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Behavior of Codecs for Multicast Video Traffic using WAN Test Bed

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Abstract— **In recent years there has been an exponential increase in the growth in multimedia applications, and in particular in video applications. Understanding the behavior of the video traffic and the requirements for the network helps network administrators to improve the traffic. In this work, a quantitative analysis is performed by experimentation, in order to evaluate the behavior and impact of video traffic on WAN networks. We propose a WAN test bed composed by a video traffic server and several client stations. This article introduces a scenario that allows to inject multicast video traffic, compressed with several codecs. From capturing video traffic, we identified several interesting performance metrics, such as multicast throughput, interframe space and frame size distributions, and the number of frames. We include detailed contributions on the impact produced by several factors, such as the configuration of the resolution of the video, the video class, the codec used for the compression, and the use of multicast traffic when there are restrictions on the bandwidth, as in a corporate real WAN link of some few Mbps. This study facilitates the comparison of the results with those obtained from analytical studies and modelling for different contexts.**

Index Terms——**multicast traffic, video codec, WAN test bed,**

I. Introduction

TODAY, it is possible to receive digital TV with high definition services and a greater number of channels. Recording and sharing videos with mobile phones has also been widespread. Large companies and organizations are using video conferencing applications such as Cisco TelePresence and WebEx, for the face-to-face collaboration in different geographical regions, and even within the same company. Consumers are increasingly demanding in terms of the quality and performance of the video-based products, and therefore, there is a strong incentive for continuous improvement in multimedia technologies.

According to a classification proposed in [1], the video traffic can be (among others): IPTV Broadcast, Live transmission of video event (webcast), IP video surveillance, Interactive videoconference, and Video on demand.

These types of traffic illustrate the variables that need to be quantified for any deployment of video and multimedia: directionality, throughput, latency and jitter tolerance, as well as the number of channels and users. Another key metric is the tolerance for error.

The principal contributions of this article are: i) to specify and experiment on a new WAN test bed as scenario, ii) to quantify metrics over the standard multicast mechanism, and iii) the contributions and conclusions made using a WAN test bed with real equipment.

The rest of this document is structured as follows. Section II introduces some background and related work. Section III provides a general view of video codecs. Section IV describes hardware and software resources of the WAN test bed. Section V presents the results obtained for the performance metrics and the statistical distributions. And section VI summarizes the most significant conclusions.

II. Background and Related Work

The data services are on their way to meet the needs of many users in the network. The voice services are already considered as a necessity by most people. And the data services, video, and TV are rapidly becoming an essential part of the daily life of consumers. It is expected for the 2018 that 65% of the total will be associated with video applications [2].

Various applications make use of growing video traffic in the LAN and WAN networks. Each one of them has its own special characteristics and demands to ensure an adequate level of QoS. There is a large amount of experimental work and simulation carried out that exhibits the behavior of each case, from an analysis of the capture of traffic. For example, in [3] the authors evaluate the performance of three state of the art video codecs on synthetic videos. An extensive number of experiments are conducted to study the effect of frame rate and resolution on codec's performance for synthetic videos. While in [4] a comparative assessment is presented for the two video coding standards: H.265/MPEG-HEVC (High-Efficiency Video Coding), H.264/MPEG-AVC (Advanced Video Coding), and also of the VP9 proprietary video coding scheme using an experimental test bed. In [5] the impact of the H.264 video codec on the match performance of automated face recognition in surveillance and mobile video applications is assessed. Other works evaluated the behavior with an

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experimental study of multimedia traffic performance in mesh networks, for performance evaluation and analysis of wireless networks [6].

In these and other research articles [2-18] there are few papers available on simulation and experimental studies on WAN networks. And to the knowledge of the authors, there are no proposals that combine, in a WAN test bed, with constraints of these links, the problematic of the variants of the codecs for video traffic, with the use of multicast flow. This new experimentation scenario allowed us to obtain the required detail of several performance metrics for this context. Our scenario assumes certain conditions, such as for example, the non-existence of voice traffic or general traffic (both, usually, in a very low proportion with respect to the video traffic), in order to facilitate the comparison and impact of different codecs on the multicast traffic.

