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Proposal of a tool for the automatic estimation of quality of experience in MPEG-DASH scenarios

***Abstract**. Service providers must be able to identify the quality perceived by users through data networks, which is the quality of experience (QoE) required to take the necessary actions to provide a service that meets the user's expectations. Therefore, this article proposes a tool for estimating the subjective QoE from objective parameters of the quality of service (QoS) for the video streaming supported by MPEG-DASH (Moving Picture Experts Group- Dynamic Adaptive Streaming over HTTP). As future work, we propose the extrapolation of the developed tool to video-on-demand services in different application contexts.*

Streszczenie.** Dostawcy usług muszą być w stanie określić jakość postrzeganą przez użytkowników za pośrednictwem sieci danych, czyli jakość doświadczenia (QoE) wymaganą do podjęcia niezbędnych działań w celu świadczenia usługi spełniającej oczekiwania użytkownika. Dlatego w niniejszym artykule zaproponowano narzędzie do szacowania subiektywnego QoE na podstawie obiektywnych parametrów jakości usług (QoS) dla strumieniowego przesyłania wideo obsługiwanego przez MPEG-DASH (Moving Picture Experts Group - Dynamic Adaptive Streaming over HTTP). W przyszłych pracach proponujemy ekstrapolację opracowanego narzędzia na usługi wideo na żądanie w różnych kontekstach aplikacji.* (Propozycja narzędzia do automatycznej oceny jakości doświadczeń w scenariuszach MPEG-DASH***)

Keywords: Adaptive streaming; MPEG-DASH; quality of experience; quality of service.
Słowa kluczowe: Adaptacyjna transmisja strumieniowa; MPEG-DASH; jakość doświadczeń; jakość usług.

Introduction

The services supported in data networks through the Internet have revolutionized society. Among these services, those supported by video streaming technology stand out due to their high demand in different contexts such as virtual education, telework, leisure, and surveillance [1–5]. According to [6] and [7], by 2022 in mobile networks, the global data traffic will reach 930 exabytes, where 79% of the traffic corresponds to the mobile video service. In response to the high demand, cloud computing has emerged, which has become a viable option for local infrastructure, both from the perspective of administration and cost [8–10]. In the same vein, one of the great challenges of data networks is to support the transmission of multimedia services considering the quality of experience (QoE). Therefore, to offer a service with QoE, it is necessary to have tools that can identify the quality perceived by users to take the necessary actions to provide a service that meets the user's expectations; thus, id losing customers.

The International Telecommunications Union (ITU) defines the quality of experience as: "the global acceptability of an application or a service, subjectively perceived by the end-user" [11, 12]. It should be clarified that, for the estimation of the QoE, it is possible to start from both subjective and objective measures, as well as their combination [13]. There are ITU-T recommendations such as the G.107 and the P1203. The first one is known as the E model which allows for evaluating the QoE in services supported by the IP internet protocol, which is used in on-off services such as voice [14, 15]. The second one is established as the first standardized model for the calculation of the QoE in adaptive video streaming services [16]. Since the quality of service (QoS) parameters are fully identified and accepted [17], research on the QoE estimation is based on demonstrating and exploiting the correlation between the QoS and the QoE [18].

Both in services whose behaviour is in bursts as is the case of services supported by video streaming and in traffic systems for video services over UDP (User Datagram Protocol) with a constant bit rate (CBR), the methods used to estimate the QoE are based on a subjective assessment called the Mean Opinion Score (MOS) [19–21]. The MOS, despite being a widely disseminated method for obtaining the QoE, has as weaknesses the time and cost required to carry out the surveys since these are carried out to different user groups under scenarios with special conditions, such as brightness, distance to screens, comfort, etc. [22, 23]. In addition, the QoE is impacted by various factors in the network such as bandwidth, latency, delay variation, lost packets, content type, video encoding type, etc. All of these added to human factors such as the emotional state of the user, the device in which the content is observed, and resolution, among many others, make the process of QoE estimation complex [24, 25].

