Using HTML5 for M-Learning Environments

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Abstract—**Currently, there are several remote learning platforms based on video streaming. In most situations, these multimedia resources are displayed using smartphones that can be wirelessly connected to networks with deficient capabilities. In this scenario, the levels of Quality of Service (QoS) and Quality of Experience (QoE) perceived by users can be very low. Therefore, with the aim of finding the most efficient combination of Web browsers, codecs and containers, this paper presents a study to analyze how the encoding used in videos can affect the network performance in terms of data transfer rate, transmission delays, transmission errors and throughput. The tests are performed using mobile devices with Android as the operating system. Different Web browsers, containers and codecs supported by HyperText Markup Language V.5 (HTML5) are also included in this study. The browsers used in this study are Google Chrome, Firefox and Opera while the containers considered to carry out our tests are MP4 and WebM. Results show that MP4 could be a good option to transmit high resolution videos while WebM would be the best option for low quality videos.**

Keywords- HyperText Markup Language (HTML5); multimedia; m-learning; audio; video; live streaming; codecs.

I. INTRODUCTION

The constant evolution of the industry sector and the Information and Telecommunications Technology (ICT) has led society to require better skilled graduates [1]. This fact is changing the way of teaching. It is changing from traditional methods, based on magisterial classes, to a new way of teaching based on new technologies. Today, electronic devices are an essential part our daily life and they are present in our day-to-day tasks in home environments, the workplace or in the academic field [2].

Blended and remote learning [3] is a new way of understanding teaching. It is characterized by accessing teaching resources from the Internet and personalizing the learning systems, which are designed for either personal computers (e-learning) or mobile devices (m-learning) [4]. Furthermore, e-learning and m-learning are characterized by:

- Their simplicity of use.
- There is no distance between professors and students.
- Their price is affordable for the students.
- They permit the interactivity between professors and students.
- They allow the ubiquity and the access to courses anywhere.

Among digital resources, m-learning, the use of video tutorials and live streaming videos with teaching purposes [5] [6] could be the ones that require knowledge of the network architecture and the features of end devices.

Historically, these platforms have been designed using Adobe Flash to allow the compatibility of this type of content on a greater number of devices. However, many mobile devices are not capable of supporting this technology. HyperText Markup Language V.5 [7] is the fifth major revision of the basic language of the World Wide Web. It is supported on a wide range of platforms and browsers which allows a greater number of devices to be able to access the contents of these learning platforms. The use of this kind of resources implies focusing part of the effort in guarantying the correct reception of content, i.e., reaching good levels of quality of service and quality of experience [8]. Issues in network capacity limit the volume of data the users can receive and thus the quality of video [9]. So, it is important to know the most adequate way of encoding the video to be transmitted.

So, considering the aforementioned arguments, this paper presents a practical study on how the encoding used in videos can affect network parameters such as data transfer rate, transmission delays, transmission errors and throughput when distributing and playing multimedia content in mobile devices, using Android as the operating system. Different Web browsers, containers and codecs supported by HTML5 are also included in this study. The browsers used in this study are Google Chrome, Firefox and Opera while the used containers are MP4 and WebM.

The rest of this paper is structured as follows. Section 2 presents some interesting previous works related to proposals of m-learning tools based on new technologies and practical tests to improve the efficiency in video transmission. The scenario, tools and the videos used to carry out or test bench are presented in Section 3. Section 4 presents the obtained results and a discussion regarding to the results. Finally, Section 5 shows the conclusion and future work.

II. RELATED WORK

This section presents some interesting works related to the use of HTML5 for teaching purposes and different practical experiments where the use of containers and codecs is analyzed for achieving the best QoS and QoE.

The current trend in academic and professional training is the implementation of distance and blended courses [3]. Many of these courses are based on the use of remote labs, video-tutorials [10] and live streaming of videos [11] that students can play on any type of device, i.e., laptops, tables, personal computers and even smartphones. Between all these devices, the one that can present the greatest limitations are smartphones because the connection to access to these teaching resources may be deficient.

