Paper

Quantifying the Suitability of Reference Signals for the Video Streaming Analysis for IPTV

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Abstract—IP networks are indispensable nowadays and they are some of the most efficient platforms. The constantly growing number of users and new services in these networks – the largest being the Internet – require a satisfactory quality of service from any application they use. So, determining the QoS in real-time services is particularly important. This work shows how to quantify the suitability of reference signals for analyzing the quality of video streaming in IPTV. The assessment relies on two different algorithms: PEVQ and VQuad-HD. Three different reference signals – two real ones and an artificial one – are used in this study, and a numerical measurement system is used, which simulates mean network impairments. These measurements provide valuable information for determining the QoS of actual IPTV services in practice.

Keywords—communication network, IPVT service, ITU-T J.247, measurement tool, PEVQ, QoS/QoE determination, reference signals, Triple Play Services, VQuad-HD, ITU-T J.341.

1. Introduction

3G and Triple play networks are expanding day by day. Their new applications and services include video telephony, video conferencing, video streaming and video podcasts. Although networks have never been as powerful and reliable as they are today, IPTV, mobile TV and others call for new fixed and mobile applications. A major factor for their increasing success will be their ability to satisfy their customers' high expectations while keeping down the costs. Operators and service providers achieve this by employing new powerful technology for their setups as well as new measurement tools that help to maintain a satisfactory level of Quality of Experience (QoE).

One of the major uses of next-generation networks is simulcast streaming (or broadcasting) of identical contents in various formats for different applications. Also referred to as the "Triple Screen" scenario, video content will typically be transmitted in high quality over cable or satellite HDTV networks. Medium quality will be available over the Internet for streaming to clients on PCs and laptops while the lowest quality will be offered on mobile multimedia devices such as mobile phones, smartphones and tablets. Triple Screen scenarios involve many steps of signal post-processing, including reformatting (e.g. 16:9 to 4:3), rescaling (e.g. from HD to VGA or CIF), reframing (e.g. from 50 f/s to 25 f/s), transcoding, and retransmission over IP-based networks. The issue for the test engineer is to maintain the best QoE possible across the various formats, given the system-bound limitations of each.

Three important measurement techniques [1] are used to assess QoE and Quality of Service (QoS). The "Full Reference Model", the "Reduced Reference Model" and the "No Reference Model" are shown in Fig. 1. These measurement techniques are also to be found in standard QoE/QoS measurement models, as described in [2] and [3]. The short texts contained in Fig. 1 explain briefly the procedure used in each of the measurement techniques and list the typical application scenarios of each.

The Full Reference Model technique was used in conjunction with two algorithms, PEVQ (ITU-T J.247) [4] and VQuad-HD (ITU-T J.341) [5], for the bulk of this study. Using these algorithms means using suitable reference signals that satisfy a number of requirements not the least of which are format and length. However, selecting suitable reference signals is not as easy as it might at first seem, as this paper will show.

First of all, PEVQ, the algorithm primarily used for this study, will be explained briefly. The chief requirements on reference signals according to international recommendations are then presented. The paper goes on to describe the selection of suitable reference signals. The investigation's goal is to find reference signals which, on the one hand, fulfill the main requirements laid out in the international recommendations and, on the other hand, deliver the best QoS/QoE values on the MOS scale. The following Section 2 will then present the analysis architecture and the scenarios chosen. A further Section 3 presents graphically several examples, the analysis results, and their interpretation. The concluding series of analyses in Section 4 presents a comparison of the algorithms PEVQ and VQuad-HD. The paper closes with a summary and an outlook on future areas of study in Section 5.

