QoE MONITORING OF IP VIDEO SERVICE

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Abstract

The IP Video service offered by MSOs is about to enter its 2nd phase, extending from the 2nd screens to the big screen. With this transition the expectations and requirements for QoE will be going up to be at par with the legacy video QAM service.

IP Video introduces new challenges when it comes to QoE monitoring. One of the most important paradigm shifts is an extremely wide range of screens and consumption habits: with screens that are few inches in size to ultra HD TVs with 80" screen; with a laid back to fully engaged experience. To make things more interesting, in some cases the format of the content itself would dramatically vary (sub-VGA to Ultra HD) while in others the exact same content, say HD, may be viewed both on a tablet and on a big-screen TV. Other critical game changers when it comes to IP video QoE monitoring are WiFi, OTT delivery of video over best effort networks which in some cases are not even owned by the operator (e.g., OTT, off-net), and of course the fact that the decoding device itself may be CE with, at best, a limited ability of the operator to control and guarantee QoE. And of course, on top of all this, operators are rightfully looking for a single QoE Monitoring solution applicable to all screens and all use cases.

In this paper we will start by discussing the differences between QoE and QoS and between QoE and video quality. We will then compare different methodologies for video quality and QoE monitoring, including full-reference vs. reduced-reference, vs. no-reference; compressed vs. pixel domain; statistical vs. exhaustive. We will conclude with a review of alternatives for embedding QoE probes in the end-to-end IP Video architecture and their ability to collect true and effective QoE information.

QoS, QoE, and Video Quality

Quality of service (**QoS**) is the overall objective performance of a network, particularly the performance seen by the users of the network. To quantitatively measure quality of service several related aspects of the network service are often considered, such as error rates, bandwidth, throughput, transmission delay, availability, jitter, etc.

Quality of Experience (**QoE**) is a subjective measure of a customer's experiences with a service. QoE systems will try to measure metrics that customer will directly perceive as a quality parameter (e.g., channel change time). In short, QoE provides an assessment of human expectations, feelings, perceptions, cognition, and satisfaction with respect to a particular product, service or application.

QoE is related to but differs from QoS, which attempts to objectively measure the service delivered by the vendor, with QoS measurement is most of the time not related to customer, but to media (customers will never tell you : the jitter is too high). It is tied closely to the black and white of a contract and measures how well the vendor lives up to its end of the bargain.

A vendor may be living up to the terms of a contract's language, thus rating high in QoS, but, the users may be very unhappy, thus causing a low QoE. Conversely, the users may be very happy with a product or a vendor, resulting in an artificially high QoE if the vendor is not, in fact, doing what he was paid to do, thus rating low in QoS.

Finally, **subjective video quality** is a subjective characteristic of video quality. It is concerned with how video is perceived by a viewer and designates his or her opinion on a particular video sequence.

As such, although video quality is definitely part of the broad definition of Video QoE, it is definitely only a sub-set. Channel change time, number of black frames in the transition between content and an ad, the contribution of the device, light conditions, and distance of viewing are just a subset of the attributes of QoE that are not related to the video quality itself.

MEASURING QoE AND VIDEO QUALITY

Full, Reduced, and No Reference

There are three basic schemes for measurement of video quality, Full Reference, Reduced Reference, and No Reference. When looking at a function or a sub-system of the network that introduces degradation to the video signal, video quality at the output of the subsystem can be measured as follows:

- Full reference involves comparing the video signal at the output of the subsystem to the uncompressed digital source.
- Reduced Reference involves comparing the video signal at the output of the subsystem to the video signal at the input to the subsystem.
- No Reference involves evaluation of the video at the output of the subsystem without using any reference.

Figure 1, Video Quality Measurements, depicts Linear IP Video delivery architecture and overlays it with video quality measurement. In this example, to use a Full Reference scheme one would need to get access to the uncompressed source video available to the content providers before it is even encoded and sent to the MSO. Assuming it was available, Full Reference can be used, as an example, for video quality measurement at the output of the IRD or of the ABR transcoder. For Reduced Reference video quality measurement the IRD or Transcoder output can be used as the reference for the video arriving to the home gateway or end device. Finally, the video quality of the video arriving to the home gateway or the end device can also be measured, on its own leveraging a No Reference scheme.