Then, the estimation of the QoE for video streaming services is an open issue in the research community. There are proposals such as the one presented in [26] and [27], where neither of the two proposals correlates with the QoS parameters, nor do they automatically estimate the QoE. In addition, the second proposal is developed for an exclusively LTE context (Long Term Evolution). Therefore, the contributions of this article focus on the automatic estimation of the QoE from the QoS parameters for the video streaming service supported by the adaptive standard MPEG-DASH protocol (Moving Picture Experts Group-Dynamic Adaptive Streaming over HTTP) [26, 28]. This estimate is an input for the service provider, and it does not automatically adjust video streaming according to user requirements. For this purpose, the automatic quality of experience estimation tool called HESCALEX (Tool for Estimating the Quality of Experience) is developed, and it takes into account the ITU-T recommendation P1203.3. and the parameters of the QoS such as the bandwidth. The HESCALEX tool was developed in the Python language, and it allows the consumption of video streams transmitted through the MPEG-DASH standard. The tool estimates the bandwidth throughout the video consumption in such a way that once the flow associated with the determined bandwidth has been identified, it is in charge of obtaining the QoE for each segment considering the QoS parameters such as the bitrate of each encoding, the identification of the audio and video components, and the bandwidth-bitrate that is used to choose video qualities according to the speed of the network. The proposed tool intends to serve as a reference for its use in experimentation environments with video streaming services that contribute to mitigating weaknesses in the estimation of the QoE through the MOS.

To demonstrate this process, the rest of the article presents in the following order: section 2 illustrates the methodology considered for the development of this worand k, and section 3 displays the results obtained in this reseahat includes the description of the tool operation and the case study carried out; finally, section 4 shows the conclusions and future work derived from this research.

Research method

For the development of this research, four methodological phases were considered: exploration of the ITU-T P1203.3 recommendation on quality of experience, selection of technologies, design, and implementation of the QoE estimation tool; and finally, the case study, see Fig. 1.

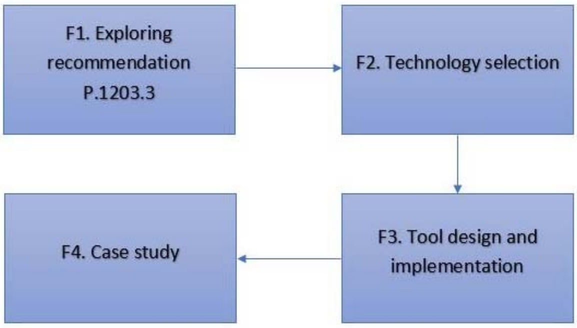

Fig.1. Methodology considered for this research.

In phase 1, the exploration of the ITU-T P1203.3 recommendation was carried tor to determine the QoS attributes needed to consider the establishment of the QoE in adaptive streaming scenarios. In phase 2, a set of technologies were explored and selected for the implementation of HESCALEX in the context of MPEG-DASH adaptive streaming. In phase 3, HESCALEX was designed and implemented over adaptive streaming environments based on the chosen tools considering the ITU-T P1203.3 recommendation. Finally, a case study was conducted where two videos were encoded according to the adaptive streaming standard MPEG-DASH, and the tool was used to estimate the quality of the experience of those videos. The two videos used correspond to categories A and E defined in [29], where category A is described as a person, mainly head and shoulders with limited detail and movement, and category E is described as the greater movement of the object and/or the camera.

Results

In this section, the results obtained through this research are shown. In the first place, the design and implementation of HESCALEX are described; and then, a case study framed in the estimation of the QoE in encoded video content under the MPEG-DASH standard is presented.

