Influence of Resolution and Frame Rate on the Linear In-Stream Video Ad QoE

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Contribution to the state of the art

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Abstract: An increasing number of services and facilities that are of interest to users is based on video streaming. Technical characteristics of video have a strong impact on the quality of a video streaming service and its perception by users. The most important measure of quality, which focuses on the user, is the Quality of Experience (QoE). Given that video advertising is a typical video streaming application, it is necessary to analyze the effect of the change of video characteristics on the QoE. This paper examines the impact of resolution and frame rate change on the QoE level by using objective and subjective QoE metrics. It also looks at the possibility of mapping the objective QoE metrics into subjective ones, if the QoE in Internet video advertising is analyzed. It was demonstrated that the values obtained by the objective assessment of quality can be mapped to the results obtained by subjective assessment of quality when the quality of experience of linear in- stream video ads is analyzed. The results indicate that temporal aspects of video quality assessment, e.g. influence of resolution and frame rate change to the level of the QoE, can be achieved by implementation of objective methods. Therefore, quality of experience can be improved by the proper selection of video characteristics values.

Keywords: Quality of Experience, Quality of Service, Linear Internet Video Ad, Objective and Subjective Video Quality Metrics

Introduction

Internet video streaming is one of the fastest growing business concepts and it has the largest share in the Internet traffic realized so far. The users have to be satisfied with the viewed content, and the marketed services must be profitable as well. Therefore, it is necessary to ensure the maximum possible level of customer satisfaction in circumstances where it is influenced by the transmission, video compression, content type, user devices, and many other factors [7]. This problem is greater when different services and business concepts are integrated, which is a trend in modern Internet communication and business.

Unlike Quality of Service (QoS) concept, which has been a subject of research in the field of information technology for a long time, and which is clearly defined and studied in detail, it can be said that a precise and universally accepted definition of the QoE does not exist yet. The working definition of the QoE states: "The quality of experience is the degree of users' satisfaction or dissatisfaction with an application or service. It is the result of fulfilling their expectations in terms of certain benefits and/or entertainment provided by using the application or service, whereby everything is considered in relation to the personality and character of the user and his/her current condition" [5]. It is important to emphasize that the QoE strongly depends on the content delivered to users, as well as the area of application. Unlike the QoS parameters that are primarily influenced by technical features of the system, the QoE parameters are influenced not only by technical aspects, but also by the subjective perception of the users' needs and users' behavior models, the adequacy of the content, context, the opportunities for content placement, etc.

The quality of video and quality of video service is commonly assessed by using subjective tests. These tests involve the presentation of test video sequences in a controlled environment and their evaluation by the respondents. It is obvious that these procedures are complicated and time-consuming, so it is necessary to investigate the methods to automate and speed up the process. Introducing the objective metrics, the expensive and complicated tests and a subjective evaluation of the results can be avoided. Some objective metrics can provide results that correlate highly with human perception of the video. The result of assessment obtained by using objective method is commonly referred as the objective quality of experience [12]. Both methods of evaluating quality of experience are important in their own way, so the best solution is to combine both methods as much as possible. In addition, it is desirable to compare and interpret the results obtained by using both methods in the best possible way.

This paper is organized as follows. In the second section, the important characteristics of linear in-stream video ad QoE are introduced and methodology for mapping objective QoE metrics into subjective QoE metrics is presented. In the third section, method for assessment of influences of resolution and frame rate change on linear in-stream video ad QoE is proposed. The experimental results are presented in fourth section. And, finally, we outline the conclusions.

Linear In-Stream Video Ad

Linear in- stream video ads, as one of the most common methods of placing video ads, are analyzed in detail in terms of the use of different modes of ads delivery in relation to the main content that the user consumes. In its recommendations, Interactive Advertising Bureau (IAB) defines appropriate guidelines, standards and best practices of digital video in-stream video ads [1]. Two categories of recommended characteristics can be emphasized: characteristics concerning the format defined by IAB and other technical characteristics of video ads, such as resolution, types of codec, number of frames per second, color depth, etc.

