SVC Tunneling for Media-Aware Content Delivery: Impact on Video Quality

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Abstract— **Today's omnipresent demand for access to multimedia content via diverse devices places new challenges on efficient content delivery. This work introduces the concept of Scalable Video Coding (SVC) tunneling developed in the EU FP7 ALICANTE project and shows that the quality impact of the transcoding steps for a transcoding chain from MPEG-2 to SVC and back to MPEG-2 accumulates to a PSNR reduction of up to 2.1 dB for transcoding at fixed target bitrate points. We also discuss research challenges and open issues in SVC tunneling.**

Keywords- Content-aware networking; scalable video coding; SVC tunneling; transcoding; multimedia distribution

I. INTRODUCTION

The deployment of Scalable Video Coding (SVC) for content delivery enables bandwidth savings for multicast scenarios and facilitates more robust video transport in content-aware networks [1]. Many devices, however, do not support scalable video formats and rely on legacy formats like MPEG-2. One solution to the problem of deploying SVC streams in such an environment is the transcoding of video streams at the ingress and egress points of the network and the deployment of SVC tunneling within the network, thus enabling SVC content delivery and device-independent access. The European FP7 Integrated Project "MediA Ecosystem Deployment Through Ubiquitous Content-Aware Network Environments" (ALICANTE) [2] follows this approach and proposes a novel concept towards the deployment of a new networked Media Ecosystem.

In our current research, we investigate the applicability of SVC tunneling for content delivery and the impact of repeated transcoding (i.e., MPEG-2-to-SVC-to-MPEG-2) on the video quality. We show that the quality impact of these transcoding steps amounts to a peak signal-to-noise ratio (PSNR) reduction of 2.1 dB for transcoding at fixed target bitrate points. Research challenges and open issues in SVC tunneling are also discussed.

II. ALICANTE ARCHITECTURE

The ALICANTE architecture depicted in Fig. 1 proposes an advanced Media Ecosystem that delivers media content to different terminals at dynamically adaptable bitrates over a Quality of Service/Experience (QoS/QoE) managed network environment [4]. Towards this goal, two novel virtual layers are introduced on top of the traditional network layer, i.e., a Content-Aware Network (CAN) layer for in-network packet processing and a Home-Box (HB) layer for content adaptation, transcoding, and delivery. An SVC tunnel is developed in ALICANTE, inspired by IPv6 over IPv4 tunnels and the quality impact is investigated. Within the content-aware network, only scalable media resources, such as SVC, are delivered, allowing for in-network adaptation at Media-Aware Network Elements (MANEs). If the content at the server side originally has been encoded in a non-scalable legacy video format, e.g., MPEG-2, it is transcoded to SVC at the HB layer before delivery. Within the CAN, only scalable media resources, such as SVC, are delivered, allowing for layered multicast and in-network adaptation. When arriving at the client side, the scalable media resources can be transcoded by the HB (which is a next generation interconnected home gateway) to a format supported by the user terminal, e.g., again MPEG-2.

For the evaluations in this work, we assume that both content provider and end user require the same video format (i.e., MPEG-2). The ALICANTE architecture is more general in this respect and allows for different video formats at the sender and receiver sides.

III. SVC TRANSCODING

SVC, which is an extension of MPEG-4 Advanced Video Coding (AVC), follows a layered coding scheme comprising a base layer and one or more enhancement layers providing scalability along various dimensions [5]. Three basic scalable coding modes are supported, namely spatial, temporal, and signal-to-noise ratio (SNR) scalabilities, which can be

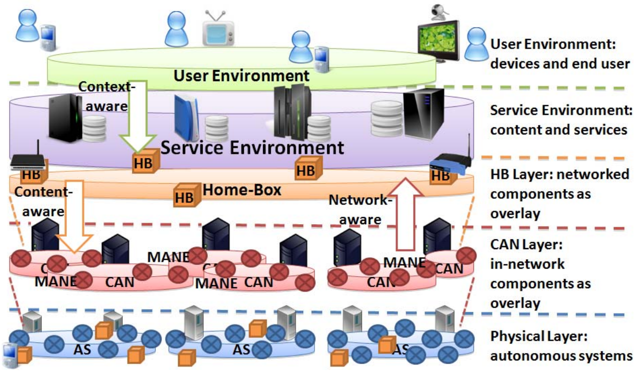

Figure 1. ALICANTE concept and system architecture [3].

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combined into a single coded bitstream.

When it comes to compression, SVC requires about 10% more bitrate than AVC for the same quality [6]. Compared to MPEG-2, which requires approx. 170% more bitrate than AVC [7], SVC still provides a bitrate reduction of about 59% (calculated from *1-(1+0.1)/(1+1.7)*) w.r.t. MPEG-2.