A. Tool design and implementation

For the design of the HESCALEX tool, the main requirement is the automatic estimation of the QoE for an adaptive streaming service according to the MPEG-DASH standard. For the consumption of the contents governed by this standard, three elements are needed: coding, hosting, and playback. The video contents used for the QoE analysis must be in DASH format. For this, each video is encoded in 1080p qualities (The "p" means progressive; the frames appear progressively, one followed by another), 720p, 480p, and 360p. In addition, the audio is encoded in a specific format such as AAC (Advanced Audio Coding). Each video with its respective encodings is described in a manifest file called MPD (Media Presentation Description), which establishes the characteristics to consider for video content playback depending on the QoS parameters of the network. This is sent by the server to the client once the latter requests content playback. Fig. 2, shows the MPD file generated for one of the videos used in this research. It describes each encoding with its respective average bitrates, resolution, and bandwidth.

For estimating the QoE, certain information must be extracted from the MPD file such as the bitrate of each encoding, the identification of the audio and video components, and the bandwidth-bitrate that is used to choose video qualities according to the network speed.

```
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     <SegmentBase indexRangeExact="true" indexRange="936-1663">
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     </SegmentBase>
    </Representation>
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bandwidth="4983886">
     <BaseURL>entrevista_1080_track1_dashinit.mp4</BaseURL>
```

Fig.2. Content of the MPD file.

In Fig. 3, the flow chart that represents the operating process of the HESCALEX tool is presented. Initially, the URL of the video MPD file to be analysed is entered. Then, the presence of the variables required for the analysis within the MPD file is examined. Thus, ensuring that the tool performs the analysis properly. The parameters are stored, and the bitrate size and the variable bitrate are calculated for each video encoding. In this way, the value that the network bandwidth must have to select the corresponding video encoding will be known. For example, when the network speed is very low, the video encoding with the lowest quality is selected. The next step is to identify the coding indexes whose value is important to determine, within the tool, the corresponding index to each coding or video quality. One option that is given to the user is to manually set the bandwidth values to analyse a specific video quality. The following process defines how many seconds of the video are needed to analyse. In that sense, when working with the MPEG-DASH protocol, there is a parameter called chunks that is responsible for dividing the video into small pieces defined by units of time in seconds. This value depends on the video encoding. The chunks are taken by the tool with timeslots as its label.

The quality scale from 1 to 5 is used for all the results, where 1 means poor quality and 5 means excellent quality as presented in [29]. The ITU-T P1203 recommendation specifies the variables named O.35 and O.46 for the final quality score of the audio-visual coding and the quality score of the final media session respectively. Considering the latter, the analysis module is executed where an estimate of the network bandwidth (BW) is made and the QoE calculation is carried out in such a way that all the variables obtained in this module as the bitrate, variable bitrate, coding indexes, BW, timeslots, O.35, and O.46, are stored in a dictionary for generating a report of both graphic and text results.