Considering these issues, there are several studies related to the optimization of video transmission. One of the most important aspects, regarding these optimization tasks, is the enhancement of QoS and QoE with the use of the most suitable codecs and containers for the type of device and, even the restrictions of the networks. In this sense, I. Mateos-Cañas et al. [12] presented the design and test of an autonomous decision algorithm that was able to analyze video content and network constraints. According to the measurements results, the system extracted the predominant color of the requested video and determined the most optimal compression codec for transmitting the video through that network. The proposal was tested with videos of different resolutions and predominant colors to measure the levels of QoS and QoE. The results showed that codecs, such as H264 (MPEG-4) would be a good option when the predominant color of videos were black or white while XVID [13] would be the best codecs to transmit videos with red, green or blue as predominant colors.

A. López-Herreros et al. [14] presented an analysis about the characteristics of some video compression codecs included in HTML5. The authors analyzed several parameters such as the type of browser, frame rate, bitrate, encoding time and final quality of the video. The results showed that values registered for PAL (Phase Alternating Line) [15] are better than the ones obtained in NTSC (National Television System Committee) [16] system in terms of compressed file size, being very similar in both MP4 (H.264) and Ogg (Theora) for PAL systems while WebM (VP8) results are identical in PAL and NTSC.

Another important front in the field of m-learning is the development of platforms that make easy the access to teaching resources or remote laboratories. N. Wang et al. [17] presented a mobile-optimized application architecture for incorporating remote laboratory practices in M-Learning environments. Through the developed platform, students can perform different experiments in a similar way as they would physically in a laboratory. The system has been developed for different mobile platforms, such as iOS, Android, Windows Mobile and Blackberry. To test the system, authors proposed the realization of practices of proportional–integral–derivative controls. The system was tested using the Baidu mobile cloud testing bed with interesting and successful results.

Finally, M. Truebano and C. Munn [10] evaluated the use of a video tutorial during active learning laboratory-based sessions. The performed study comprised undergraduate students divided into three groups, one that received face-to-face training, one that received training only through the videos and one that received a mix of both methodologies. The tests were performed in terms of behavior, the end result of the procedure and the answers to a questionnaire. Results showed that a blended approach yielded the greatest success when performing the procedure alone. So, video tutorials can be considered as a good tool to complement a blended learning to teach practical skills.

As we have seen through these works, there is a great interest in the development of systems to facilitate the implementation of remote and blended learning. However, none of the proposals and others we have read, present real experiments on video streaming on mobile devices. Therefore, this article tries to collect these values. We think this study can serve as a reference for the development of future remote learning platforms.

III. TOOLS AND EQUIPMENT USED IN TEST BENCH.

This section presents the different pieces equipment as well as the tools used to carry out our test benches.

A. Scenario

In order to perform our experiments and test bench, we have implemented the network shown in Figure 1. It is composed by 2 different mobile Android devices with very similar characteristics but different operating systems. Videos were stored in the server and were transmitted wirelessly to the smartphones. Both devices are connected to a router (192.168.0.1/24), which establishes the link between the end devices and the video server (192.168.0.10/24). Wireless devices are connected using the IEEE 802.11n standard and the connection between the router and server is a Cat5e link.

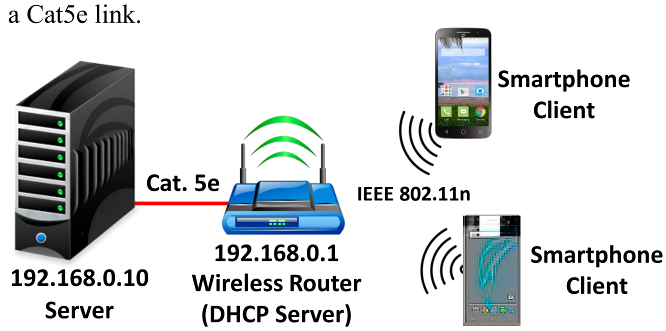

Figure 1. Scenario used during the test bench.

The hardware features of these devices are shown in Table 1.

B. Videos used to perform to tests

In order to carry out our test benches, we have selected a free distribution video developed by the Blender Institute called Big Buck Bunny [18]. The original features of this video are shown in Table 2.