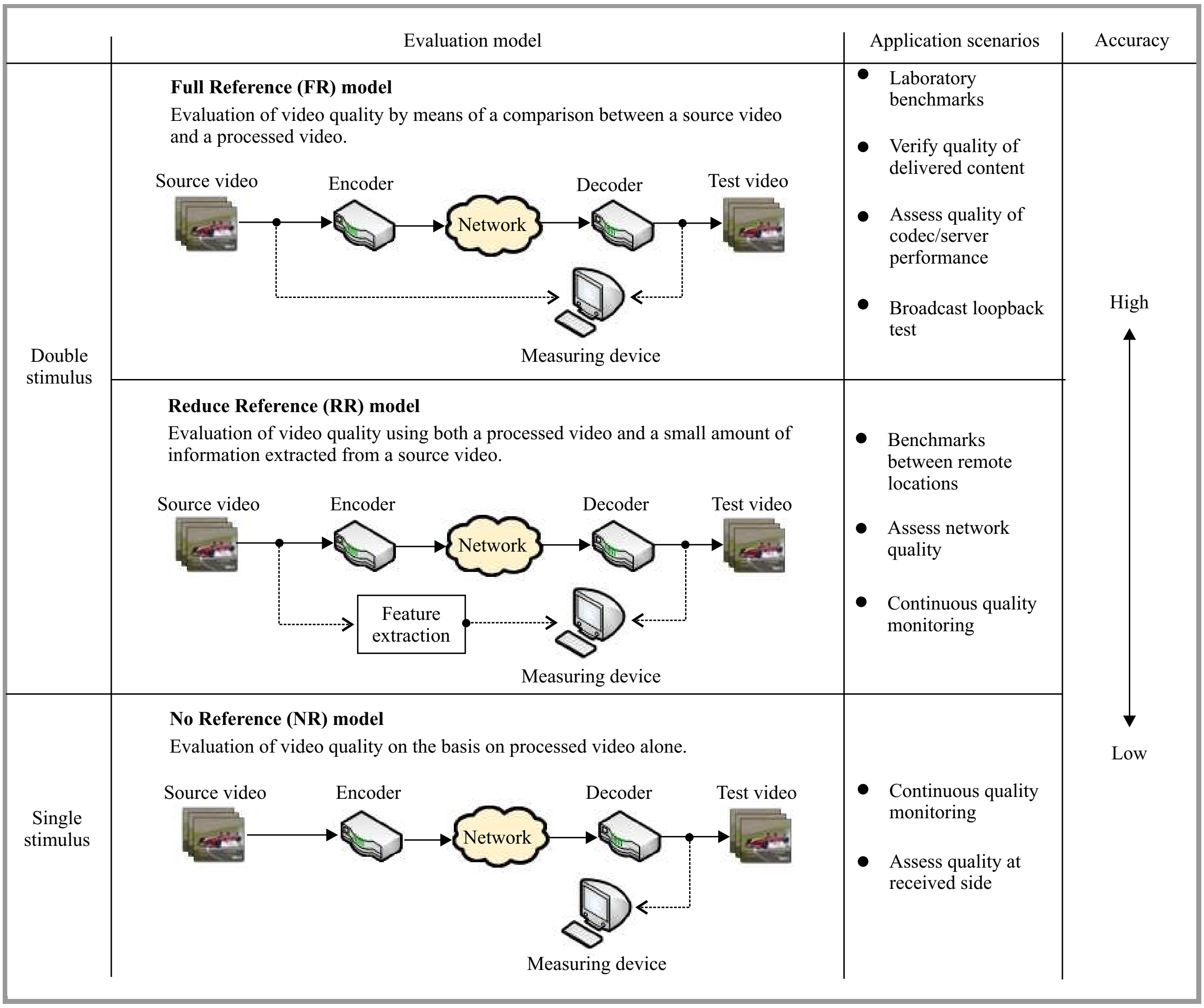

Fig. 1. Overview of QoE/QoS measurement techniques. (See color pictures online at www.nit.eu/publications/journal-jtit)

2. The PEVQ Algorithm

PEVQ is designed to predict the effects of transmission impairments on the video quality as perceived by a test person. Its main application areas are mobile multimedia applications and IPTV. It fulfills the ITU-T Recommendation J.247 [4] for full reference quality measurements. The key features of PEVQ (Fig. 2):