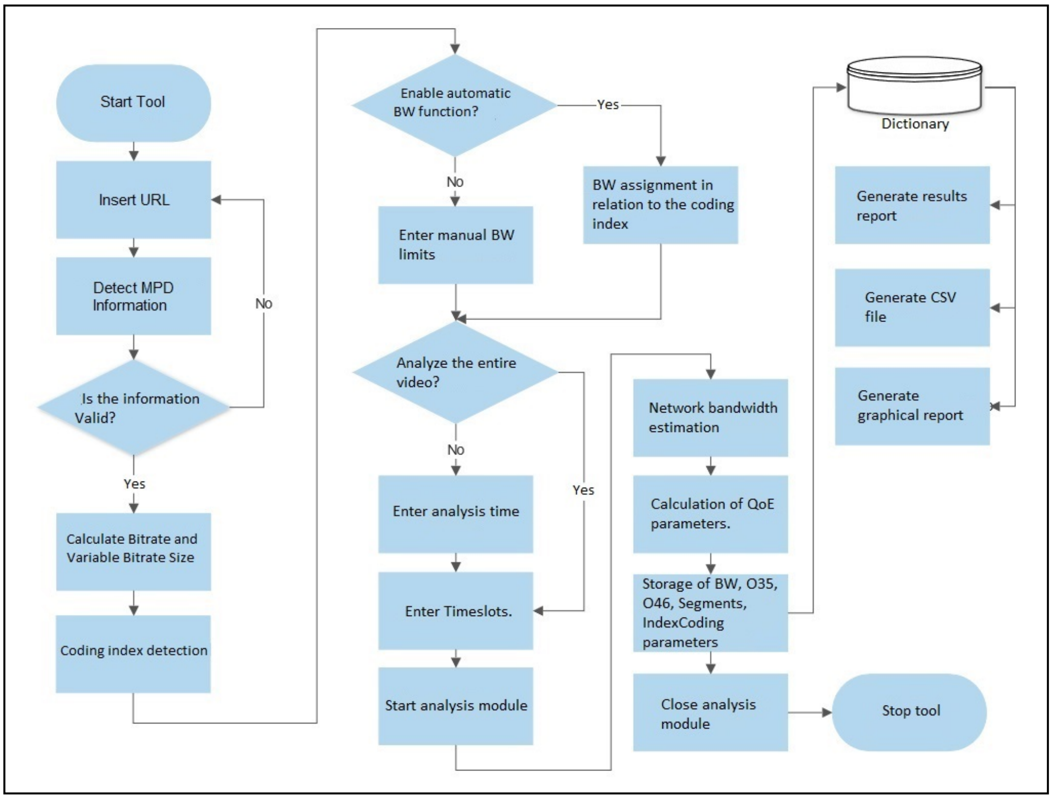


Fig.3. Flow diagram for the HESCALEX tool

On the other hand, Fig. 4, shows the end-to-end diagram of the video consumption scenario in which the HESCALEX tool is framed; it fulfils the MPEG-DASH client functionality in the client-server architecture (see Fig. 4). For the logical process of the tool, the detection and analysis modules are created, which carry out specific functions for each process within the tool; that is, in the detection module, the necessary data is acquired on the video and audio encodings from the MPD file. This module is very important because according to the value of the index in which these encodings are specified, the precision of the results will depend on the estimation of the QoE. In addition, the videos in MPEG-DASH format do not always have the same indexes. There is also an encoding classifier that is responsible for organizing the information according to the bitrate size of each video within the MPD file. In this way, each bitrate can be related to specific video quality, so that the encoding selector found in the analysis module can select the correct video quality to be evaluated by the QoE analyser. All information from the detection module is stored for being used by the analysis module. The operations carried out by the detection module are carried out through the ffprobe library, which is executed as a service in the Linux operating system where the proposed tool is executed.

The analysis module is responsible for estimating the network bandwidth. Depending on the information from the encoding classifier, the appropriate video quality is chosen at the network speed through the encoding selector and then the model of the ITU-T P1203.3 recommendation is applied to perform the QoE analysis. The encoding selector is implemented using the free ffmpeg library. Then, using the code available in the P1203-Standalone repository described in [26] and [30], the QoE estimation process is carried out using the QoE analyser. Likewise, the bandwidth estimator was possible to implement thanks to the speed test-cli software, which is executed as a subprocess. Finally, the data is stored to view the report of the results obtained from the complete analysis of the video, which is presented graphically through the Python matplotlib libraries, where the data related to bandwidth, QoE, video encoding quality, encoding index, and bitrate size are shown. The libraries and repositories used for this tool are implemented on the Ubuntu Linux operating system.

Considering the process of operation of the modules explained previously, the estimation of the QoE on a video encoded in DASH format must be carried out by requesting the MPD file that is hosted on an HTTP server, where the video encoded in different qualities together with its respective MPD description file must be found.