III. Brief Description of CODECs

Codec is an acronym for coder-decoder. Describes a specification developed in software, hardware, or a combination of both, able to transform a file with a data stream or a signal. Codecs can encode the flow or the signal for transmission, storage or encryption, and recover or decrypt the same way for the reproduction or manipulation in a format more suitable for these operations. Fig.1 shows a partial progression of the recommendations of ITU (International Communication Union) and MPEG (Moving Pictures Experts Group) standards. In our case study we have worked with the following 3 codecs:

A. H.264/MPEG-4 AVC

H. 264 / MPEG-4 AVC provides a significant advancement in the efficiency of compression to achieve a reduction of around 2 times in the bit rate compared to MPEG-2 and MPEG-4 simple profile. In the formal testing by the JVT (ITU), H. 264 gave an improvement of the efficiency of 1.5x or higher in 78% of the cases and 77% in those who showed improvement 2x or greater and up to 4x in some cases. The 2x improvement allowed H. 264 the creation of new market opportunities, such as: Video VHS-quality 600 Kbps. This can enable the delivery of video on demand via ADSL lines. Provides excellent clarity for the profiles covered by extensions of range of fidelity which extends the levels to "loseless" or very close to this and supports chroma 4:4:4 and bit depth of up to 12. MP4-AVC is more efficient than "Visual Coding" (part 2), MP4-AVC provides better quality at the same sampling rate or equal quality at lowest rates.

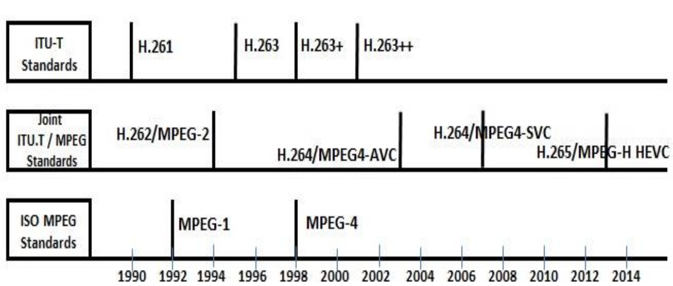

Fig. 1. View of the progression of ITU and MPEG standards.

B. H.263/MPEG-4 PART 2

MPEG4 Part 2 called MPEG4 VISUAL, belongs to the family of standards MPEG-4 ISO/IEC. There are several implementations of this standard, being DIVX, Xvid, Nero Digital the most popular. MPEG4 VISUAL was put on the market with a family of configurations called parties. We are dealing with part 2 which supports three profiles, these are: Simple Profile, Advanced Simple Profile and Advanced Studio Profile. ASP was the profile used in our tests, this allows the use of the following types of visual objects: Simple (rectangular video that uses frames intra and predicted) and Simple Advanced (rectangular video, improved compression and bidirectional frames). Six compression levels are allowed (0 to 5). Levels 0 to 3 have data rates from 128 to 768kbps, levels 4 and 5 added interlaced encoding to achieve rate of 3 to 8 Mbps. MPEG4 VISUAL has a good support for moving image. Concerning the clarity, it places from moderate to very good taking into account that the sampling is limited to 4:2:0 and that MP4 is a lossy compression format. Both video interleaving and progressive are supported.

C. MPEG-2

MPEG-2 was published as ISO standard 13818. MPEG-2 is typically used to encode audio and video for broadcasting signals, including digital terrestrial TV, satellite or cable. MPEG-2 with some modifications, is also the coding format used by commercial discs and DVD SVCD movies. MPEG-2 is similar to MPEG-1, but also provides support for interlaced video (the format used by the TV). MPEG-2 introduces and defines Transport Streams, which are designed to carry digital video and audio through unpredictable and unstable environments, and are used in television broadcasts. With some enhancements, MPEG-2 is also the current standard for HDTV broadcasts.

IV. Experimentation Scenario and Resources

In the present work we experimentally evaluated the performance of streaming of video stored on a WAN test bed.

A. Working Topology

Fig. 2 shows the working topology. It uses a PC as server and 6 PC's as clients. In this topology the links indicated with continuous line are of type FastEthernet with a transmission rate of 100 Mbps, while the links indicated with dashed line are dedicated with serial interfaces to a transmission rate of 2Mbps. For the operation of the OSPF routing protocol v2 between routers R1 to R6 is configured. For the case of multicast, routing protocol PIM dense mode for the same routers was configured.

B. Hardware Resources of Experimentation

For the scenario shown in the topology of work we used desktop computers with the following features: Processor: AMD Athlon(tm) II X2 250 at 3GHz with 2GB of RAM, and Operating System: Windows 7 Professional 32-bit. Routers R1, R2, R3 and R4 were Cisco Model 2811, and Routers R5 and R6 were Cisco Multilayer Model WS-CS3750 switchs.