The advantage of a Full Reference scheme, such as SSIM, is that it provides the ability to separate the artifacts inherent to the original video signal from the artifacts introduced by the delivery network, including compression artifacts. A Reduced Reference scheme enables a good measurement of the degradation of the video quality of the signal passing through the subsystem. The only scheme that actually attempts to truly measure video quality and not degradation is the Non Reference scheme. As such, to truly measure video quality the above schemes need to be revised:

- No Reference applied to the uncompressed digital source plus Full Reference comparing the video signal at the output of the subsystem to the uncompressed digital source.
- No Reference for the input to the subsystem plus Reduced Reference involves comparing the video signal at the output of the subsystem to the video signal at the input to the subsystem.
- No Reference applied to the video at the output of the subsystem

One should ask, if No Reference is mandatory for video quality evaluation why not rely solely on the No Reference scheme. The challenge there is that there is no widely acceptable and standardized No Reference video quality measurement scheme. Moreover, in the MSO space, access to the original uncompressed digital source is not available either. As such, at the end of the day we are left with measuring degradation rather than absolute quality using a Reduced Reference scheme. This is “translated” to video quality under the assumption that the video signal ingested by the MSO is of perfect quality. For “true” video quality measurement one can consider using proprietary No Reference protocols.

When it comes to Reduced Reference video quality degradation measurement, MSE, and PSNR are the most common. That said, none of them was proven to achieve high correlation to human perception across a wide variety of content, a wide variety of artifacts, and a wide range of the severity of the artifacts.

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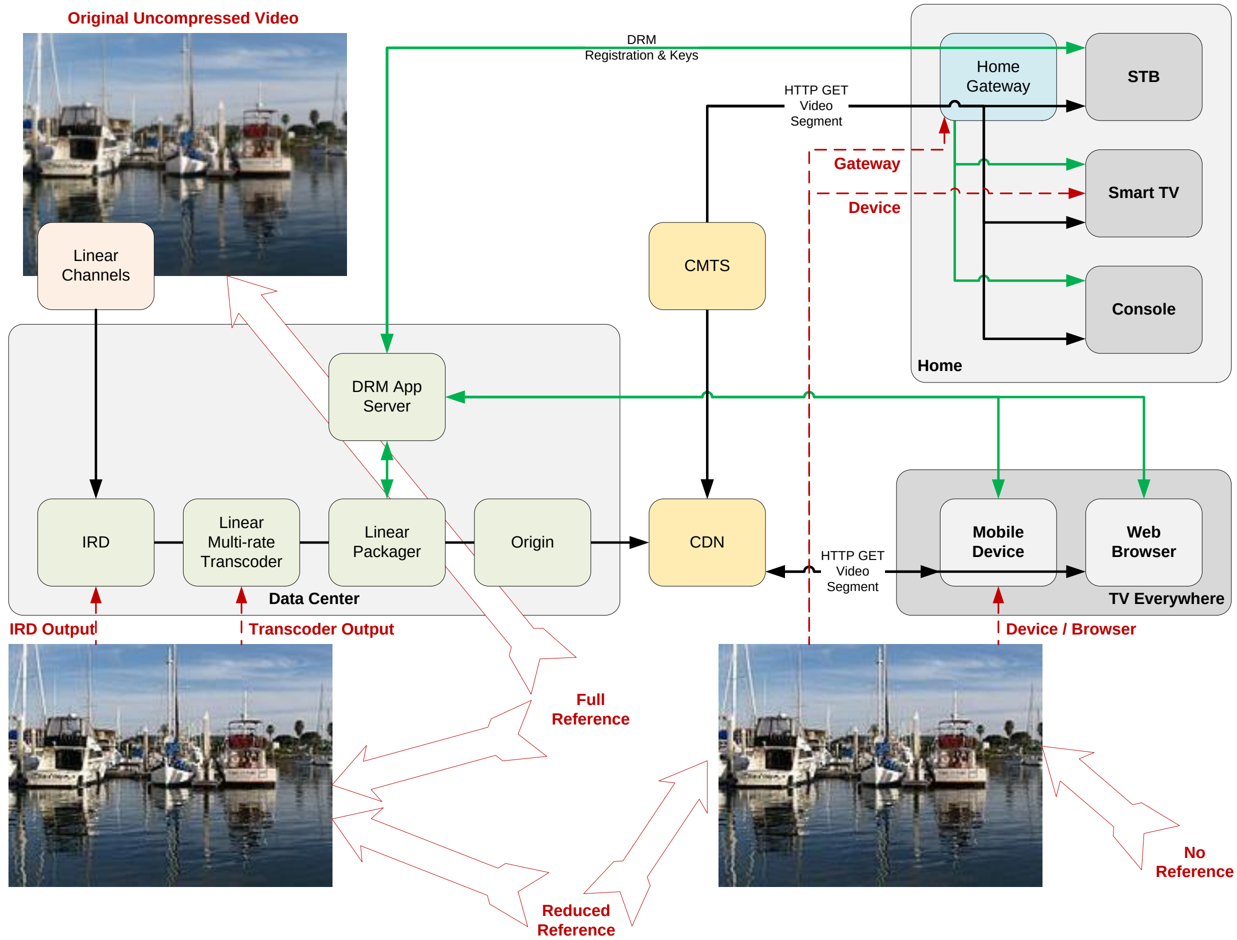