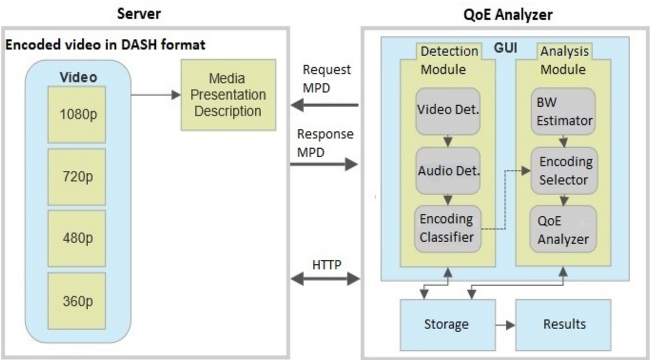


Fig.4. Block diagram.

The user graphical interface of the HESCALEX tool is displayed in Fig. 5, where the text boxes to enter the parameters such as the URL of the MPD file, the bandwidth limits, the length of the video, and the timeslots can be seen. When the URL of the MPD file is entered, all its information must be obtained through the Detect button, the tool will automatically detect the number of video indexes, so the corresponding bandwidth text boxes will be enabled to enter the data manually or automatically. Then, the parameters such as video length and timeslots must be entered. It must be highlighted that the default time of the timeslots is 5 seconds due to the variation of the chunk time in MPEG-DASH. This time usually varies between 2 to 5 seconds, and it is possible to perform a complete analysis on the entire segment of the video by using 5 seconds. The Start button must be used for estimating the QoE, so the tool will carry out the entire process shown in Fig. 3, autonomously. During the process, the status of the analysis with the previous results can be seen in the text window at the bottom; that is, the generation of results reports. At the end of the process, it is possible to generate a graphical report as well as a report in CSV format; it is also possible to save a record of the entire interface text window.

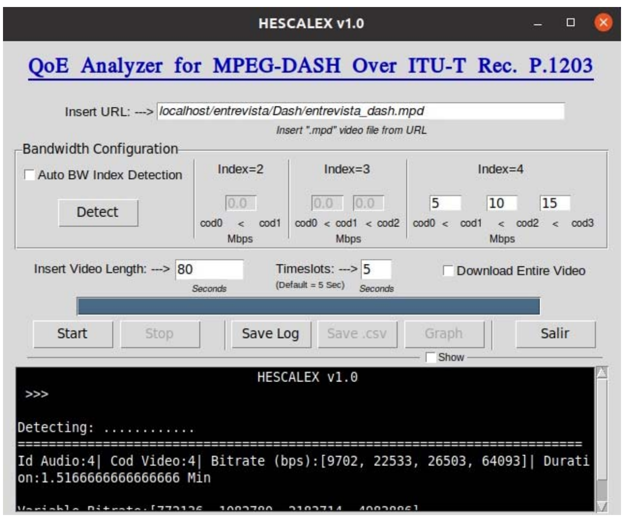


Fig.5. User graphical interface of the HESCALEX tool.

B. Case study

For the case study, 2 videos from different categories were chosen. One is an interview-type video, and the other is a sporting event video (soccer match). These videos were particularly chosen because they represent a great difference in their content. Interviews usually have limited content in detail and image movement while a soccer match has many detailed objects and a high camera movement. According to the ITU-T 910 [29] recommendation, these videos are classified as category A for a video interviews and category E for sporting events.

To achieve the QoE estimation, the videos were encoded in MPEG-DASH format through the free Linux MP4Box tool. There, a series of parameters are established that allow encoding the videos in different qualities, in addition to obtaining the descriptive MPD file required by the HESCALEX tool. The qualities used for these videos are 1080p, 720p, 480p, and 360p, considering that these are the most used video streaming services on the Internet [31]. It should be noted that the audio must also be encoded separately since the MPD file is responsible for managing both the video and the audio depending on the conditions of the network in which the video is played. Fig. 6, shows the result of the MPEG-DASH encoding for both videos, where they are stored on a web server for later accessing the respective MPD file through any network scenario.

Fig.6. Video files encoded in DASH format.

Table 1. Analysis results for the category A video.