When transmitting videos through Web pages, they are usually adapted to the different devices that requested them. This fact gives us videos with different resolutions. In mobile devices, the kind of networks that give them Internet access should also be considered when video is streamed. Therefore, in order to consider the final quality of the displayed videos, we have encoded the video with different

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codecs. In this case, H.264 [19] and WEBM [20] has been considered in this paper. Regarding to the video resolutions, we have used video resolutions of 360p, 480p, 720p and 1080p. Table 3 shows the characteristics of the encoded videos.

C. Web browsers and mobile operating systems

In order to decide which operating systems and browsers we want to include in our study, it is interesting to firstly analyze their uses. As Figure 2 shows, the number of users of mobile devices (44.2%) is almost the same of Desktop users (52%) in contrast to the number of users of tables which is very low (< 4%) [21]. Regarding the most used operating system (see Figure 3) [22], it is easy to see the predominant domain of Android as a mobile operating system with a percentage of users of 72.23% followed by iOS with a percentage of users near to 24%. Finally, regarding the use of Web browsers [23], Figure 4 shows that Chrome is the Web browser that presents the biggest percentage (47.20%). So, it will be included in our experiments. Firefox and Opera which are also included in our tests present a percentage of 3.35% and 5.01%, respectively.

TABLE I. FEATURES OF SMARTPHONES USED DURING THE TESTS

Device	Smartphone features				
	Model	***Processor***	***Graphic Card***	***O. S.***	***Max. Resolution***
Xiaomi Mi A1	Snapdragon 625 octa-core 2.2GHz	Android 8 One	Android 8 One	5.5”	1920 x 1080
Samsung Galaxy S4	Snapdragon 400 dual-core 1.7 GHz	Android 4.2.2 Jelly bean	Android 4.2.2 Jelly bean	4.3”	540 x 960

TABLE II. FEATURES OF THE ORIGINAL VIDEO USED IN OUR TESTS

Video	Original video features						
	Size	***Original Container***	***Video format***	***Audio format***	***Duration***	***Overall bit rate***	***Width x Height (pixels)***
Original	85.5 MiB	MPEG-TS	AVC	MPEG Audio	56” 382ms	12.7 Mbps	4000x2250

TABLE III. FORMATS, RESOLUTION, FRAME RATE, BITRATE AND SIZE OF THE DIFFERENT VIDEOS USED IN OUR TESTS

Codec	Features						
	Video	***Resolution***	***FPS***	***Bitrate (KBPS)***	***Size (MIB)***	***Video Format***	***Audio Format***
None	Original	2250	60	127000	85.5	AVC	MPEG Audio
		2160	30	3950	77.4	AVC/AAC	MPEG Audio / AC-3
MP4		720	30	1992	13.4	AVC/AAC	MPEG Audio / AC-3
MP4		480	30	965	6.41	AVC/AAC	MPEG Audio / AC-3
MP4		360	30	774	5.16	AVC/AAC	MPEG Audio / AC-3
WebM		1080	30	0.167	12	VP8	Vorbis
WebM		720	30	0.055	5.69	VP8	Vorbis
WebM		480	30	0.021	2.21	VP8	Vorbis
WebM		360	30	0.036	2.61	VP8	Vorbis