- temporal alignment of the input sequences based on multi-dimensional feature correlation analysis with limits that reach far beyond those tested by the Video Quality Experts Group (VQEG), especially with regard to the amount of time clipping, frame freezing and frame skipping which can be handled;
- full frame spatial alignment;
- color alignment algorithm based on cumulative histograms;
- enhanced frame rate estimation and rating;
- detection and perceptually compliant weighting of frame freezes and frame skips;
- only four indicators are used to detect the video quality. Those indicators operate in different domains (temporal, spatial, chrominance) and are motivated by the Human Visual System (HVS). Perceptual masking properties of the HVS are modeled at several stages of the algorithm. These indicators are integrated using a sophisticated spatial and temporal integration algorithm.

Apart from the MOS value, which is the ultimate yardstick of quality, PEVQ offers several other indicators that are used to analyse the reasons for quality impairments such as:

- distortion,
- delay,

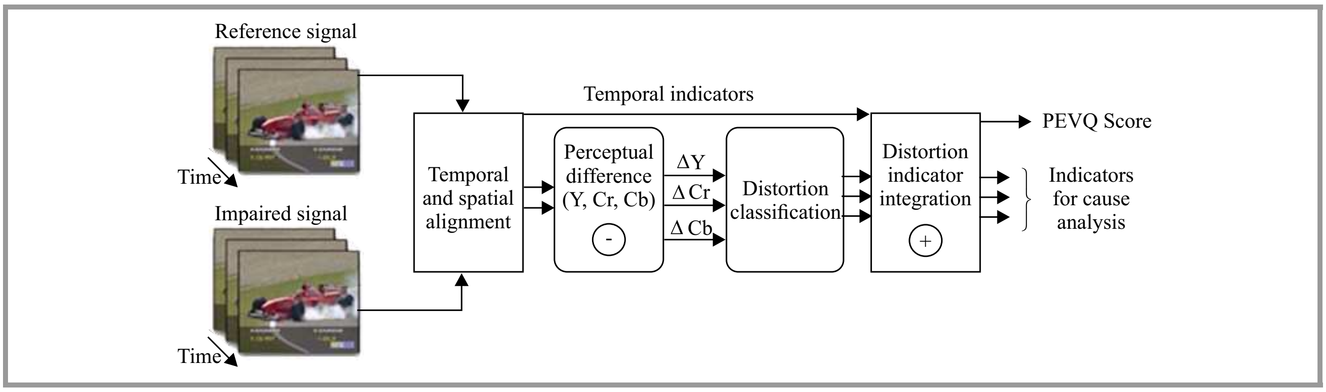

Fig. 2. Sequence diagram of PEVQ score calculation.

- luminance,
- contrast,
- peak signal to noise ratio,
- jerking,
- blurring,
- block constriction,
- frame freezing and frame skipping,
- effective picture rate,
- time and areal activity.

The PEVQ algorithm is the tool used for the bulk of the analyses described in this paper. For the sake of comparison a second algorithm, VQuad-HD, is introduced. The two algorithms necessitate the use of specifically formatted reference signals. That is the theme of the next chapter.

3. Requirements on Reference Signals

Many factors need to be taken into consideration when selecting reference signals. These factors can be found in the ITU-T Tutorial [6] and in publications of the VQEG [7]. The video format requirements and recommendations of the algorithms and tools used state that the best results will be obtained if the reference file is an uncompressed AVI (Audio Video Interleaving) file in the YUV 4:2:0 color space. A short video sequence of around 10 s is ideal since the algorithms would take far too long to process longer sequences whilst the influence of network impairments in shorter sequences would hardly coax sufficiently meaningful responses from the algorithms. In Europe full HD videos are usually in 1080i50, which means a resolution of 1920×1080 pixels at 25 full frames per second are ideal parameters for the reference signals. The reference signals should of course be free from distortions, errors and coding artifacts to preclude influences above and beyond network impairments.

The sequences selected for the comparison described here differ with regard to spatial details, motion and color intensity. A selection of reference files can be found in the consumer digital video library [8] or from the license holders of the two measurement algorithms (Opticom [9] and SwissQual [10]).

