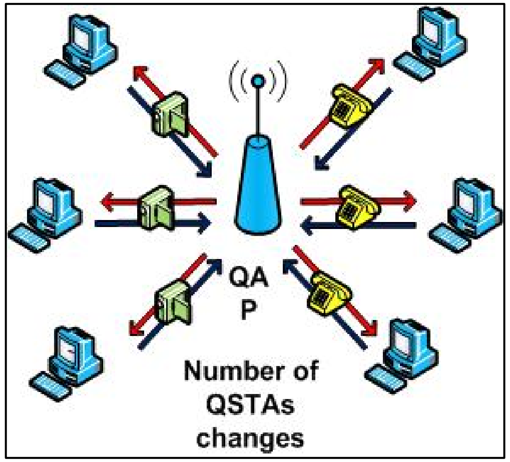
2 QAPs Scenario

Next slides compare video downlink traffic flow's QoS parameters for this three scenarios:

- Network with 2 QAPs accepting both types of traffic
- Network with 2 QAPs accepting only one type of traffic
- Network with 1 QAP



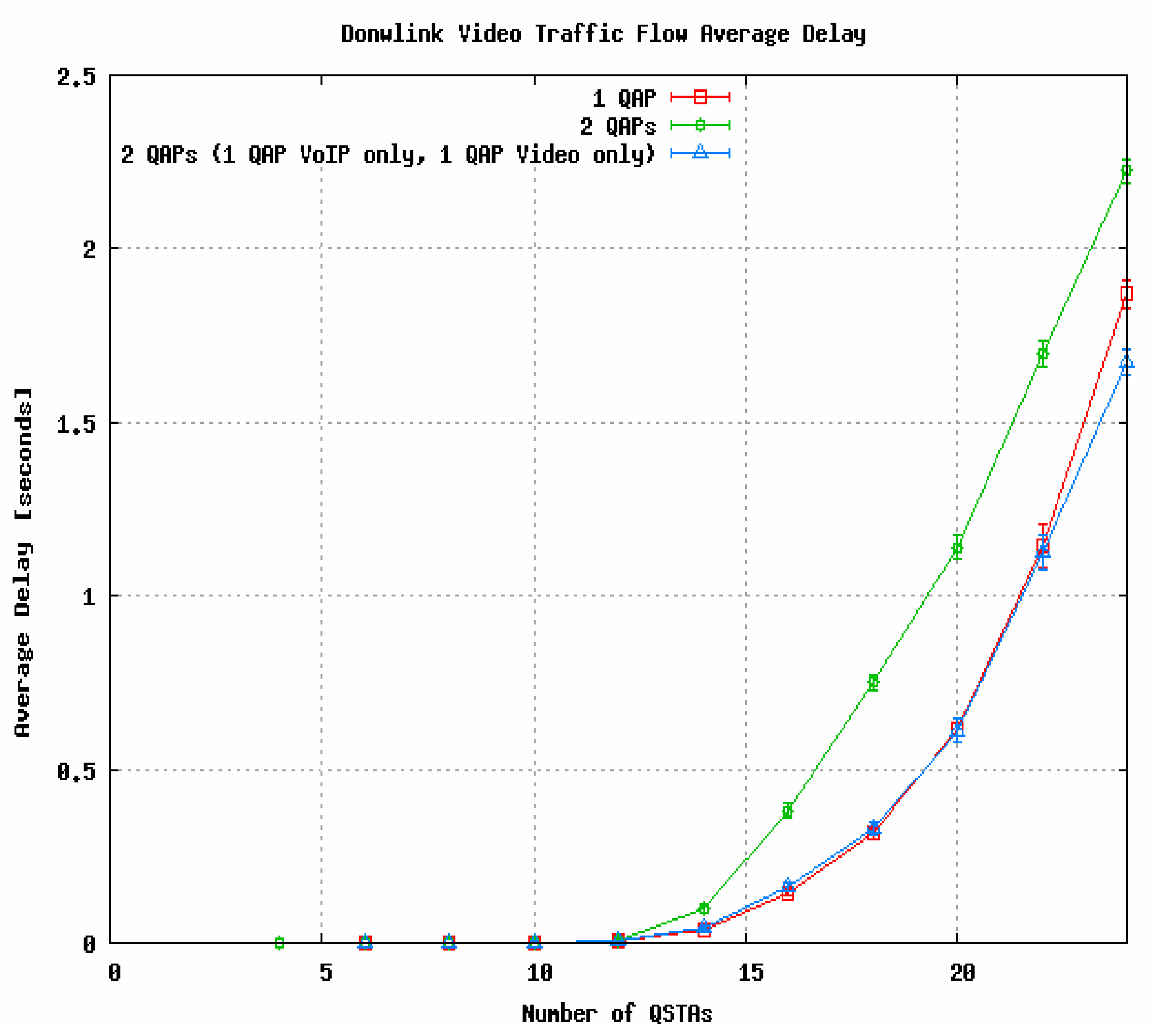




2 QAP scenario

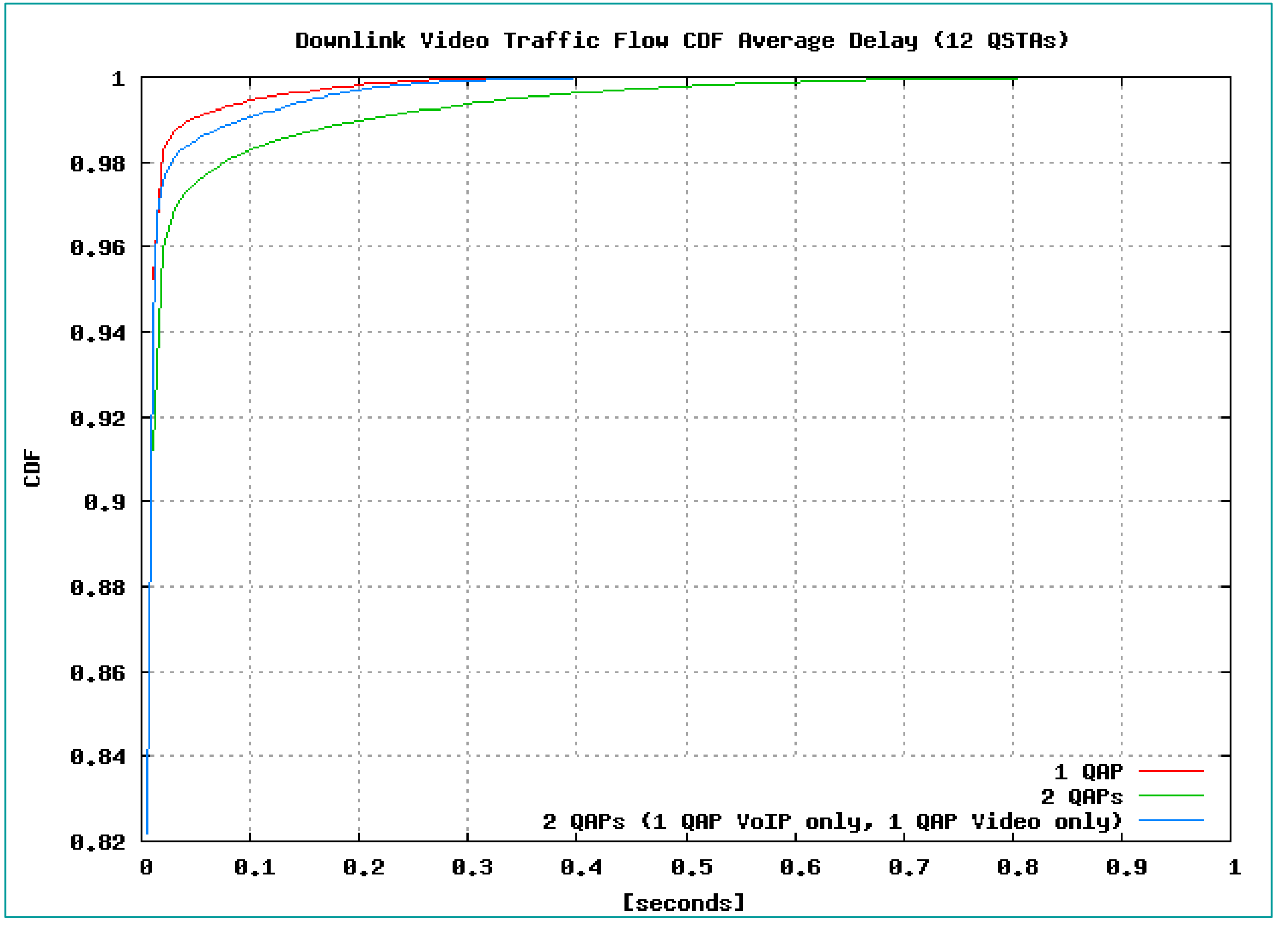
- ✓ Using 2 QAPs both managing class 0 and class 1 traffic type deteriorates performances. For the same traffic, collisions' number augments, deteriorating all QOS parameters.
- ✓ Using 2 QAPs, each of these for a single class traffic type, performances are similar to the 1 QAP way. When medium becomes hardly loaded Video DL flows performances little improve because Class 0 Queue on Video QAP is now empty (and there are no more conflicts between different queues)