Figure 1 - Video Quality Measurement

<u>Pixel and Compressed Domain</u>

Video going through the MSO network is compressed, and in many cases even encrypted. No Video Quality measurement scheme exists for encrypted video, however, in most cases, no QoE degradation is expected while the video is encrypted as lossy video processing are not applied once the video is encrypted (although QoS degradation may take place, e.g., packet drop).

Video Quality estimation in the compressed domain is very attractive as it doesn't mandate extra decoding, which can pose a problem, especially with high scale. The most common compressed domain parameter used for video quality (degradation) estimation is the quantization parameters. The higher the parameters the higher the quantization noise is. Compressed domain schemes can offer a good tradeoff of performance and accuracy.

In the pixel domain multiple schemes exist. MSE, PSNR, and SSIM were mentioned before. On top of these, many proprietary schemes are leveraging techniques to identify blockiness, blurring, and noise enhancement. Moreover, spatial and temporal tools can be used to identify objects across a video stream and use that to identify artifacts. Once artifacts are identified the video quality degradation can be evaluated based on parameters such as the number of artifacts, their position, and severity.

Statistical vs. Exhaustive

Exhaustive video quality measurement implies that all the data, both spatial and temporal, is being used. Statistical approaches would analyze just a portion of the video frames, just a subset of the pixels / spatial data, or just a subset of the Chroma components (e.g., luma only). Very good results can be achieved while performing spatial decimation or by relying only on the luma component.

OVERLAYING QoE AND VIDEO QUALITY PROBES OVER THE VIDEO DELIVERY SUBSYSTEM

Figure 1 suggests key locations where video quality and QoE measurement probes can be inserted into the IP video delivery network.

The first place where MSOs impact the video quality is the IRD. Since the IRD is controlled by the content provider this is an excellent place to take reference measurement for the video quality. Any further degradation is under the responsibility of the MSO. In the case of VOD the equivalent would be to measure the video quality of the original assets.

A key place for a second probe is the output of the ABR transcoder. Reduced Reference is a very effective tool to compare the video quality at the transcoder output to that of the IRD output as both are likely to be co-located and serial.

The packager, Origin server, and CDN are not expected to generate any video quality artifacts. However, the packager may still create QoE degradation if the segmentation process is not done properly. The first time to check that would be the qualification of the packager. A real-time option involves taking the packager output, decrypting it (the packager is also used to apply DRM) and using a probe that simulates the behavior of an ABR client to check for QoE degradation (e.g., lost data at the seam, degradation at the transition between segments of different profiles).