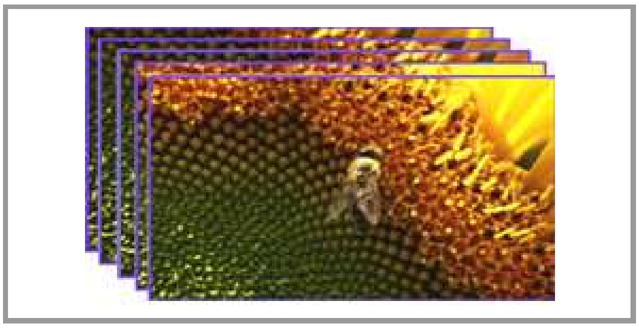

Fig. 3. Sunflower images (name: Sunflower) [9].

Fig. 4. Tractor images (name: Tractor) [9].

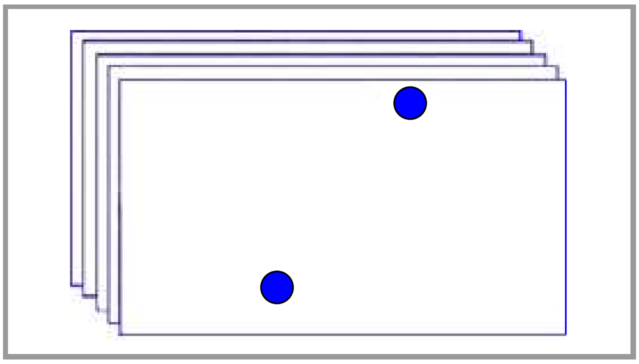

Fig. 5. Videotoms images (name: Artificial) [11].

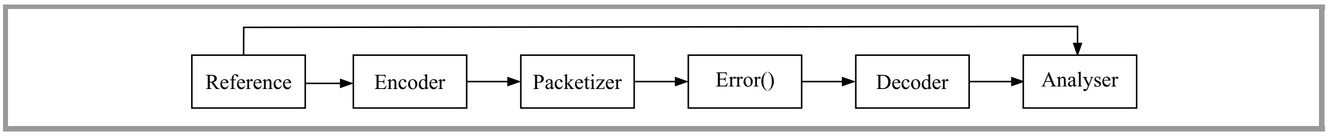

Fig. 6. Schematic representation of quality measurement by QoSCalc(IPTV).

The following reference signals were chosen for this analysis:

- little movement and slow, small changes in the images with relatively high color intensity (Fig. 3),
- greater movement and changes in the image background due to zooming with relatively low color intensity (Fig. 4),
- simple geometric shapes (circles) with rapid and random movement with minimal changes in color intensity (Fig. 5).

QoE/QoS measurements can be conducted in two different ways: in a real environment, or in an emulated environment. One evaluation of QoE/QoS on the basis of a reference signal takes several minutes. A number of measurements for each parameter setting are needed to arrive at any meaningful results. In a real environment, this ties up both network and measurement resources. That is why it is better to conduct analysis like this in an emulated measurement environment. This also allows a range of parameter settings to be used automatically and yields results that are duplicable in similar measurement scenarios. That explains why a numerical tool has been used for the analysis described in this paper. The next chapter is a brief description of the tool.

4. The Analysis Environment

For the reasons given above a numeric software tool QoSCalc (IPTV) [12] was used to analyze the quality of a video stream. The tool automates the entire measurement process.

The following explains each block in the sequence shown in Fig. 6. in order to compare the real environment with the measurement tool:

- a reference video file is loaded;
- the video is encoded in accordance with the selected codec by FFmpeg [13];
- the coded data is encapsulated according to the selected transport protocol (e.g. native RTP [14], MPEG2-TS [15], etc.) by FFmpeg;
- the block "Error" represents the generation of a selected level of network impairments;
- the packeted video is decoded to the same format as the reference (raw video, same resolution and bitrate) by FFmpeg;
- finally, the decoded data and the video reference file loaded at the start are passed on to the evaluation algorithm (here PEVQ or VQuad-HD). This computes the quality score on the MOS [16] scale and then saves it.