The simplest but slowest architecture of transcoding between two video formats is accomplished by fully decoding the video and then encoding the pixels into the target format, which is known as pixel domain transcoding (PDT). Advanced transcoding techniques, such as transform domain transcoding (TDT), reduce the computational complexity by using information from the coded source video to create the target video without full decoding. TDT is faster than PDT but introduces higher quality losses [8].

A special case of transcoding is bitstream rewriting, which converts the video from one format to another without any quality losses. Bitstream rewriting is only possible if both video formats use the same bitstream syntax and coding techniques, which is the case for AVC and SVC [9][10]. Note that lossless bitstream rewriting may nevertheless increase the bitrate if the target format has a lower coding efficiency, as it is the case for AVC-to-SVC rewriting.

While a variety of transform domain transcoders from different formats to AVC exist (e.g., from MPEG-2 [11]), for SVC only transcoding and rewriting techniques from AVC as the source format have been researched so far [9]. To the best of our knowledge, no MPEG-2-to-SVC TDT has been addressed in any research so far. In order to transcode from MPEG-2 to SVC, either PDT or cascaded TDTs can be deployed. In the first case, the video is decoded from MPEG-2 and then re-encoded to SVC. In the latter case, a fast MPEG-2-to-AVC transform domain transcoder and a fast AVC-to-SVC rewriter are cascaded.

The full SVC bitstream can be converted to AVC through lossless bitstream rewriting [10]. To the best of our knowledge, transcoding techniques from SVC have only been researched for AVC as target format. For transcoding SVC to other target formats, such as MPEG-2, two architectures are possible, i.e., PDT and cascaded TDTs, similar to the X-to-SVC transcoding architectures described above.

Although the quality impacts of single transcoding steps are well known for a variety of video coding formats, the implications of two consecutive transcoding steps cannot be predicted from the individual steps.

In our research, we focus on MPEG-2-to-SVC PDT and SVC-to-MPEG-2 PDT rather than cascaded TDTs. The PDT architecture is more generic and allows for transcoding from virtually any source format to SVC by simply plugging in the appropriate decoder. PDT also establishes a proper baseline for both transcoding directions.

For multicast scenarios in which the content has been originally encoded to a legacy format like MPEG-2 (e.g., DVD-Videos) and also the user terminals require MPEG-2, an SVC tunnel for content delivery, as proposed by ALICANTE, could be deployed, enabling QoS/QoE management at the network and reducing network load.

In order to evaluate the quality impact of the transcoding steps at the ingress and egress points of the network, we performed the transcoding operations on two standard test sequences, *Foreman* and *Mobile*.

Each sequence was encoded from raw YUV to MPEG-2 in the first step, decoded and re-encoded to SVC with a base layer and two enhancement layers in the second step, and transcoded back to MPEG-2 in the final step. In order to establish a valuable baseline, encoding was performed at fixed target bitrate points at all three steps, i.e., the video was encoded to MPEG-2 at the same target bitrate as it was transcoded to SVC and back to MPEG-2. The differences in PSNR and bitrates between two steps were calculated as the Bjontegaard Delta (BD) [12]. The BD measures the average distances between two rate-distortion (RD) curves along the PSNR and bitrate axes as scalar values.

IV. DISCUSSION OF EXPERIMENTAL RESULTS

The RD curves of the repeated transcoding for the *Mobile* sequence are shown in Fig. 2. The *Mobile* sequence indicates slight quality losses for MPEG-2-to-SVC transcoding (BD-PSNR of 0.5 dB between first and second curve) compared to the impact of SVC-to-MPEG-2 transcoding (BD-PSNR of 1.5 dB between second and third curve). For the *Foreman* sequence, which is not shown here, both transcoding steps (MPEG-2-to-SVC and SVC-to-MPEG-2) have nearly the same impact on the video quality.

On average, the repeated transcoding results in a total PSNR drop of 2.1 dB or conversely a bitrate increase of 43% in order to compensate for the PSNR drop. Out of the total quality impact, 0.8 dB can be attributed to the first transcoding step (MPEG-2-to-SVC).

