In-network Real-time Adaptation of Scalable Video Content on a WiFi Router

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Abstract—**One of the most active research topics in the field of video signal processing is scalable video coding (SVC). The recently published extension of the H.264/AVC video coding standard introduces scalability features by employing a layered encoding of the video stream. In our work we investigated the usage of this scalable extension of H.264/AVC for in-network multimedia adaptation. We developed an RTSP/RTP-based proxy which exploits the layered encoding of the video and can perform real-time video adaptation on an inexpensive off-the-shelf WiFi router. This is achieved by applying a stateful, packet-based adaptation approach that keeps the computational costs at a minimum. With that approach it is possible to simultaneously adapt multiple video streams to varying network conditions or to the capabilities of the consumers' end-devices. In our demonstration we show the streaming of two scalable video streams from a server to a client and the in-network adaptation of the video at the WiFi router. The adaptation can be controlled interactively in the temporal, spatial and SNR domains.**

I. Introduction

In the past, the adaptation of video content according to different end devices was in general a computationally expensive process. Recent advances in the field of scalable video coding aim to reduce the complexity of video adaptation. The most prominent example is the scalable extension of the H.264/AVC video coding standard [1], later referred to as H.264/SVC. It introduces a layered encoding of the video and enables scalability in the temporal, spatial and SNR domains by discarding layers of the video stream. This means that variations of the video with different spatial resolution, frame rate, quality and bit rate can be extracted from the scalable bitstream. In contrast to older scalable video coding approaches the flexibility only comes with a very low bit rate overhead. These advances in the video coding domain open new perspectives in the context of multimedia communication and consumer applications. By utilizing the low complexity of the adaptation process, it is now possible to adapt the video content individually to the consumers' end devices. In our research we tackled the challenges of performing video adaptation during the streaming of the video from a server to a client and delevoped an RTSP/RTP proxy that is capable of adapting SVC video streams. As a result of the low resource requirements, the proxy software can be deployed on an off-the-shelf WiFi router.

II. H.264/SVC Adaptation Proxy

The core element of the demonstration is the H.264/SVC adaptation proxy [2] that runs on the WiFi router. The proxy implementation is based on the RTSP/RTP protocol suite which is commonly used in unicast video streaming applications. By applying certain firewall rules on the router, each RTSP request of a client located in the LAN/WLAN for a media resource on the Internet is redirected to the adaptation proxy instead of being forwarded directly to the media server. Since the proxy automatically intercepts outgoing RTSP connections without having to configure the clients in the LAN/WLAN, it can be characterized as intercepting proxy. The proxy itself connects to the actual media server and forwards the RTSP requests of the client and the corresponding RTP stream sent by the server. As the RTP stream is forwarded by the proxy it allows for in-network adaptation of the scalable video stream carried in the RTP packets. In our approach the adaptation of the video stream is performed directly on the RTP stream on a per-packet basis, based on the RTP payload format for H.264/SVC streams [3]. This implies that it is not necessary to depacketize the NAL units and aggregate them to a complete access unit for the task of adaptation. Therefore, our adaptation approach keeps the memory footprint of the proxy very low, which is important since memory typically a scarce resource on embedded devices. As a consequence of the efficient implementation of this light-weight adaptation approach it is possible to adapt around four streams (2 Mbps each) simultaneously on the WiFi router. Although the approach is packet-oriented it cannot be compared with a simple packet dropper or traffic shaper, since it uses stateful information in the proxy and is session-oriented.

The adaptation proxy offers a SOAP-based interface which is used for obtaining both monitoring information on the proxy and for specifying adaptation parameters. The adaptation can be steered by specifying adaptation parameters for the temporal, spatial and quality dimensions. The parameters can be set separately for each of the sessions that are served by the proxy. In a real deployment the adaptation will be controlled via the SOAP interface by a dedicated process on the router which has knowledge about the device capabilities and network conditions. For demonstration purposes this process is emulated by a control application, which allows for selecting