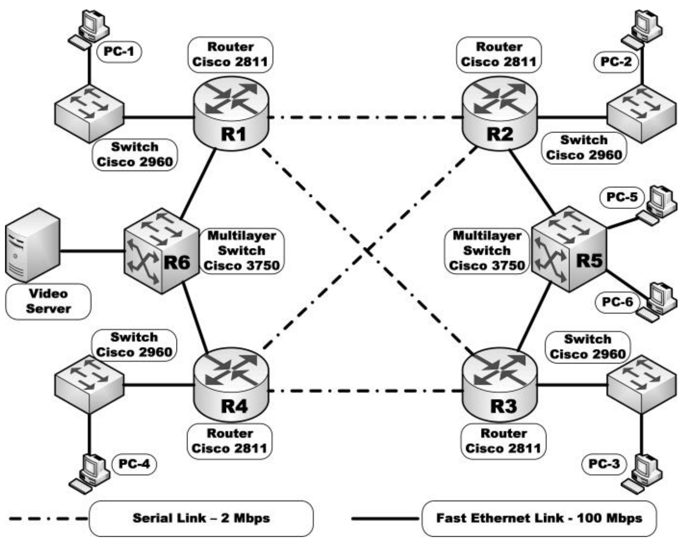

Fig. 2. View of the topology of the WAN test bed.

Finally for the connection of the routers to the PCs Cisco Layer 2 Catalyst Model WS-2950-24 switchs were used.

C. Software Resources of Experimentation

For the experimental development Unreal Media Server [19] v.11.0 was used, and media player v.6.1 as streaming client software. It is a multi-protocol, high performance and small resources footprint software platform for streaming live and on demand audio video content over IP networks. It streams with variety of streaming protocols to deliver content to Flash Player, Silverlight, Windows Media Player, Unreal Media Player, mobile devices and Set-Top boxes. The server supports UMS (proprietary, DirectShow-based, codec-independent) protocol for streaming to Unreal Media Player in unicast and multicast modes, and any multimedia file format, encoded with any codec. Supported container formats include but are not limited to: MP4, ASF, AVI, MKV, MPEG, WMV, FLV, OGG, MP3, 3GP, MOV. Unreal Live Server supports any possible capture device attached to a PC. Capturing network streams over RTSP, RTMP, MPEG2-TS, HLS and MMS protocols is supported as well. Unreal Live Server encodes / transcodes captured audio-video with H.264, VC1, AAC, MP3, WMA codecs and streams it over UMS protocol to Unreal Media Server.

D. CODECs for Experimentation

We used three different codecs, those described in section III, and a commercial video [20] of 29 s with the configurations given in Tables I, II and III.

V. Evaluating The Experimentation Scenario

A. Analysis of the Performance Metrics

Using the test bed detailed in the previous section, a series of experiments were performed transmitting a video encoded with MPEG-4/AVC, MPEG-4 or MPEG-2, from the server to the network in multicast format to six PCs distributed in the network according to the topology of Fig. 2.

TABLE I
Parameter Setting of H.264/MPEG-4 AVC

H.264/MPEG-4 AVC	
Coding options	**Parameter setting**
Video Duration	29 s
Codec Format	MPEG-4
ID Codec	isom
Size file	616 Kib
Bit Rate	169 Kbps
Video	
Codec ID	avc1
Codec ID/Info	Advanced Video Coding
Format	High@L1.1
Bit rate	166 Kbps
Width	176 pixels
Height	164 pixels
Display aspect ratio	1,734
Frame rate mode	Constant
Frame rate	25.000 fps
Color space	YUV
Chroma subsampling	4:2:0
Bit depth	8 bits
Scan type	Progressive
Bits/(Pixel*Frame)	0.231
Stream size	607 KiB (99%)

TABLE II
Parameter Setting of MPEG-4 VISUAL

MPEG-4 3gp6	
Coding options	**Parameter setting**
Video Duration	30 s
Codec Format	MPEG-4
Codec ID	3gp6
Size file	292 Kb
Bit Rate	79.4 Kbps variable
Video	
Codec Format	MPEG-4 Visual
Format settings, Matrix	Default (H.263)
Format	Simple@L0
Bit rate	53.7 Kbps variable
Width	176 pixels
Height	144 pixels
Display aspect ratio	1.222
Frame rate mode	Constant
Frame rate	8.333 fps
Color space	YUV
Chroma subsampling	4:2:0
Bit depth	8 bits
Scan type	Progressive
Bits/(Pixel*Frame)	0.254
Stream size	198 KiB (68%)

Measurements were taken with Wireshark [21] sniffer software on the server and on each client PC, to obtain the following metrics: total time of the video, total number of packets (o frames), total number of bytes, average size of packets, average interframe time of packets and effective transfer rate of each codec.