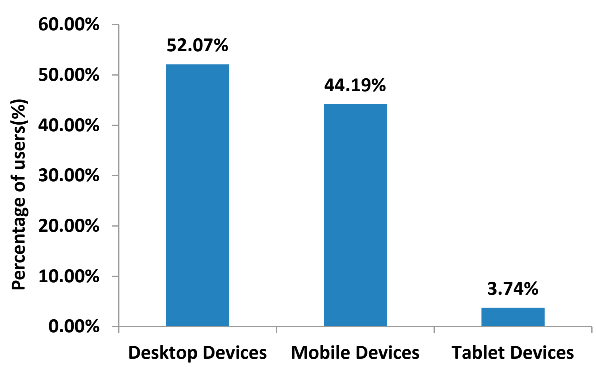

Figure 2. Desktop vs Mobile vs Tablet Market Share Worldwide

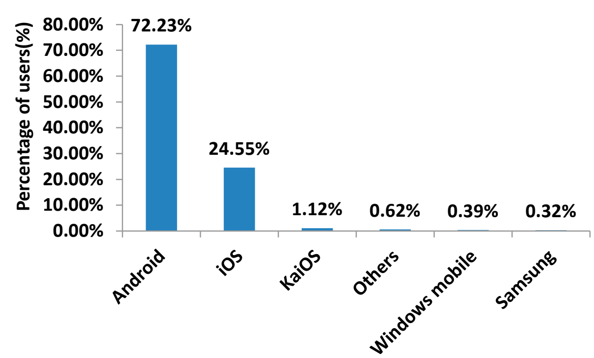

Figure 3. Mobile Operating System Market Share Worldwide

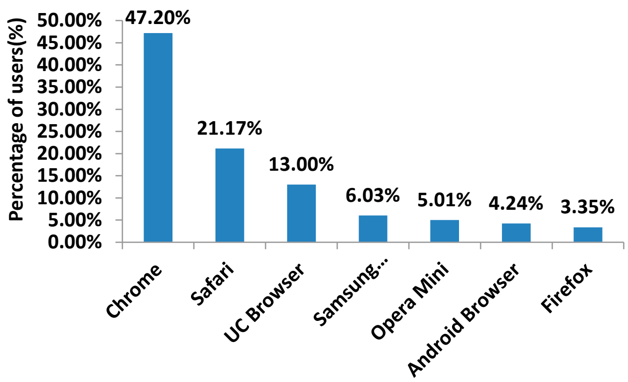

Figure 4. Browser Version Market Share Worldwide

After considering the statistics shown in this section, we decided to use Android as the mobile operating system and Chrome, Opera and Firefox as Web browsers because all of them are capable of supporting the requirements of HTML5 videos.

IV. RESULTS

This section presents the results obtained after performing our tests for both devices using different Web browsers and containers. Results have been divided by operating system, showing the average value of the studied parameter.

A. *Results for Android One*

Figure 5 shows the values of data transfer rate as a function of the video resolution on Android One devices wirelessly connected to an IEEE 802.11n network. As we can see, the browser that, in general, registers a higher data transfer rate is Firefox when using MP4 container, reaching values of 3 Mbps in 720px video resolution. Opera browser in combination to MP4 registers the biggest value of data transfer rate for 720px videos. Comparing the behavior of the three browsers, the one that presents the best values is Chrome with values around 1Mbps for the videos with the highest resolution.

Figure 6 shows the delay (in ms.) as a function of the video resolution for Android One devices. In this case, the browser that presents the worst results is Chrome when videos are encoded using WebM. The combinations that show the best results are the use of Firefox and Opera, using a MP4 container.

Regarding the error rate (see Figure 7), the behavior of all Web browsers and containers present values of error rate lower than 2% being the Chrome-WebM combination the one that presents the worst results with a percentage error of 1.58%.

Finally, Figure 8 shows the throughput registered for Android One devices as a function of the selected browsers and containers. As we can see, the general trend is that the average throughput is between 0.5 and 1.3 Mbps, highlighting the case of Opera- MP4 for 720px videos which presents a value of 5 Mbps.

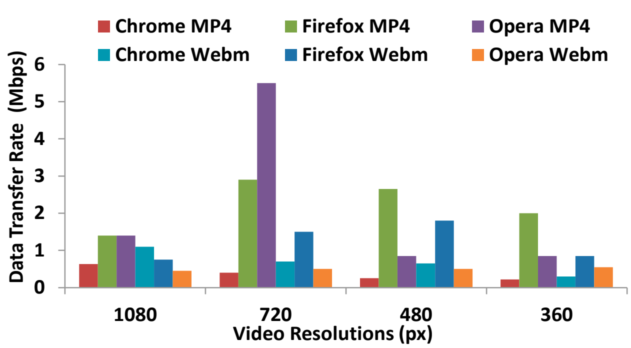

Figure 5. Data transfer rate as a function of the video resolution on Android One