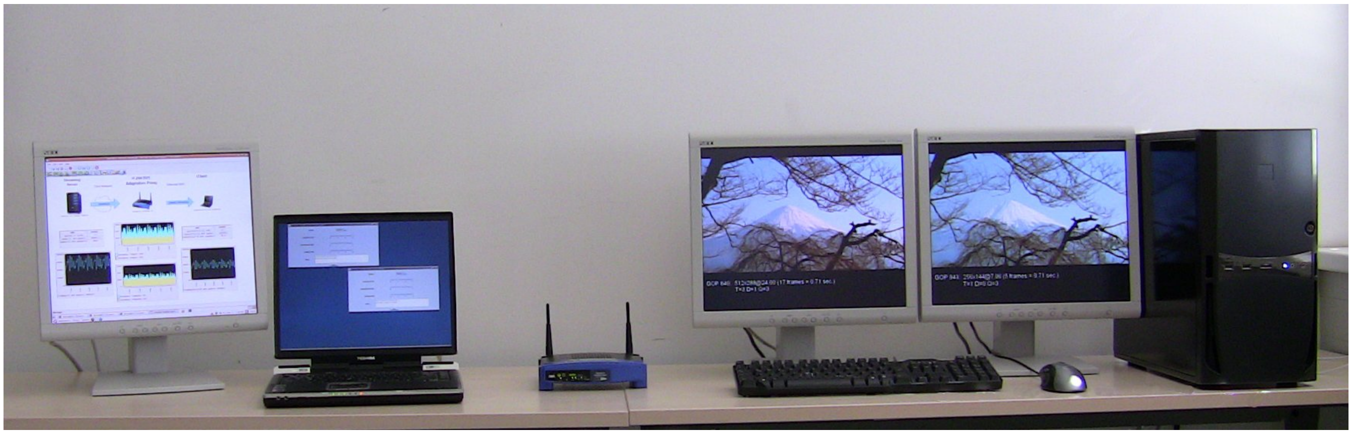

Fig. 1. Demonstration setup

the adaptation parameters by a graphical user interface.

III. Demonstration setup

The demonstration setup consists of two computers of which one acts as the server and the other one as a client. Both computers are interconnected by Ethernet links to the WiFi router which hosts the adaptation proxy. Figure 1 gives an overview of the setup with the server on the left and the client on the right hand side.

The server is a Linux-based machine that runs an RTSP/RTP streaming server. This server is based on Apple's Darwin Streaming Server and was extended by H.264/SVC support. Additionally, the server runs an application to visualize the impact of adaptation on the network. This monitoring dashboard constantly collects monitoring information from the client, the router and the server. The collected information, like the bit rate of the original and the adapted streams, CPU usage and other performance metrics, is visualized by real-time graphs. The WiFi router that runs the adaptation proxy is a Linksys WRT54GL Wireless-G Broadband Router. It is based on the Broadcom System-on-Chip BCM5352EL and contains a 200 MHz RISC CPU, 16 MB of RAM and 4 MB of flash memory. This device is very suitable for research purposes since it allows to replace the original firmware by a Linux-based firmware. For our developments we used OpenWrt[1], a small-scale Linux distribution tailored to embedded devices. The proxy was developed as a research prototype from scratch in ANSI C. The client receives the (possibly) adapted video stream, decodes it and renders the video onto the screen. In order to visualize the impact of adaptation, two unicast streaming sessions are received and rendered by the client in parallel. During the course of the demo it is possible to steer the adaptation of each video stream interactively by manipulating the adaptation parameters through the control application.

[1] http://www.openwrt.org

IV. Conclusion

In our work we demonstrate the real-time adaptation of scalable video content on a network device by exploiting the recent advances in the context of video coding, i.e., the scalable extension of the H.264/AVC standard. Our stateful, packet-based adaptation approach makes it possible to adapt several streams in parallel on existing networking hardware. The ability of performing in-network adaptation on a consumer's network device enables a variety of new applications and technologies. For example, cross-layer adaptation can be performed on the WiFi router in order to cope with varying network conditions of the wireless link. Additionally, profiles of the consumer's devices can be stored on the router and the video content can be adapted according to the device's capabilities on-the-fly and without having to transcode the video. This can be especially useful when performing session migration between different devices in the consumer's home network, e.g., when transferring a streaming session from the PC to a mobile device. The interested reader is kindly refered to our recent publication [2] and to a video of the demo[2].

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[3] S. Wenger, Y.-K. Wang, T. Schierl, and A. Eleftheriadis, "RTP Payload Format for SVC Video," Internet Draft, Jul. 2008.

[2] A high-definition video of the demonstration is available for download at http://www-itec.uni-klu.ac.at/~inkofler/demo/