The "Error" block has been designed for non-deterministically distributed packet loss (binominal distribution with probability P) and non-deterministically distributed burst size (exponential distribution) with a selectable mean value.

Two different versions of the tool QoSCalc(IPTV) were used, utilizing different versions of FFmpeg. The first version is the default FFmpeg with its main error concealment techniques enabled. In the second version the error concealment methods are disabled. This is done specifically to analyze the influence of the error concealment methods.

Different error concealment algorithms for video streaming exist [17]. The FFmpeg uses the techniques "Macro Block Detection" [18], and "Motion Vector Search" [19], which are designed to detect and predict movement of macro blocks in the pictures and substitute missing information. FFmpeg first counts how many macro blocks are intact (not lossy). If that number is above a set threshold then intra concealment is used. Otherwise, an inter error concealment is used.

Intra error concealment involves averaging the pixels of the macro blocks surrounding the damaged one. The result of weighting and averaging the uncorrupted blocks is the block used for concealment. Inter error concealment works differently for I, P and B frames. In I and P frames the surrounding blocks are analyzed using the motion vectors, and several replacement block candidates are calculated using different methods including median and means. The block which produces the smoothest transitions is then chosen. In B frames the decoder uses the nearest P reference frame and creates a forwardly and backwardly weighted version of the motion vector.

The following configuration has been chosen for the measurement scenario in the testing environment:

- Reference files: Sunflower 1080p25 (similar 1080i50), Tractor 1080p25, Artificial: 1080p25,
- Packet loss: 0–12 (in steps of 1), 14, 16, 20%,
- Burst size: 1–5 (in steps of 1),
- Packaging: MPEG2-TS,
- Encoding: H.264 (medium),
- Bitrates: 1,000, 3,875, 6,750, 8,625 and 10,500 kb/s.

Using the numerical tool described above several analysis were conducted over several days for each scenario. The most significant results of the measurement scenario are presented and interpreted in the following section.

5. Quantitative Comparison of the Reference Signals

First of all it is necessary to describe the expectations which might be had. Due to network impairments, in this case packet loss, the expectation is that higher packet loss would result in a lower MOS value. Regarding the video content at one test point, e.g. 1% packet loss, and assuming that at this test point information is missing in scenes with a large degree of motion or rapid changes in color intensity the expectation would be a lower MOS value.

Given the nature of the test results from the configuration described in Section 4 a representations of the following configurations have been selected:

- Reference files: Sunflower.avi, Tractor.avi and Artificial.avi video content,
- Packet loss: 0–12 (in steps of 1), 14, 16, 20%,
- Burst size: 1 and 2,
- Packaging: MPEG2-TS,
- Encoding: H.264 (medium),
- Bitrates: 3,875 kb/s and 10,500 kb/s,
- Evaluation algorithm: PEVQ.

Figures 7–10 represent the results, starting with 3,875 kb/s and burst size 1.

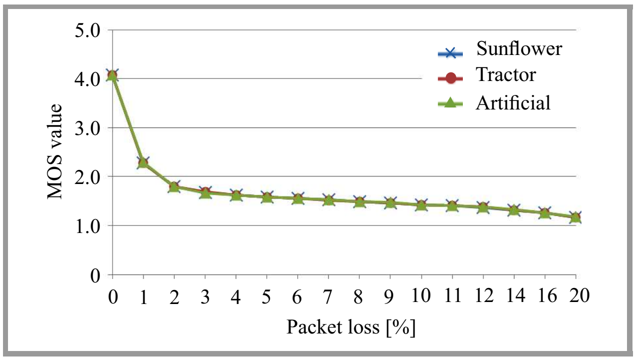

Fig. 7. Comparison of all three reference signals at 3,875 kb/s and burst size 1.

From these results, it is obvious that the MOS values for all bit rates and bursts are very close to each other. These results differ widely from the expectations, which led to two assumptions: either the video content does not affect the MOS value at all, or the functionality of FFmpeg decoding techniques is fully able to cope, or both. So the FFmpeg decoding techniques had to be examined in greater depth.