Temporal aspects of linear in-stream video ad

Three basic formats of linear in- stream video ads are: pre-roll, mid-roll and post-roll video ads. Pre-roll video ads refer to the display of video ads before the video user wants to consume; mid-roll ads refer to the display of ads during consumption of the video; and post-roll ads to display of ads after the desired video has been viewed. These video ad formats and their impact on the level of users' attention represent an important time aspect of video ads. Duration of video ads is also an important feature that contributes to the QoE analysis from the point of impact of the factors related to the temporal aspect of the Internet video consumption.

In addition, various technical features of video ads, as well as their recommended range of values, are presented in the IAB recommendations. Characteristics of video ads usually comply with the characteristics of the basic video. Bearing in mind that the recommendations refer to a large number of characteristics with different values, it is desirable to analyze the impact of some video ads parameters that can directly affect the level of customer experience. The implementation of appropriate values of certain technical characteristics as early as the phase of Internet video ad modeling could provide the maximum possible quality of users' experience with the viewed video. The aforementioned characteristics of video ads are the basis for the definition of the metrics that can also be used for the study of the efficiency of video advertising.

QoE and QoS of linear in-stream video ad

QoE does not just represent an extension of QoS concept, but it can be used also a particular component in the evaluation of the quality of the application and service. Although the QoE is dependent on many factors (subjective, psychological, cognitive, social, environmental, etc.), the ones that directly impact the level of the QoE are the QoS parameters (video bit rate, packet loss, jitter etc.). For this reason, when designing video ads, attention must be paid to the characteristics of the videos that differently influence QoS and QoE. It is also essential to determine the possibility of establishing correlations between QoS and QoE parameters.

The possibility of a connection between the objective and subjective methods of evaluating the quality of experience is indeed of great importance, and mapping of appropriate values is one of methodologies often used for this purpose. The value of the QoS parameters, which can be easily monitored and controlled, should be mapped into the values which are difficult to control, as is the case with the QoE parameters. Mapping QoS parameters into QoE parameters allows for easier and more complete evaluation of multimedia services and applications.

In general, Internet video services, the mapping of the QoS parameters to QoE parameters is based on the layered protocol stack, Figure 1. It is a known that the QoS refers to a set of measures whose objective is to improve the network performance, as well as the performance of the system and application. Therefore, we can talk about the network, system and application layers of the QoS. The authors in [16] illustrated the complexity of the QoS and pointed out that the QoS application parameters directly affect the QoE. The mutual relationship between QoS and QoE in terms of the impact of QoS parameters of the different layers on the level of the QoE is shown in Figure 1.

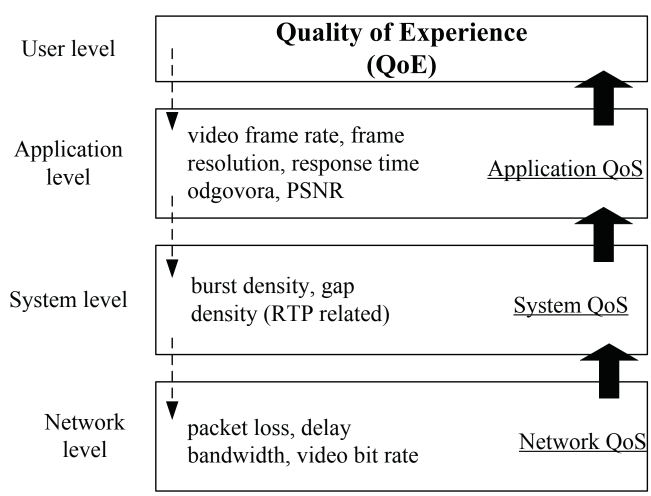

Figure 1. QoE and the layered protocol stack QoS, [16].

Arrows in Figure 1 illustrate the impact of QoS on QoE and vice versa. It is obvious that there are effects in both directions. Due to the stratification of QoS, it is important to identify QoS factors in the protocol stack, as well as their potential impact on the QoE. The QoS parameters that are present in different layers can be mapped into each other, and in this way the effects of the parameters of the lower layers are transferred to the higher ones. Hence, direct and indirect influences of environment, that are expressed with QoS, to the user's QoE, are both present. On the other hand, QoE factors do affect the QoS. This effect can be described as an impact of users' specific requests and responses regarding the offered service on the modification of the QoS parameters.