Based on these results, the bandwidth requirements for a multicast streaming architecture can be estimated for three scenarios as shown in Fig. 3. The MPEG-2 simulcast mode, in which multiple quality versions of the content (according to the configuration of our test setup) are streamed, requires 145% of the bitrate of the original MPEG-2 video. The simulcast mode is depicted as a baseline in Fig. 3, labeled *Scenario 1*. The other two scenarios considered in the figure are the full SVC tunneling mode, labeled *Scenario 2*, with MPEG-2-to-SVC and SVC-to-MPEG-2 transcoding, and, as *Scenario 3*, SVC multicast streaming with only MPEG-2-to-SVC transcoding at the ingress point of the network. SVC content delivery in both latter scenarios reduces the

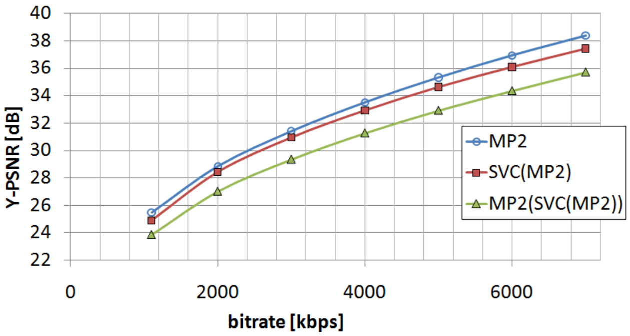

Figure 2. Y-PSNR for repeated transcoding of *Mobile* sequence.

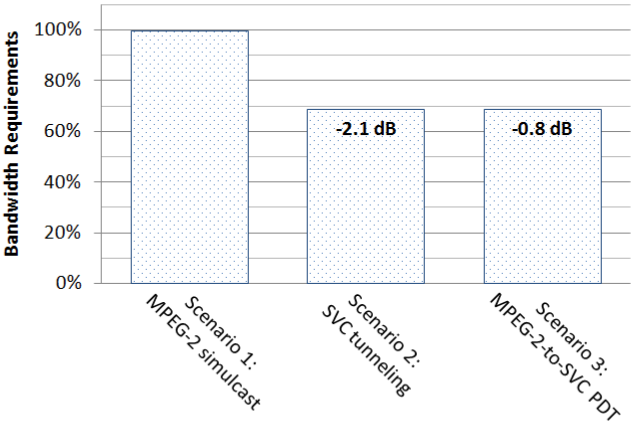

Figure 3. Estimated bandwidth requirements at the core network and corresponding quality degradation for multicast streaming.

bandwidth requirements at the core network by approx. 31% w.r.t. the simulcast mode, at the expense of degraded video quality (-2.1 dB for *Scenario 2* and -0.8 dB for *Scenario 3*). *Scenario 3* assumes that the end user terminals also support SVC and thus no SVC-to-MPEG-2 transcoding is required.

Note that the content delivery in all three scenarios is based on the same video at the sender. In order to obtain equal video quality results at the end user terminals for MPEG-2 simulcast mode and SVC layered multicast, the bitrate of the MPEG-2 video for simulcast mode (*Scenario 1*) could be throttled accordingly. However, this would imply deliberately sending suboptimal video quality to simulcast mode users, which is only useful if the available network bandwidth is scarce.

The current architecture can be improved for both transcoding steps. In the MPEG-2-to-SVC transcoding step, it should be possible to reduce the target bitrate for SVC according to SVC's higher coding efficiency over MPEG-2 while maintaining BD-PSNR results similar to fixed target bitrate points. In the SVC-to-MPEG-2 transcoding step, the final video quality could be additionally improved by artificially bloating the bitrate of the MPEG-2 bitstream.

Further open research challenges comprise subjective quality tests for evaluating the QoE, but also timing constraints (e.g., for live content).

V. CONCLUSIONS AND FUTURE WORK

In this work, the concept of SVC tunneling for multicast content delivery has been presented. The proposed architecture may require video transcoding from and to non-scalable legacy video formats, such as MPEG-2, at the borders of the network. We have evaluated the quality impact of the repeated transcoding at network borders, which results in a total PSNR decrease of 2.1 dB, with around 1/3 of the quality impact attributed to the initial MPEG-2-to-SVC transcoding step. A bitrate increase of 43% is required to compensate the quality loss, which is still less than the necessary bandwidth for MPEG-2 simulcast-based streaming.

Our measurements are expected to serve as guidelines for the estimation of quality reduction and its possible compensation in SVC tunneling scenarios.

In our research, test results for two standard test sequences have been presented. A wider variety of test content, also comprising (ultra) high-definition resolutions, will be considered in future work.

The goals of SVC tunneling for content delivery are the reduction of network load through layered multicast and the provisioning of QoS management in CANs. Within the ALICANTE project, the exploitation of content-aware networking for SVC tunneling is explored, ranging from in-network adaptation to intelligent routing mechanisms. Future work will elaborate the evaluation of bandwidth savings for SVC tunneling, its impact on video quality, and its deployment in ALICANTE's advanced Media Ecosystem.

ACKNOWLEDGMENT

The author thanks Prof. Hermann Hellwagner and Dr. Christian Timmerer for their guidance and support in this research. This work is supported in part by the EC in the context of the ALICANTE project (FP7-ICT-248652).

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