Two techniques, called “Macro Block Detection” and “Motion Vector Search”, are used to conceal errors. They obviously do a good job. They were the subject of the next series of tests with the expectation being a lower MOS value when error concealment techniques are disabled. Figures 11–14 represent the results; they include the representation to allow a comparison of the Tractor.avi reference signal with and without error concealment.

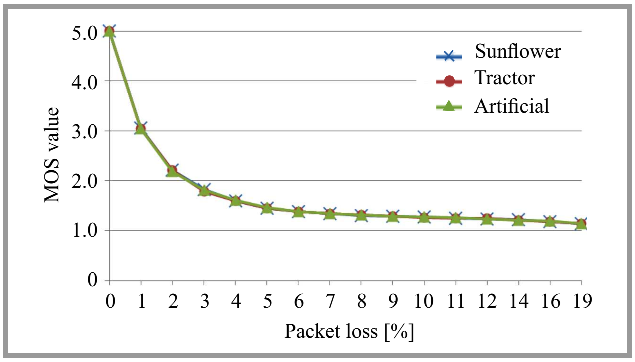

Fig. 8. Comparison of all three reference signals at 10,500 kb/s and burst size 1.

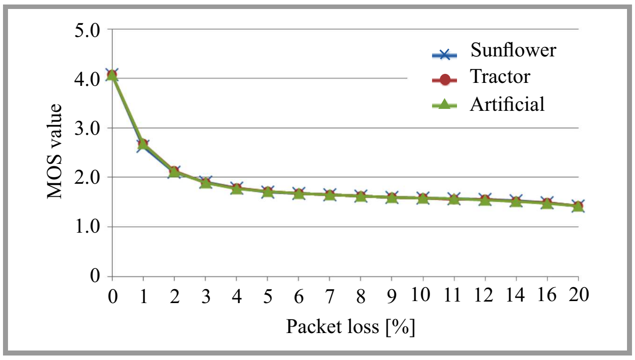

Fig. 9. Comparison of all three reference signals at 3,875 kb/s and burst size 2.

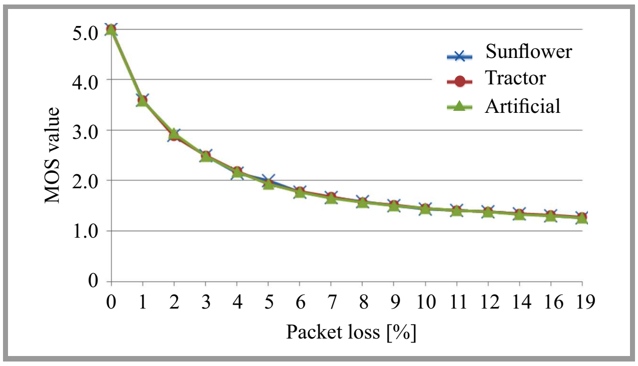

Fig. 10. Comparison of all three reference signals at 10,500 kb/s and burst size 2.

In conclusion, it can be said that the expectation was justified, at least as far as lower packet losses as the network impairment are concerned. When error concealment is enabled, the MOS value is indeed higher. With regard to the second point of intersection of all diagrams and curves the following observations can be made:

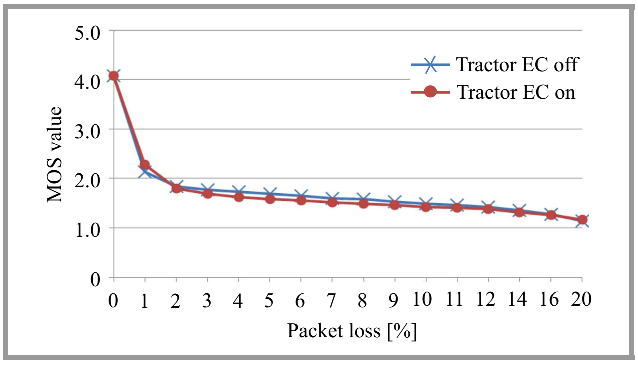

Fig. 11. Comparison Tractor with and without EC at 3,875 kb/s and burst size 1.