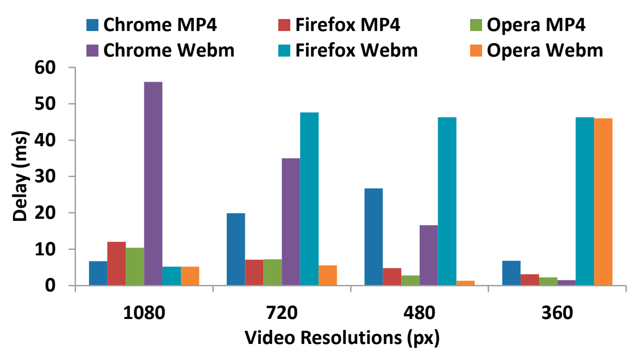

Figure 6. Delay as a function of the video resolution on Android One

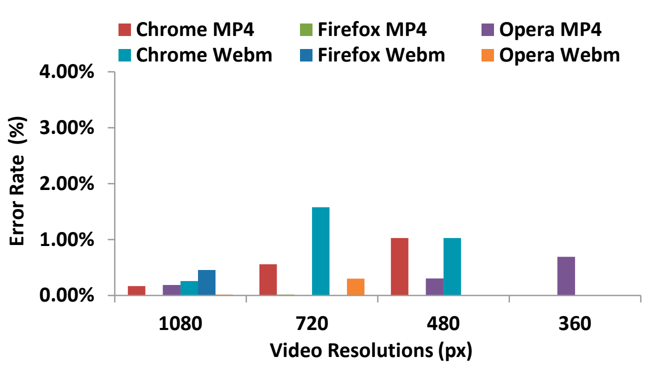

Figure 7. Error rate as a function of the video resolution on Android One

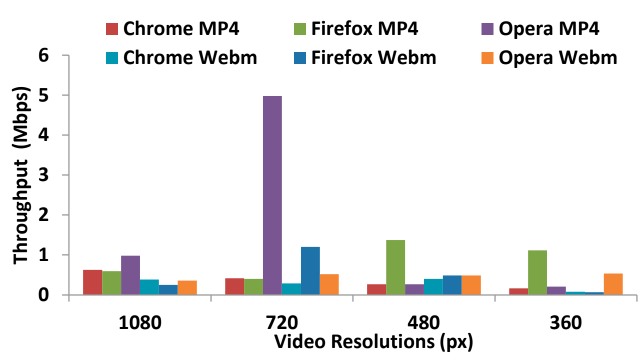

Figure 8. Throughput as a function of the video resolution on Android

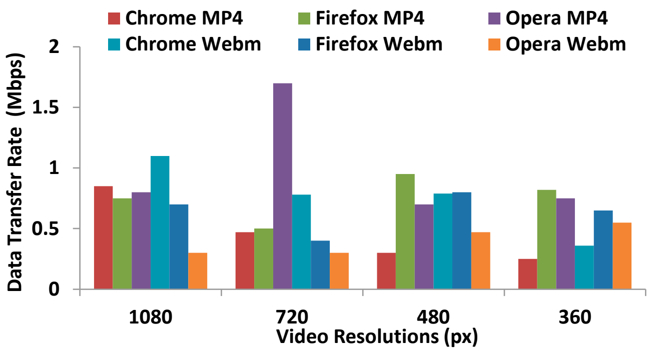

Figure 9. Data transfer rate as a function of the video resolution on Android Kit Kat

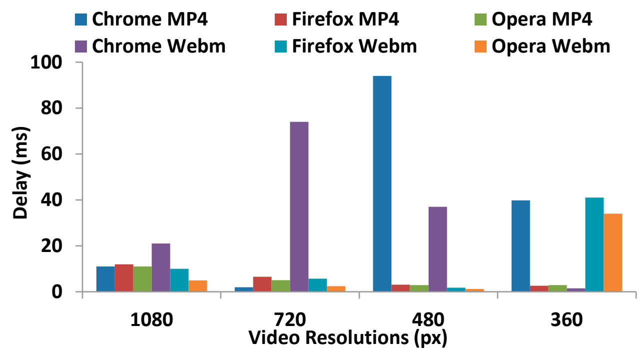

Figure 10. Delay as a function of the video resolution on Android Kit Kat.

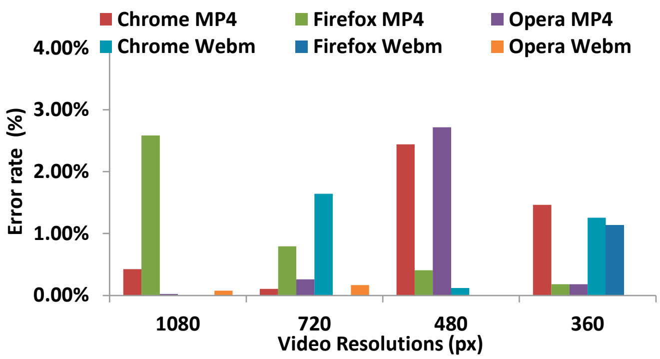

Figure 11. Error rate as a function of the video resolution on Android Kit Kat.