Segment	Encoding quality	QoE	Bandwidth (Mbps)	Encoding index
1	5	4.827	37.05	3
2	4.836	4.683	30.25	2
3	4.827	4.676	32.41	2
4	4.839	4.685	34.52	2
5	4.701	4.576	30.28	2
6	3.018	3.054	21.34	0
7	5	4.846	35.19	3
8	4.780	4.639	33.99	2
9	4.715	4.587	32.22	2
10	3.000	3.026	15.55	0
11	4.816	4.668	32.73	2
12	4.829	4.677	33.81	2
13	4.820	4.670	33.44	2
14	2.961	2.979	10.39	0
15	3.452	3.480	25.47	1
16	4.250	4.187	31.28	2

C. Category A video results

The estimation of the subjective QoE from the QoS objective parameters shows that network fluctuations have a high impact when consuming a multimedia file. This parameter also influences the type of content being evaluated. In Table 1, the results obtained through the HESCALEX tool corresponding to the interview video are presented. 80 seconds of video are analysed, which are divided into 16 segments of 5 seconds each. Additionally, manual assignment of bandwidth limits is performed to evaluate the performance of the encoding selector in case the network speed changes. It is established that speeds greater than 35Mbps enable encoding index 3, speeds between 35Mbps and 30Mbps enable index 2, speeds between 30Mbps and 25Mbps enable index 1, and values below 25Mbps for index 0.

From the results presented in Table 1, HESCALEX generates the curves shown in Fig. 7.a. A comparison can be seen between the bandwidth speed with the MOS of each segment of the evaluated video.

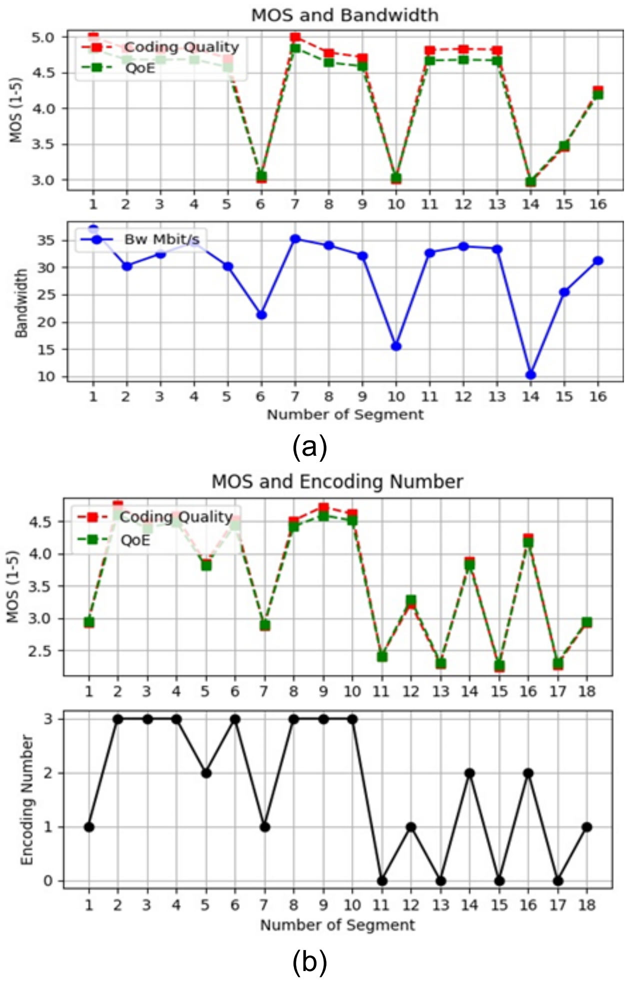


Fig.7. Category A video: (a) MOS vs video segments and network bandwidth. (b) MOS vs encoding used for each video segment.