TABLE III
PARAMETER SETTING OF MPEG-2

MPEG-TS	
Coding options	**Parameter setting**
Video Duration	29 s
Codec Format	MPEG-TS
ID Codec	TS
Size file	724 Kib
Bit Rate	202 Kbps variable
Video	
Codec ID	MPEG
Codec ID/Info	MPEG-2
Bit rate	192 Kbps variable
Width	176 pixels
Height	160 pixels
Display aspect ratio	1,100
Frame rate mode	Variable
Frame rate	60.000 fps
Color space	YUV
Chroma subsampling	4:2:0
Bit depth	8 bits
Scan type	Progressive
Bits/(Pixel*Frame)	0.113
Stream size	676 KiB (93%)

Table IV summarizes the measurements that were captured.

The time video has minimal differences between playing in different PCs as according to the different codecs. The total number of packets, transmitted by the server and received in each PC, are virtually the same for a codec in particular and different PCs as shown in Fig. 3. A difference however is noticeable in the number of packets for different codecs, when representing the average of all PCs for the same codec. MPEG-4 Visual is the one that used the most number of packets, with little difference on MPEG-4 AVC; while for MPEG-2 the number of packets is much lower (33.54% less).

Concerning the total number of bytes, transmitted by the server and received in each PC, they are virtually the same for a codec in particular and different PCs as shown in Figure 4. As in the case of the total number of packets, MPEG-4 AVC is the one which transmitted more number of bytes (or used a larger file size), with little difference with MPEG-2; while for MPEG-4 Visual, the number of bytes is much lower (45.75% less).

With regard to the average packet size transmitted by the server and received in each PC it is noted that they are virtually the same for a codec in particular and different PCs as shown in Fig. 5. On the contrary, for the average size of packets between different codec MPEG-4 Visual has the smallest size (63.58% less than MPG2).

Another important parameter is the average interframe time of packets transmitted and received by the server in each PC. They are quite similar for a codec in particular and different PCs, as shown in Fig. 6. However it highlights a difference in average interframe times between different codecs. The average of all PCs for MPEG-2 is higher compared to other codecs. MPEG-4 AVC has the shortest interframe time (a lower 30.24%).

TABLE IV
SUMMARY OF THE MEASUREMENTS

	Codec	Video Time [s]	Number of packets	Number of bytes [Mbytes]	Average Packet Size [bytes]	Average Interframe Time [s]	Bit Rate Average [Mbps]
Server	MPEG-4AVC	29,7109	906	0,70405	777,10	0,0319	0,18957
	MPEG-4 V	29,9737	913	0,38192	418,31	0,0338	0,10193
	MPEG-2	29,2756	608	0,69526	1143,51	0,0443	0,18999
PC1	MPEG-4AVC	29,7102	906	0,70405	777,10	0,0314	0,18958
	MPEG-4 V	29,9725	914	0,38196	402,89	0,0312	0,10195
	MPEG-2	29,2746	608	0,69526	1143,51	0,0449	0,19000
PC2	MPEG-4 AVC	29,7099	907	0,70410	776,30	0,0311	0,18959
	MPEG-4 V	29,9733	913	0,38192	418,31	0,0310	0,10194
	MPEG-2	29,2747	609	0,69530	1141,71	0,0443	0,19001
PC3	MPEG-4 AVC	29,7078	906	0,70405	777,10	0,0315	0,18959
	MPEG-4 V	29,9819	913	0,38192	418,31	0,0319	0,10191
	MPEG-2	29,2730	609	0,69530	1141,71	0,0461	0,19002
PC4	MPEG-4 AVC	29,7099	906	0,70405	777,10	0,0324	0,18958
	MPEG-4 V	29,9730	914	0,38196	417,90	0,0311	0,10195
	MPEG-2	28,9142	598	0,68141	1139,48	0,0444	0,18853
PC5	MPEG-4 AVC	29,7094	907	0,70410	776,30	0,0320	0,18960
	MPEG-4 V	29,9729	914	0,38196	417,90	0,0322	0,10195
	MPEG-2	29,2745	609	0,69530	1141,71	0,0476	0,19001
PC6	MPEG-4 AVC	29,7096	907	0,70410	776,30	0,0322	0,18960
	MPEG-4 V	29,9730	914	0,38196	417,90	0,0322	0,10195
	MPEG-2	29,2744	609	0,69530	1141,71	0,0476	0,19001
Average	**MPEG-4AVC**	**29,7097**	**906**	**0,70407**	**776,76**	**0,0318**	**0,18959**
	MPEG-4 V	**29,9743**	**914**	**0,38194**	**415,93**	**0,0319**	**0,10194**
	MPEG-2	**29,2230**	**607**	**0,69330**	**1141,91**	**0,0456**	**0,18979**