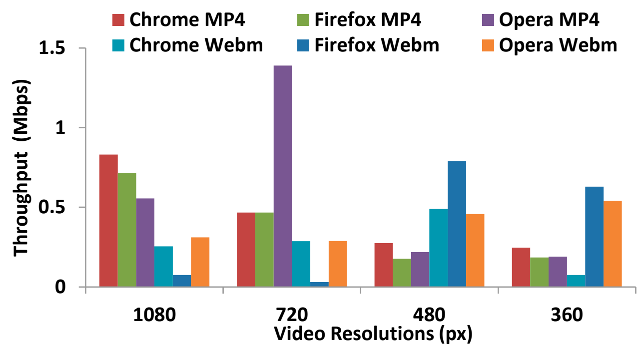

Figure 12. Throughput as a function of the video resolution on Android Kit Kat

B. *Results for Android Kit Kat*

Figure 9 shows the values of data transfer rate in Mbps for different video resolution and Web browsers for Android Kit Kat devices wirelessly connected to an IEEE 802.11n network. As Figure 9 shows, the browser that registers the highest data transfer rate for high resolution videos is Chrome, reaching values of 1.1 Mbps when a WebM container is used. Firefox registers the biggest value of data transfer rate when 480px videos are transmitted using MP4 containers. Finally, Opera browser in combination to MP4 registers the biggest value of data transfer rate for 720px videos. Comparing the behavior of the three browsers, the one that presents the best values is Opera with values around 0.33 Mbps for the videos with the highest resolution.

Figure 10 shows the delay (in ms.) as a function of the video resolution for devices running Android Kit Kat. In this case, the browser that presents the worst results is Chrome when videos are encoded in any of the containers under study, with values higher than 80 ms. For transmitting videos with the highest resolution, the best option is to use Opera in combination to WebM containers, with average values of delay lower than 5ms.

Regarding the error rate (see Figure 11), we can see that the worst cases present values of error rate lower than 3%. Opera in combination with WebM is the combination that presents the best results, reaching values lower than 0.2% in the worst case (values for videos of 720px).

Finally, Figure 12 shows the throughput registered for devices running Android Kit Kat as a function of the selected browsers and containers. As we can see, MP4 is the container that presents the best results for high resolution videos although it is the worst option for transmitting low resolution videos. In contrast to this fact, WebM presents the best results for low resolution videos. Finally, Opera in combination with WebM is the combination that presents the best results for 720px videos, reaching values higher than 1.35 Mbps.

V. CONCLUSION AND FUTURE WORK

The growing interest in the development of remote learning platforms has led to the need of improving the capabilities of networks to facilitate the access of users to multimedia resources and to improve their QoE. To this end, one of the strategies is the choice of the most appropriate codec and container for transmitting multimedia files such as video. Therefore, this paper has presented a practical test bench to analyze the network parameters when videos are processed with different containers for finally reproducing them in different Web browsers based on HTML5. The videos have been reproduced using smartphones running Android One and Android Kit Kat operating systems. After carrying out our tests, we extract the following conclusions:

For the Chrome browser, MP4 is presented as the best container in terms of lower data transfer rate. In terms of delay and error rate, MP4 presents better statistics in high resolution videos while WEBM is the best option for low

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quality videos. In the case of Firefox, MP4 appears as the container with the highest data transfer rate and throughput. However, it has a greater delay and error rate. WEBM is the container that presents the better delay, although the values of throughput and error rate are high. Finally, the use of Opera in combination with the WEBM container presents the best results in terms of delay and throughput while MP4 has better behavior in terms of error rate and data transfer rate for high resolution videos.

As future work, we want to perform similar tests to other kind of devices and operating systems and finally, we think it could be interesting to consider the design of an intelligent algorithm for real-time transcoding [24] to transmit video in different media and platforms based on HTML5 through the new generation of networks (5G) [25].

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