Translation between the Application QoS parameters and users QoE is often called service adjustment. Service adjustment enables the video to be displayed at the appropriate level of perception quality (high, medium or low). In addition, it enables the internal mapping of the quality of perception of video into the Application QoS, along with the use of media characteristics such as frame rate and resolution. Service providers adjust the values of the system and application QoS parameters in accordance with the rules of translation between them. For example, if the bandwidth is changed, the service provider adjusts the frame rate or resolution to fit the current situation in order to provide the required level of the video quality [13]. This directly affects the level of customer satisfaction, or results in the changed level of QoE.

The process relevant for this study is mapping of QoS parameters of the application layer into the user's QoE parameters, or precisely the impact of frame rate and resolution change in video with in-stream video ad to the user's quality of experience. It is assumed that the parameters of the remaining layers have constant values.

Mapping objective into subjective QoE metrics for linear in-stream video ad

Classification of objective metrics in three categories (*Full Reference-FR, Reduced Reference-RR the No-Reference-NR)* is mainly motivated by the availability of reference video sequences. When it comes to Internet video advertising, many forms of video are available for the realization of an experiment aimed at evaluating the quality of experience in a simulated environment, as well as for the realization of advertising campaigns. For example, not only original, ("reference" or "undamaged") video ads are available, but also video ads that users will consume after their placement ("degraded" video ads). These two video contents (reference video ad and placed video ad) can be compared using full-reference metric.

One of the full-reference metrics is the SSIM (Structural Similarity Index Metric), presented in a study [17] where image is the subject of analysis, whereas another study [15] demonstrates that when SSIM is used, there is a high correlation between the assessment of image quality and the assessment of video quality. For this reason, SSIM has been widely adopted as a metric for assessing the quality of video. The most important feature of SSIM, which is important for this research as well, is that it is based on the same principles that characterize human visual perception. This metric, compared to other objective metrics for the video quality assessment, is better adapted to the selection of the structural information, which is one of the characteristics of the visual system.

Easy testing and the possibilities for integrating with subjective methods results are significant features of the objective assessment method. The authors in [19] proposed a solution that is based on the mapping results obtained by the SSIM and VQM (Video Quality Metric) objective metrics into the nominal MOS (Mean Opinion Score) scale with 5 levels which is the result of the subjective assessment of video quality. SSIM metric correlates well with the human perception of video and has been used in our research also.

The way of creating a relation between the objective and subjective methods of video QoE assessment by mapping SSIM objective metric into MOS scale is given in [19]. Authors in [19] used test video sequences without video ads to generate mapping as it is described in the Table 1.

Table 1. Mapping of objective QoE metrics into subjective QoE metric [19].

MOS	SSIM
5 (excellent)	<0,99 ; 1]
4 (very good)	[0,95 ; 0,99>
3 (good)	[0,88 ; 0,95>
2 (satisfactory)	[0,5 ; 0,88>
1 (unsatisfactory)	[0 ; 0,5>

Mapping of objective QoE metrics into subjective QoE metric enables a fast and simple establishment of connections between these metrics. If the SSIM value is under 0,5, the mean value of the score is unsatisfactory (1), whereas when the SSIM value is over 0,99, the score mean value is excellent (5). Such principle of establishing correlations makes possible a quick control of obtained values and it is often used for scientific purposes.

This methodology based on the mapping of objective QoE metrics into subjective QoE metrics has been used in this research also, but we investigate these relationships for linear-in stream video ads.

We used this method to assess influence of resolution and frame rate to user's QoE in online video advertising. In the rest of the paper we will see that maping of objective quality metrics to objective quality metrics is possible if QoE analysis of linear in-stream video ads is performed.