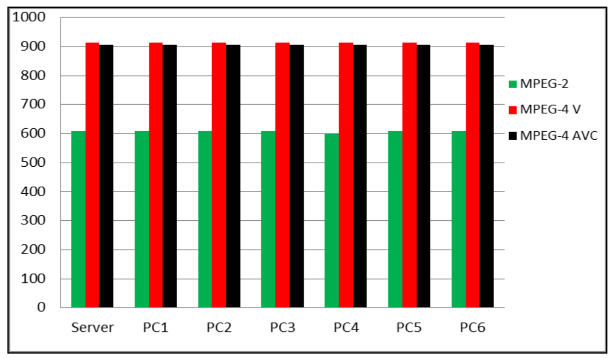

Fig. 3. Packet number for PC.

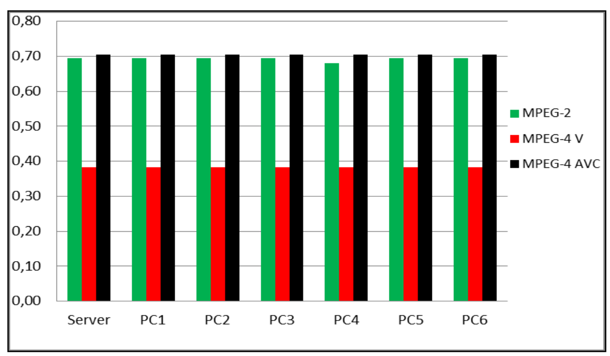

Fig. 4. Video Mbytes for PC.

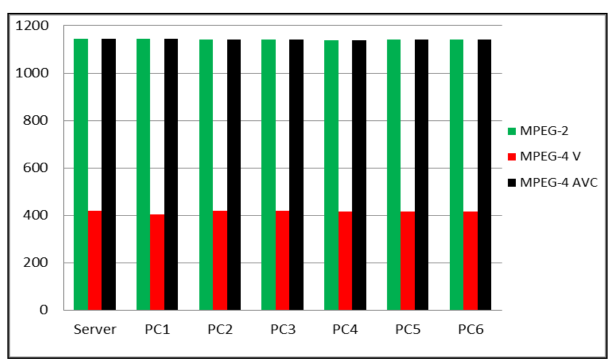

Fig. 5. Average packet size (bytes) por PC.

Finally we analyzed the average transmission rate between the server and each PC, and noted that they are virtually the same for a codec in particular, as shown in Fig. 7. But when comparing average speeds between different codec, MPEG-4 Visual is the one with the least bit rate respect to the other videos (one less 46.29%).

B. Analysis of the Statistical Distributions

We also analyzed the statistical distributions of frame sizes and of interframe spaces for each codec, of the video multicast traffic on one of the stations.

The Fig. 8 and 9 show the distribution of the 906 packets grouped by size and interframe spaces for MPEG-4 AVC, respectively. In the Fig. 8, a significant number of packets has a length less than 500 bytes (35%) and others have 1442 bytes (18%). The rest of packets are distributed in the different lengths between 500 to 1442 bytes. And in the Fig. 9, the highest number of packets is below 5 ms (50%) and between 68 and 78 ms (32%) of interframe spaces.