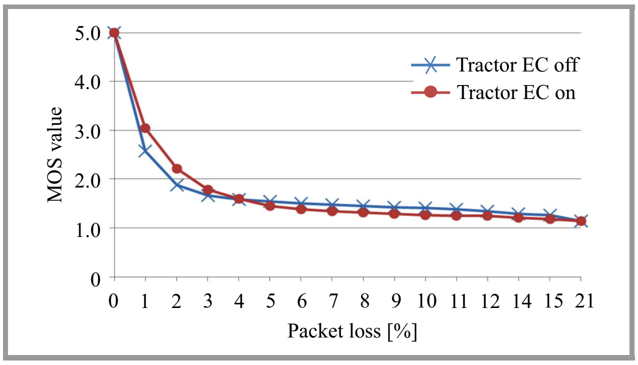

Fig. 12. Comparison Tractor with and without EC at 10,500 kb/s and burst 1.

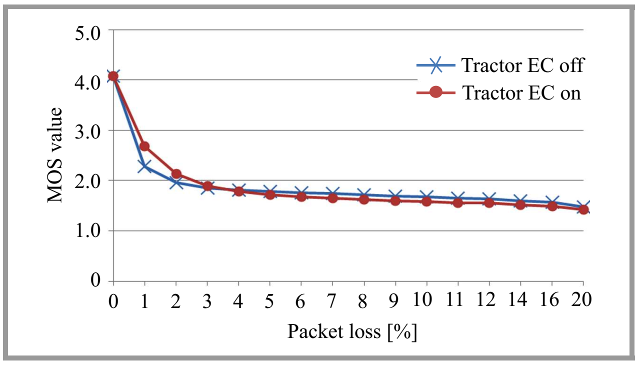

Fig. 13. Comparison Tractor with and without EC at 3,875 kb/s and burst size 2.

First, at some points with high packet losses, the MOS value obtained when error concealment is disabled is actually higher than that obtained when it is enabled. The video quality, with a MOS value of less than 2, is really poor nonetheless. The reason for that could be that these techniques substitute wrong video content. In severely lossy networks it might be better to disable error concealment techniques.

Second, the second point of intersection of both curves can be shifted in the direction of higher packet loss by increasing either the bit rate or the burstiness, so that the resulting higher MOS value, with error concealment enabled, would lead to improved video quality. These observations could lead to useful implementations which improve video quality by artificially increasing network burstiness, which is already present anyway, whenever packet losses occur.

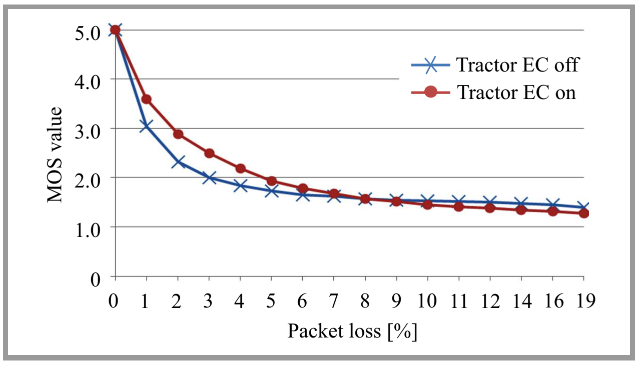

Fig. 14. Comparison Tractor with and without EC at 10,500 kb/s and burst size 2.

As far as reliability is concerned Figs. 15–16 represent results using both PEVQ (ITU-T J.247 [4]) and VQuad-HD (ITU-T J.341 [5]) prediction algorithms for video content of the reference signals Tractor.avi and Artificial.avi, the expectation being that these algorithms should yield only slightly differing respective MOS values.