The Influence of Resolution and Frame Rate on Linear In-Stream Video ad QoE

Experimental testing of the quality of experience by using subjective and objective methods should be in accordance with generally accepted recommendations and standards of the QoE evaluation. The authors in [11] proposed a methodology for the efficient design of the objective model that describes the effect of packet loss when a transfer of high-resolution video occurs. The principles on which the proposed methodology is based are usually used in research related to the study of the video quality of experience. Experimental procedure consists of several key steps:

a. Selection of test video sequences,
b. Designing environment in which the simulation will be conducted,
c. Selection of the subjective and objective metrics for quality assessment,
d. Subjective video quality assesment and objective video quality assesment
e. Establishing correlations between results obtained by subjective and objective quality assesment methods.

A similar methodology was used in this paper, but with all the modifications that must be made in order to be implemented in the analysis of the linear in-stream video ad QoE. We analyzed the impact of those characteristics whose change is possible during video service delivery. In order to improve the level of user's QoE their value can be modified and adapted to current conditions and to network requirements. Video frame rate and resolution change are of interests for practical use. The level of the QoE in linear video in-stream advertising was evaluated by using objective methods, in this case the SSIM. In order to confirm the results obtained by using the objective SSIM, a subjective test was performed as well. Mapping the objective QoE metrics into subjective ones is performed using previously described methodology.

Test Video Sequences

The test video sequences, created especially for this research, that enable the testing of the impact of the frame rate and resolution were used in the experimental part of the study. Since the linear in-stream video ads are embedded in the primary video content, technical characteristics of video ads often correspond to the technical characteristics of the primary video content consumed by users. Given that the impact of the changes in the characteristics of video ads that are inserted into the main video content is the topic of our research, test sequences consist of two segments: video ads and a part of the primary video content.

Bearing in mind that testing the impact of resolution and frame rate on the quality of the users' experience with displayed video ads is the task of the experiment, and taking into account the recommendations made by the IAB, we tested video ads with three different resolutions (640x480, 400x296 and 352x288 pixels) and three frame rate values (25fps, 20 fps and 15 fps). Video sequences were encoded by using the MPEG-4 codec. The content of the video sequences was designed to contain different spatial changes of the video content scene in the test video sequences. The duration of a test video sequence is 30 seconds, with 15 seconds for a video ad and other 15 for the main video content, Figure 2.

video ad (15 second)	primary video (15 second)

Figure 2. Example of test video sequence format.

Simulation Environment and Testing Methodology

The methodology for video streaming QoE assessment requires the provision of adequate video delivery to the end user. This includes the functionalities of streaming video over the network infrastructure and the possibility of viewing with the option to save placed video. An environment enabling a full functionality of these tasks was created to perform experimental part of this research.

The testing environment for this experiment consists of three blocks: a video server, a communication infrastructure emulator and a client on which video is placed. The architecture of the network environment is shown in Figure 3, and it is based on the architecture and video distribution process proposed in [10]. The software solutions that are not subject to licensing i.e., open source solutions were selected. It makes the implementation of the research simple and efficient.

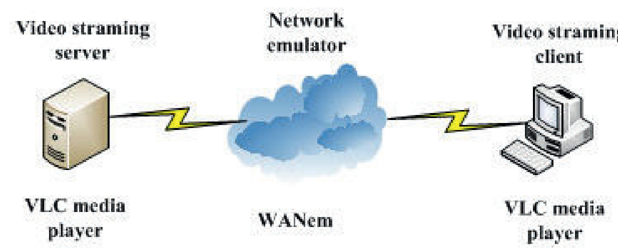

Figure 3. Experimental network environment for the linear video placement

The video server and the client are a free Video LAN streaming software solution. VLC media player is used as a video streaming server and as client software used for the consumed video stream viewing and recording [4]. The RTP protocol, which is widely used for multimedia streaming, was used for video streaming in this research as well. A similar concept of analysis was used in the studies by authors [6], [8].

WANem emulator *(Wide Area Network Emulator)* [9] was used as the network environment emulator. WANem is open-source software and free to download and use in one's own network environment. A study [3] shows that WANem can be used for emulation of real WAN networks in a test environment realized within the LAN network. It was demonstrated that this tool can be used for analyzing and exploring the functionalities of applications in a variety of situations. The analysis, based on the observation of environmental problems such as delay, package loss, limited bandwidth, etc., of the effects of the network environment on services and applications, is an example of this process.