For an on-net service involving transcoding in the home, the home gateway (or the home transcoder) can be used to measure video quality degradation. Reduced Reference can be used in case the platform is capable of measuring both input and output. If not, one option is to use No Reference scheme for the output. Another option is to extract key parameters from the output and make them available to a QoE Estimator located in the network, which may have access to the network transcoder output thus leveraging a Reduced Reference scheme.

Finally, the MSO application running on the device can be used to collect critical QoE information. This information may include the device type, the ABR profile of each segment, decryption problems, decoder buffer underrun or overrun, decoder resets, as well as other decoding problems. With this information made available to a QoE Estimator located in the network, a complete QoE picture can be made available for the MSO. To create this complete QoE picture, the QoE Estimator would cross the QoE data coming from the devices with video quality information associated with the video content coming from the network transcoder as well as potentially from the IRD. Figure 2 provides a simplified network diagram showing the network QoE Estimator and its interfaces to the various probes.

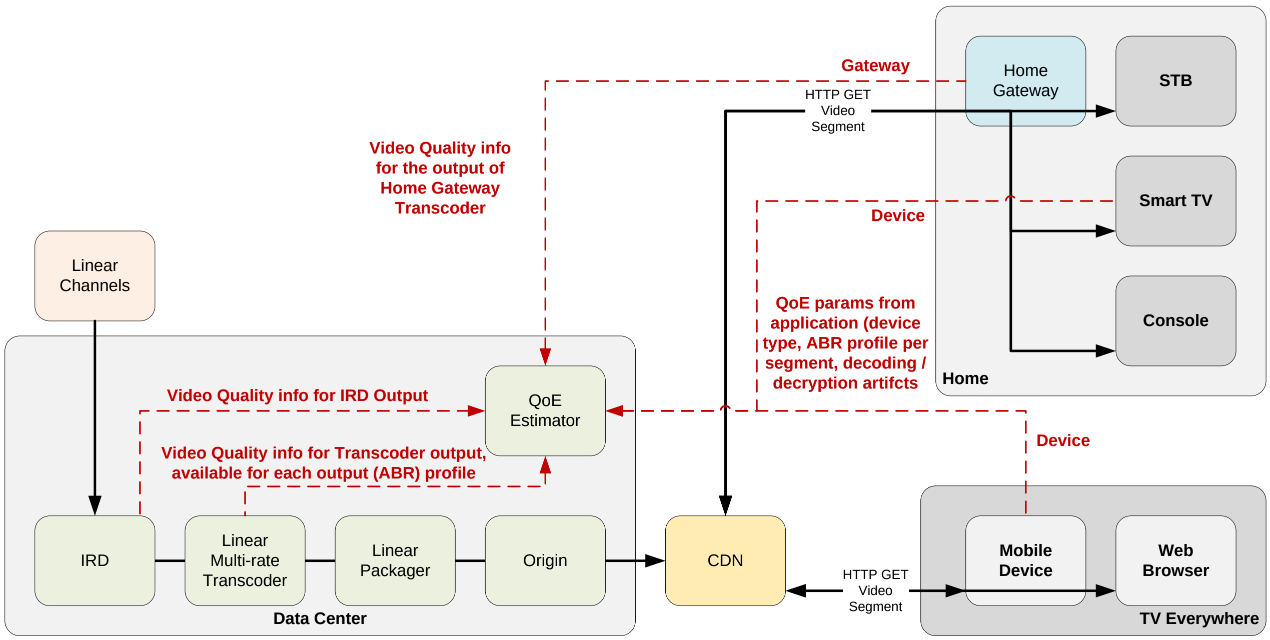

Figure 2 - QoE Estimator

SUMMARY

IP Video provides new challenges and opportunities when it comes to monitoring QoE. The uncast nature of the IP Video delivery calls for the ability to monitor each viewer independently, as QoE will vary from viewer to viewer. At the same time the IP Video delivery architecture allows for a highly effective QoE measurement solution leveraging a network QoE Estimator, taking advantage of the centralized nature of the video processing and the ability to retrieve critical QoE information from the ABR clients at minimal effort and complexity.