2 QAPs: Video Downlink Traffic Average Delay

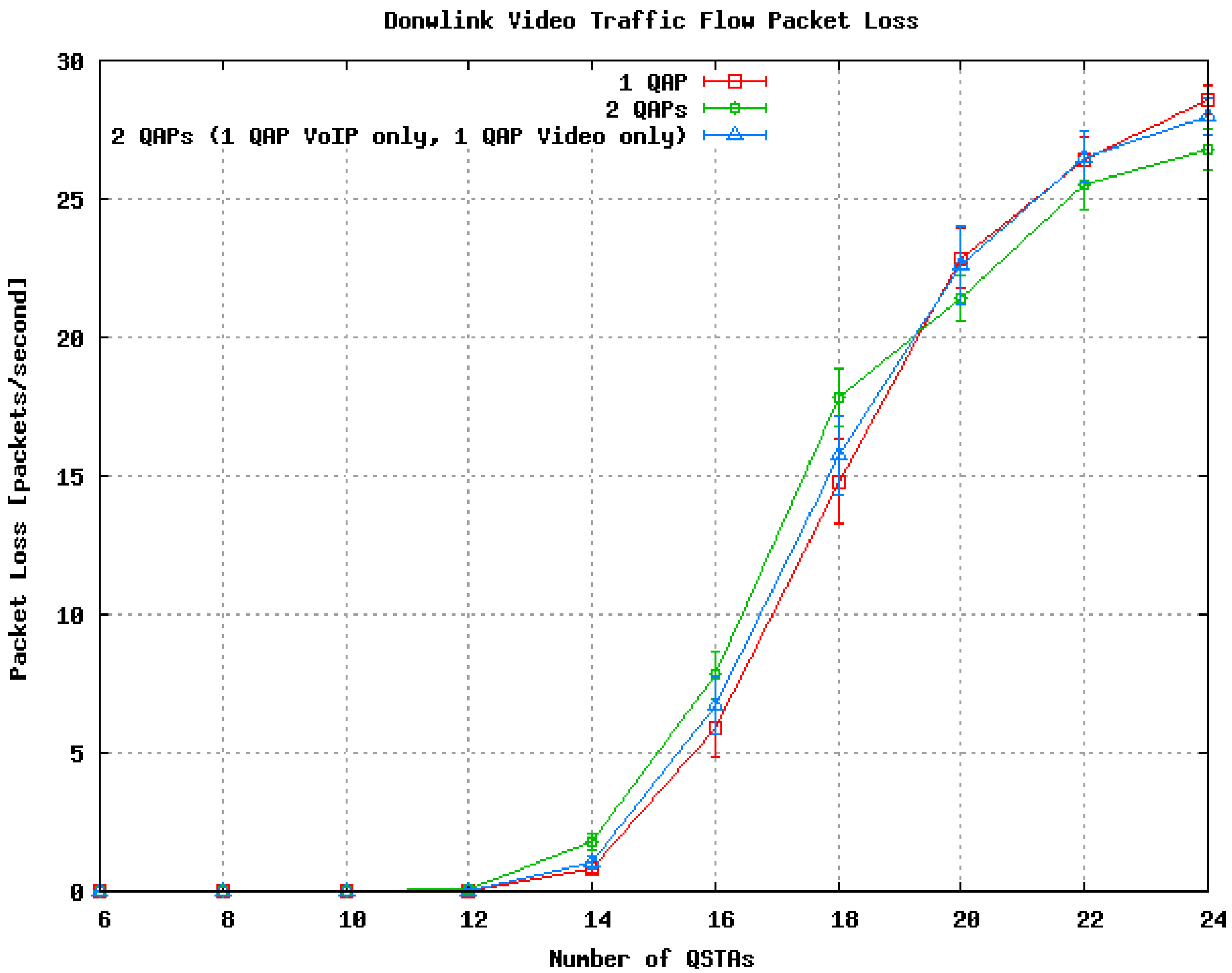


At most the same performances than 1 QAP.

2 QAPs: Video delay CDF



2 QAPs: Video Down Packet Loss



Using 2 QAP, both for all traffic type, presents a useless improvement when downlink video traffic flows' performances are totally compromised. This improvement comes from double queues (because of double QAP).