The possibility of the emulator application in the LAN testing environment was explored in this research. The WANem software which emulates the WAN network in which two hosts are communicating was used. The two hosts representing a video streaming server and a client device are used for video placement and consumption. The performances of the network environment emulated by WAN amulator have an impact on the transmission of video from the video server to the client. Under these circumstances, it is possible to emulate and involve, different network influences, such as package loss, delay, bandwidth limitation into the experimental environment.

The simulation of video streaming was carried out in three phases by using simmilar methodology presented in [11]. The first phase represents a video streaming in an 'ideal environment', where the package loss and delay emulated by WAN emulator are equal to zero. In that way were obtained the video sequences, which are considered as 'reference sequences'. These sequences are considered referential because the package loss in the network environment emulator was set on zero value. Transmission flow, package losses or delays do not interfere with these sequences, and they have to be treated as referential to eliminate influences which cannot be fully controlled, such as the influence of the streaming software, client software and etc. Such influences are not present in the same form only in referential sequences, but also in consumed, damaged sequences.

The second phase is based on video sequence streaming in the network environment where the 0,5% of package loss is emulated. The selected value of the package loss percentage is in the range of tested values of packet loss that has also been used in the studies dealing with the analysis of the users' quality of experience of the consumed video content [18]. Obtained results are denoted as 'damaged' sequences.

Together with referential sequences, 'damaged' sequences are used in the implementation of objective, Full-reference method of testing and SSIM calculation. Mean values of SSIM for all frames of tested sequences were also calculated. SSIM values were calculated with MSU Video Quality Measurement Tool (VQMT) [14]. This program is commonly used for an objective assessment of video quality. It makes possible the testing in the presence of a reference (two videos are analyzed, one referential and the other after the distortion) and testing without a reference (only one video is analyzed). This program enables the testing of quality by using different metrics, and SSIM was also used in our research [14]. Finally, in phase three, we carried out a subjective assessment of the placed video QoE by applying procedures described in the ITU-T Recommendation-P.910 [2].

Experimental Results

Test video sequences were in the form of pre-roll video ad, consisting of 15 second advertising content and 15 seconds primary video content. The influence of content context and video ad duration were not investigated in this research. Referent and damaged video sequences are generated using different resolution (640x480, 400x296 and 352x288) and three different frame rates (25fps, 20 fps and 15 fps). For emulation of network impact the WANem emulator is used, and the packet loss was set to 0,5% when damaged sequences were delivered.

Respondents were watching the test video sequences obtained by inserting of the pre-roll video ads in the main video content. They evaluated the quality of video by using a five-level MOS scale, while the grading system was from unsatisfactory to excellent. After the testing which included the previously described phases, analyses and processing of the results, the corresponding SSIM and MOS values were obtained. The SSIM values were calculated by using the program for objective quality evaluation (MSU Video Quality Measurement Tool) and previously obtained 'reference' and 'damaged' video sequences. The results are presented in Table 2.

Table 2. Results of objective and subjective video quality assessment

SSIM			
Resolution	**Frame rate per second (fps)**		
	15	20	25
640x480	0.93477	0.93083	0.93171
400x296	0.93311	0.92781	0.92921
352x288	0.9292	0.92474	0.92471

MOS			
Resolution	Frame rate per second (fps)		
	15	20	25
640x480	3.6	3.45	3.8
400x296	3.4	3.2	3.4
352x288	3.05	3.1	3.05

The values obtained after the objective assessment can be mapped in the results obtained by a subjective quality assessment, as the case was in the research that authors presented in [18]. Namely, base on those authors findings it is possible to assess the quality of the placed video by applying an objective SSIM, under conditions where the package loss amounts to less than 0,5%. Based on that research in this experiment emulated packet loss was 0,5%.

