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A concise review of the quality of experience assessment for video streaming

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ABSTRACT

The widespread use of mobile and high definition video devices is changing Internet traffic, with a significant increase in multimedia content, especially video on demand (VoD) and Internet protocol television (IPTV). However, the success of these services is strongly related to the video quality perceived as by the user, also known as quality of experience (QoE). This paper reviews current methodologies used to evaluate the quality of experience in a video streaming service. A typical video assessment diagram is described, and analyses of the subjective, objective, and hybrid approaches are presented. Finally, considering the moving target scenario of mobile and high definition devices, the text outlines challenges and future research directions that should be considered in the measurement and assessment of the quality of experience for video streaming services.

1. Introduction

The rapid development of mobile and high definition video devices and of the network infrastructure used for video streaming requires a permanent evolution of the techniques used to assess the video quality of experience (QoE). The objective of this paper is to provide a concise, up-to-date view of this research field.

In the last decade, interactive voice traffic (Voice over IP – VoIP) has been added to the traditional network data traffic (web, email, file transfers). Today, VoIP is common in IP networks, and the trend is a rapidly increasing in video traffic, namely, video on demand (VoD) and IP television (IPTV). Moreover, the rapid popularization of mobile devices with video display support, such as notebooks, tablets and smartphones, and the dissemination of wireless networks (WLANs and 3G/4G) contribute to this scenario. In a few years, 90% of the content transmitted over the Internet will be related to videos, which will be viewed by over a billion people [1,2].

These services are transmitted using a streaming technique through an Internet service provider or a private corporate IP network. The contents are presented to the user as they are sent by the source, without the need to store the complete file for later viewing. A buffer is used to store a few seconds of content before their display to minimize sporadic failures or delay fluctuations in the network transmission.

A typical infrastructure used to provide a video streaming service is composed of three elements (see Fig. 1). In the *headend*, the contents are created, edited, encoded, and stored in a multimedia database, which is made available by a streaming server. Next, the contents are divided into several IP packets and transmitted to the customers through the *core network*. Finally, via an access node in a *customer network*, the contents are displayed on the user's device, which can be a television, a desktop computer, a notebook, a tablet, or a smartphone.

As the success of a video streaming service is heavily linked to the quality level assurance, the contents are displayed on customer devices with minimal failures or delays. Usually, a network manager monitors network information, such as bandwidth, delay, jitter, throughput, and packet loss, to provide adequate quality for each customer. However, this task becomes difficult due to the complexity of the network infrastructure, and when mobile devices are included in this scenario, the difficulties are even greater due to new problems, such as wireless signal coverage, a high rate of packet loss, and wireless channel instability.

Given the required conditions for video transmission to customers over IP networks, the features offered by the network define the concept of quality of service (QoS). However, other information can also be measured, such as resolution and codification of video contents. All of these factors strongly influence the quality as

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perceived by the user, which in turn determines the level of quality of experience (QoE). Presently, the rapid development of new technology allows for the emergence of devices with new resolutions, screen sizes, and contrast and brightness features. For this reason, the techniques used to measure perceived quality, as described in the remainder of this paper, must be carefully reexamined.

Various papers have explored the approaches and methodologies used to evaluate video quality in multimedia services. Winkler and Mohandas [3] discuss the evolution of subjective and objective metrics used for video quality measurement and introduce a new hybrid metric named V-Factor. A state-of-the-art perceptual-based audio and video quality assessment is described by You et al. [4] as are some relevant quality metrics to develop a joint audio and video assessment. Seshadrinathan and Bovik [5] present recent developments in a multimedia signal (audio, image, and video) quality assessment with a focus on full-reference methods. A classification scheme for full-reference and reduced-reference video quality assessment methods is introduced by Chikkerur et al. [6] that takes into account the natural visual characteristics (natural visual statistics and natural visual features) and perceptual characteristics (frequency-domain and pixel-domain methods). Yang and Wan [7] analyze the factors that may affect the quality of the networked video method and some bitstream-based methods to evaluate video quality. Finally, a classification of objective video quality and a comparison with different metrics, distortion types, and video databases is provided by Vranješ, Rimac-Drlje, and Grgić [8].