The Fig. 10 and 11 show the distribution of the 913 packets grouped by size and interframe spaces for MPEG-4 Visual, respectively. In the Fig. 10, a more important number of packets are between 200 and 300 bytes (71%) and other group between 700 and 1000 bytes (20%). And in the Fig. 11, the highest number of packets (39%) has 50 ms of interframe space. Other group has a lower interframe space of 10 ms (21%) and between 25 and 35 ms (30%).

Finally, Fig. 12 and 13 show the distribution of the 609 packets grouped by size and interframe spaces for MPEG2, respectively. In the Fig. 12, the highest number of packets has 1442 bytes (60%). The rest of the packets are distributed in the different lengths between 60 to 1420 bytes. And in the Fig. 13, the highest number of packets is below 5 ms (60%) and in the remaining between 90 and 125 ms (40%) of interframe spaces.

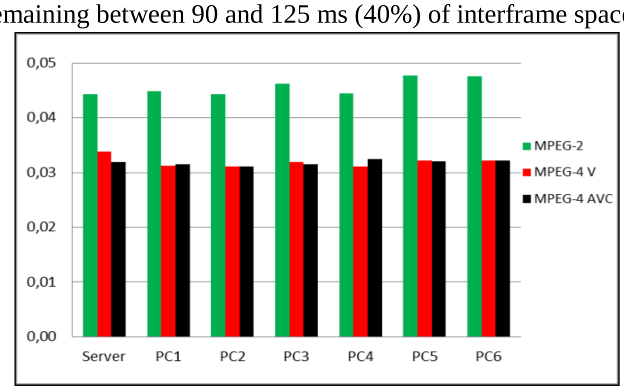

Fig. 6. Average interframe time (s) for PC.

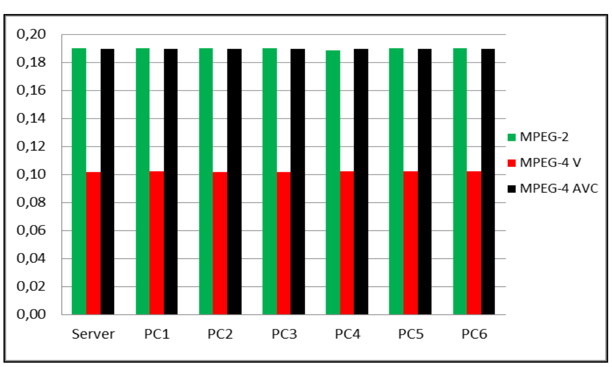

Fig. 7. Bit rate (Mbps) for PC.

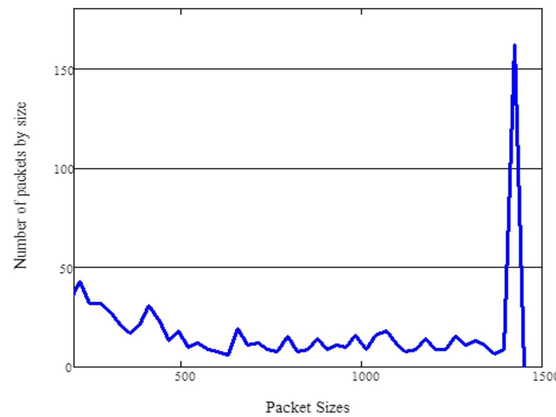

Fig. 8. Distribution of the packets grouped by size MPEG-4/AVC.

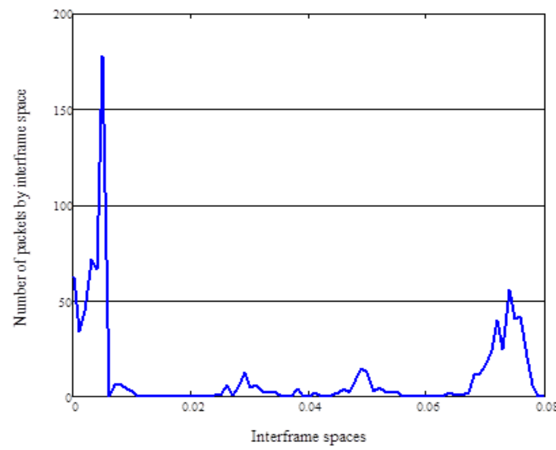

Fig. 9. Distribution of the packets grouped by interframe space MPEG-4 AVC.