Obtained results of the subjective MOS assessment are in line with the value findings presented in [10]. Consequently, it was confirmed that the usual quality assessment principles, used in other areas of the Internet video content application, can also be used for an application such as Internet video advertising. The results of the impact of the frame rate and resolution on SSIM and MOS values are illustrated in Figure 4.

a)

b)

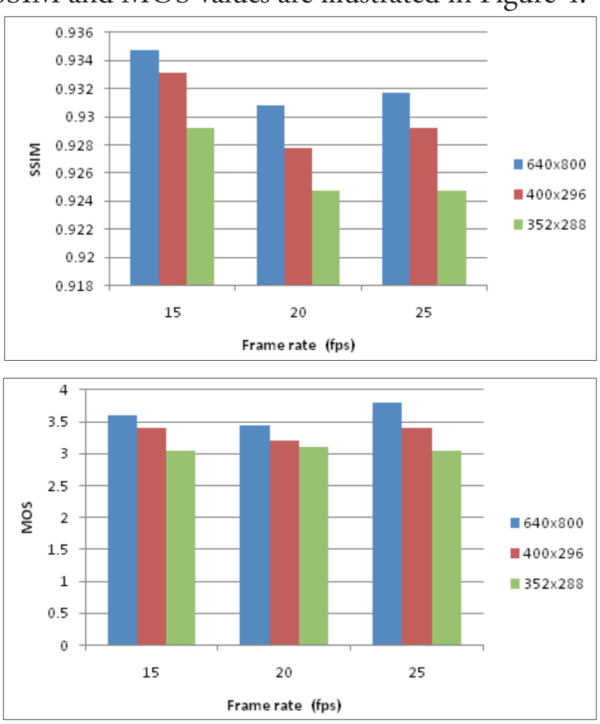

Figure 4. Illustration of the impact of resolution and frame rate on: a) objective SSIM and b) subjective MOS assessment

It can be concluded that for resolutions 352x288 and 400x296 mapping SSIM to MOS in video ads QoE is in accordance with Table 1 [19], that is valued for general video assessment. Small deviation can be seen at higher resolution. Therefore, further research are necessary to find more precisely SSIM to MOS mapping when packet loss belongs to wider range.

Conclusion

The purpose of this research is to point out the possibility of modeling the video Quality of Experience during Internet video advertising. In such modeling, if network environment affects the quality of video content, it is possible to improve QoE by selecting the resolution and frame rate values. This research is also significant because it uses a widely accepted methodology, adjusted for the assessment of the QoE within a specific application as it is linear in-stream video advertising. It was demonstrated that the values obtained by the objective quality assessment can be mapped in the results obtained by subjective assessment, if the quality of experience of linear in-stream video ads is being assessed, and packet loss was 0,5%.

Experimental results show that the mean value of SSIM metric for all test video sequence frames increases with the increased video content resolution. Such increased value of SSIM is in line with the results of subjective video content quality assessment expressed in MOS, as the MOS value increases with the increased resolution. Considering the effects of frame rate on SSIM metric, the specific rule for change of SSIM value is not identified. They were analyzed because they are in the range recommended by IAB.

The obtained results make possible, through the implementation of subjective and objective methods, a more detailed analysis of the QoE with a specific Internet video ad application. Unlike previous research, the mapping of SSIM values in MOS values, aimed at improving the assessment of the QoE, was carried out on a specific Internet video advertising application. Moreover, compared to previous research, when testing video sequences were mostly used, testing video sequences that include linear in-stream video ad were specially designed for this occasion. The design was adapted to fit the research goals which depend on the actual tested application. In this research, the application was in-stream video advertising.

Owing to the obtained results, it is possible to include the effect of changed technical features in the unified model for the assessment of the QoE of linear in-stream video ads. The subjective assessment, due to its complexity, is rarely carried out in the course of the placed service design or testing. Therefore, quality assessment of the QoE of linear in-stream video ads can be improved by integrating the results of the objective assessment with the results of subjective assessment.

Authorship statement
Author(s) confirms that the above named article is an original work, did not previously published or is currently under consideration for any other publication.

Conflicts of interest
We declare that we have no conflicts of interest.

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