The main goal of this paper is to summarize current and emerging approaches to evaluate the quality of a video streaming service. It presents concepts related to QoS and QoE as well as factors that influence each one. A typical process of video service quality evaluation is detailed and the different assessment methods are divided into subjective, objective and hybrid approaches and compared. A discussion about future trends and challenges in video quality assessment completes the study.

The remainder of this paper is organized as follows. Section 2 defines QoS, QoE and related factors. Section 3 details the video quality assessment process, the available methodologies, and the various approaches. Section 4 discusses future trends and challenges in video quality assessment, and Section 5 presents the conclusions.

2. Concepts of quality in a video service

2.1. What is Quality of Service (QoS)?

QoS is defined by the International Telecommunication Union (ITU) as a set of characteristics of a telecommunication service that focuses on user satisfaction [9,10], while the Internet Engineering Task Force (IETF) summarizes QoS as a collection of requirements to be met by the transport data stream of a particular service [11]. Bandwidth, delay, jitter, and packet loss rate are some of the most common parameters used to measure QoS.

In addition to QoS, the services can also be evaluated according to the grade of service (GoS) and the quality of resilience (QoR). The GoS is related to events that occur during communications between the server and the client, such as the configuration, release, and maintenance [12], and it is based on parameters such as setup time, blocked communication probability, client authentication delay, and connection drop probability. The survival rate of data flow in a network is assessed by the QoR, which considers how long it takes to recover from a broken connection or on the availability of the service from the server [13]. Furthermore, when the connection is restored after a failure in communication, the QoR is responsible for verifying if the level of the GoS and the QoS are the same as they were before the connection failure, if the route reestablished to deliver the contents is congested, and how many packets were lost during the service outage.

In a video streaming service, a QoS measurement occurs inside the network used to transmit data packets from the server to the user's receiver. This type of assessment is called the network QoS (NQoS). Additionally, it is possible to investigate the relationship between the QoS parameters and the video quality perceived by the user (Perceived QoS – PQoS). Over the years, this term has evolved into QoE, where the focus is on the user experience rather than on the specific quality of service provided.

2.2. What is Quality of Experience (QoE)?

QoE is an assessment of the user satisfaction with the contents played or displayed on the client's device [14,15]. It is based on human auditory and visual systems (HAS and HVS, respectively) and relates the perceived auditory and visual experience of the user with the contents. This paper focuses on the visual component of the QoE.

QoE is based on subjective parameters, i.e., it measures the interaction between the contents presented and the user's perception (color, light intensity or failure of some pixel) and expresses it in words, such as excellent, good, fair, poor or bad. Cost, availability, usability, and fidelity are also taken into consideration [16].

When compared with QoS, QoE does not have well-defined metrics as the evaluation depends on the perception of each user. On the other hand, there does exist a relation between QoS and QoE. A possible relation is shown in the three regions of Fig. 2. In Region 1, there is no disturbance during the video transmission from the server to the receiver, and QoE is considered excellent. In Region 2, there are some failures during the transmission

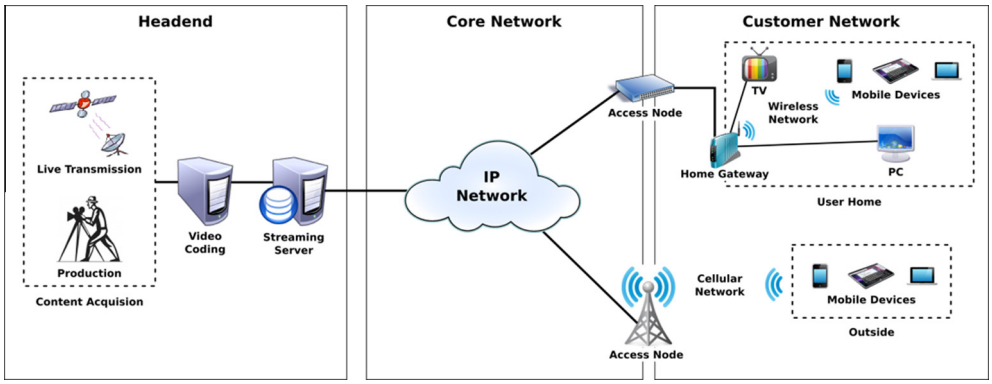

Fig. 1. Architecture of a typical video streaming system.