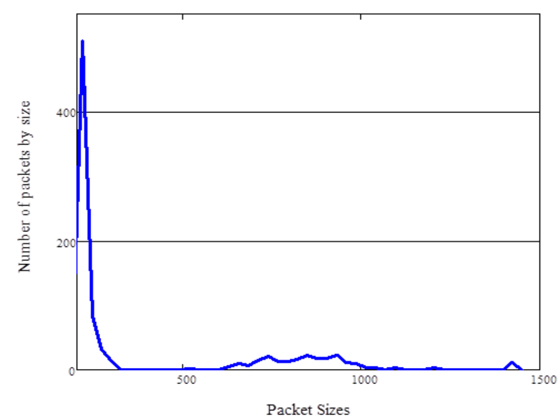

Fig. 10. Distribution of the packets grouped by size MPEG-4/V.

VI. Conclusion and Future Work

This study used a new WAN test bed as scenario offering metrics evaluation while using typical video codecs. Metrics were exhaustively analysed for multicast network traffic in line with the expectations of a real WAN. Direct metrics and their averages, and the statistical distributions were quantified over real equipment. Obtained figures show that the multicast traffic provides the QoS and the performance that is expected over each station using different types of codecs. Differences in the behavior of the multicast traffic are given by differences between codecs, and not by the multicast traffic in itself.

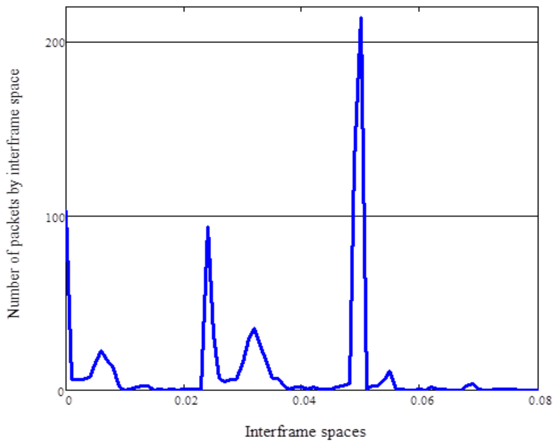

Fig. 11. Distribution of the packets grouped by interframe space MPEG-4/V.

Statistical analysis for this scenario shows that different codecs display a different behaviour in the distribution of packet lengths and of interframe spaces. The impact on the overall traffic of a WAN link depends on the codec used, its setting and in the resulting mixture with others traffics. Results complement, enrich and can be used for comparison with other analytical and of simulation studies over video traffic. We foresee future studies offering a quantitative behaviour evaluation at different 802.11 physical layers. These studies would precisely determine the best general network behaviour for higher Wi-Fi velocities. Finally, a new line of study could be developed regarding the impact of queue length on maximum throughput for each codec.

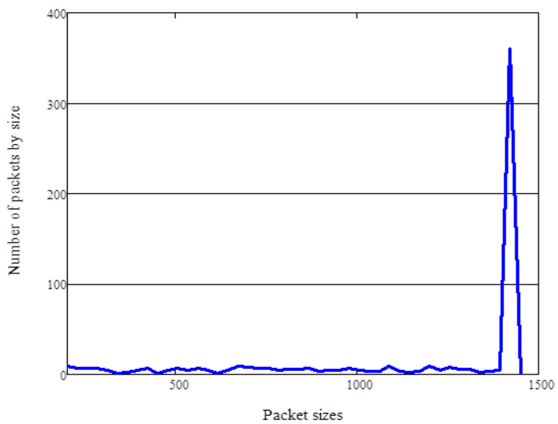

Fig. 12. Distribution of the packets grouped by size MPEG2.

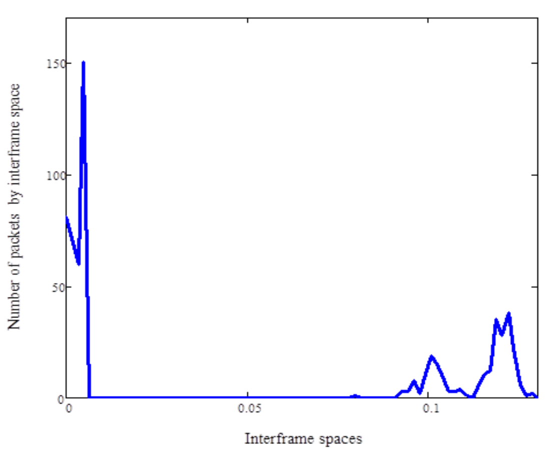

Fig. 13. Distribution of the packets grouped by interframe space MPEG2.

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