As can be seen in Fig. 7.a, the fluctuation of the network speed has a negative impact on the QoE of the video service, verifying how the adaptive streaming protocol MPEG-DASH adapts to the conditions of the network, sacrificing the video quality which in turn has an impact directly proportional to the MOS that determines the QoE. It is also possible to show how the encoding quality parameter represented by the red lines is usually higher than the quality of experience since it qualifies the quality of the encoding of the video file, but not the consumption of the service through the network as the QoE does. In video segments 7 to 9 and 11 to 13, it can be determined that with a stable speed there are no variations in the quality of the service experience since they remain above 4.5 according to the MOS scale, but when the Network speed decreases considerably, the most affected video segments are 6, 10, and 14 with an average MOS of 3.1. It should be remembered that this is a class A video, and it does not have much detail and movement in the image, so a MOS rating with a value of 3 is considered acceptable. In Fig. 7.b, the operation of the analysis module can be evidenced using the encoding selector, where the video encodings adapt to the variation of the network speed and consequently have a proportional direct impact on the MOS that determines the QoE.

D. Category E video results

In Table 2, the results obtained through the HESCALEX tool corresponding to the category E video are presented. Here, 90 seconds of video are analysed, which are divided into 18 segments of 5 seconds each. For this test, the selection of encoding through bandwidth is done automatically on a lower-speed network.

Table 2. Analysis results for the category E video.

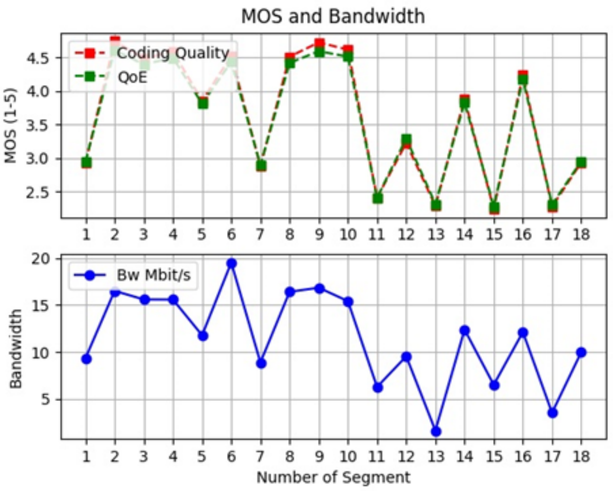
Segment	Encoding quality	QoE	Bandwidth (Mbps)	Encoding index
1	2.924	2.946	9.33	1
2	4.748	4.612	16.5	3
3	4.484	4.398	15.59	3
4	4.594	4.496	15.58	3
5	3.855	3.813	11.78	2
6	4.524	4.436	19.51	3
7	2.883	2.897	8.89	1
8	4.513	4.420	16.4	3
9	4.726	4.595	16.84	3
10	4.618	4.515	15.41	3
11	2.412	2.410	6.28	0
12	3.226	3.293	9.54	1
13	2.287	2.316	1.64	0
14	3.884	3.828	12.38	2
15	2.244	2.283	6.51	0
16	4.242	4.181	12.12	2
17	2.277	2.307	3.53	0
18	2.935	2.906	9.97	1

As presented in Table 2 and Fig. 8.a, the MOS presents values above 4 when the network speed is above 15 Mbits/s ensuring a good video quality for the client; however, segments 11, 13, 15, 17, and 18 present a MOS below 2.9 which is classified as poor service. From the above, it can be inferred that since it is a class E content, it is more susceptible to fluctuations in network speed; therefore, it has a worse rating in its QoE. In Fig. 8.b, it is possible to observe the correct operation of the encoding selector of the analysis module, where the video encodings are adjusted to the speed variations of the network. Something very important to consider is that if the encodings are of the same quality, it does not mean that they must have the same QoE; there are always variations depending on the type of content. That is why the QoE obtained for category A video is much more stable than the QoE obtained for category E video.