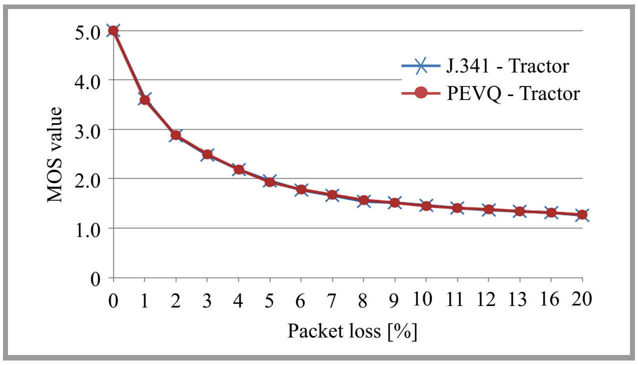

Fig. 15. Comparison of J.341 and PEVQ for Tractor at 10,500 kb/s and burst size 2, with EC.

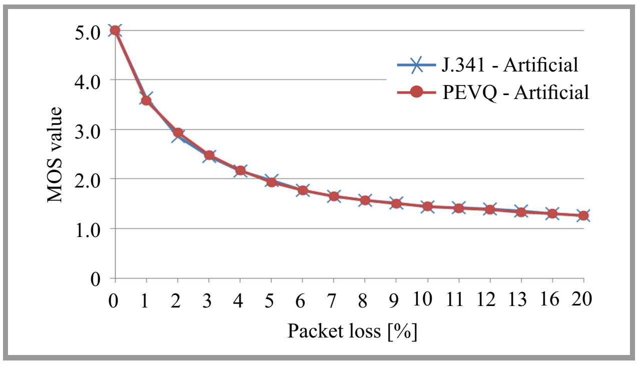

Fig. 16. Comparison of J.341 and PEVQ for Artificial at 10,500 kb/s and burst size 2, with EC.

Again, it can be said that the expectation was justified, which leads to the following two final conclusions. First, both algorithms are suitable for the perceptual evaluation and measurement of HD video quality and second, artificial video content is suitable as a reference signal: its use leads to simpler realization of initial scenario criteria.

6. Summary and Outlook

This paper has assessed the suitability of video reference signals for the PEVQ (ITU-T J.247) and the VQuad-HD (ITU-T J.341) algorithms for evaluating the video quality in IPTV. To that end numerical software tool was used that had been developed previously on the basis of FFmpeg to provide encoding, packaging, degrading (packet loss, burst) and decoding techniques. Both algorithms are full reference models, that is: they necessitate the use of two signals – the original signal on the one hand, and a degraded signal on the other. Research on the topic of suitability has shown that there are recommendations regarding the composition of reference files with regard to, for example, changes in movement, color and luminescence. Accordingly, two reference files provided by "Opticom" and one provided by [11] were selected and the analysis environment was set up to implement the files and initiate the measurements. The results obtained for the video quality under evaluation differed from the expectations, one of them having been, for example, better video quality for the reference file that contained less movement when video content information loss occurs. There were, however, hardly any differences. That led directly to an investigation of FFmpeg's "Decoder", which showed that the existing error concealment techniques provide very good functionality in repairing and concealing issues. Nevertheless, as was expected, increasing packet loss caused an exponential decrease in the resulting MOS value for the video quality of a reference file examined in isolation. One surprising result must be spotlighted: the "artificial" signal Artificial.avi proved to be just as suitable for use in QoE/QoS measurements as the very complex reference signals recommended by the license holder Opticom [9]. Further analysis, which cannot be described here owing to lack of space, confirm the good functionally of the EC techniques implemented in FFmpeg.

The results obtained in the course of the work described here could serve as a basis on which to develop parameterized QoE/QoS models, that are widely known to be simple and easy to implement in practice, yet provide reliable meaning results. It is therefore very worthwhile developing such QoE/QoS models. Further work in this direction is already being planned.

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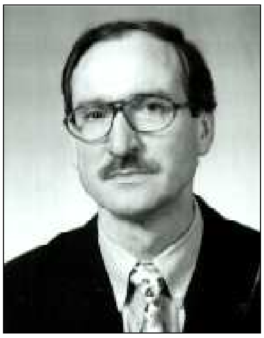

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