According to the previous results, it is observed how the MOS that estimates the QoE through HESCALEX is affected directly proportional to the fluctuations of the network variation. However, it should be noted that the category E video has a greater impact on the QoE than the category A video due to the difference in the scene movements which are greater than those of category E.

As seen in the results, the tool proposes a different approach concerning traditional QoE estimation methods [15, 32] where, through a graphical interface it is possible to operate and manage the processes and the results of the required QoE estimations, in addition, its design basis is given by a standardized estimation model [16, 26], achieving reliable and consistent results.

a)



b)

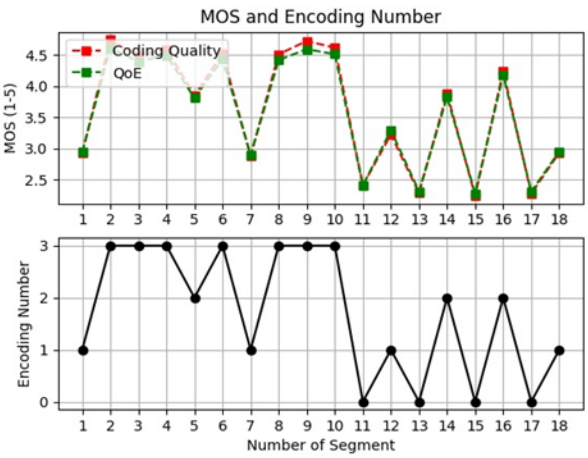


Fig.8. Category E video: (a) MOS vs video segments and network bandwidth. (b) MOS vs encoding used for each video segment.

Discussion

Considering that one of the challenges of modern telecommunications networks is to adequately support and manage the traffic generated by multimedia services, it is necessary for telecommunications service providers to guarantee a good quality of experience (QoE) and to have tools that allow automatic QoE estimation. In this sense, in this paper we propose as a contribution the automated tool HESCALEX, which allows the automatic estimation of QoE over MPEG-DASH adaptive streaming scenarios, which are suitable for the deployment of high traffic demand services, such as video-on-demand or live video services.

With respect to state-of-the-art works such as those presented in [26] and [27], where the QoE is obtained without considering QoS parameters, the proposed tool has the contribution of linking QoS parameters such as bandwidth for the determination of MOS. In the same way, this proposal is a contribution at the level of automation with respect to the traditional methods of determining the MOS, which are based on the execution of surveys to the end user, after consuming a video service.

Conclusions

This article proposes an automated tool for estimating the quality of the QoE experience on adaptive streaming MPEG-DASH scenarios called HESCALEX, which considers the QoS parameters to determine the MOS. In this sense, the proposed tool intends to serve as a contribution to the enrichment of conventional methods for the determination of MOS that have as a problem the time and cost of the surveys due to the deficiency of veracity or error margin of the user opinions.

The proposed tool has chosen a set of libraries and technologies from the free software context, which articulated within the tool allows to carry out the bandwidth estimation processes, analysis of the QoS parameters associated with the selected bandwidth, calculation of the MOS of each segment, generation of graphs with the MOS trace throughout the video content, and generation of reports. The tools and libraries selected are intended to serve as a basis for replicating the quality of experience analysis in other scenarios or video distribution services such as live video.

The case study developed in this article made it possible to verify the usefulness of the tool to estimate the quality of the experience in different types of videos encoded using the MPEG-DASH standard. Thus, evidencing the typical degradations of adaptive streaming in the quality of experience. The results obtained show that when the scenario conditions are not adequate or the QoS parameters are not stable, the QoE tends to vary considerably.

As a future work derived from this research, it is intended to extend the functionality of the developed tool in functional terms such as video analysis in very high resolutions (4k, 8k), as well as the use of different video and audio codecs, in addition to including the tool to other contexts related to video on-demand services such as video on demand services derived from OTT platforms like Netflix, Amazon Prime, Disney+, among others. Likewise, it is convenient to characterize live services in diferent application context that use open standards or proprietary adaptive streaming.

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