ABSTRACT

In this paper, we empirically investigate the performance of path selection and packet scheduling algorithms for the delivery of H.264/SVC scalable video streams to users in multihomed mobile networks. These algorithms use the aggregated bandwidth of multiple concurrent paths to deliver media streams in environments where no single, sufficiently high bandwidth path is available. The problems associated with delivering video streams in this challenging environment are examined and the performance of our multihomed mobile networks specific scheme is compared to that of an ideal single high bandwidth path. We further extend previously proposed algorithms by the inclusion of an H.264/SVC-specific packet priority weighting scheme. We highlight the improvements offered by our optimized algorithm over representative algorithms and identify the remaining challenges that must be overcome if such algorithms are to offer performance close to that of the ideal single high bandwidth path.

Keywords

H.264/SVC, Multihomed Mobile Networks, Multipath Streaming.

1. INTRODUCTION

The use of sophisticated personal wireless devices (laptop, netbook, smartphone, tablets etc.) capable of the playback of streamed video has risen sharply in recent years. Users of these devices increasingly expect to use them “anywhere, anytime”, including whilst travelling on public transport. However, current mobile network infrastructures often fail to deliver a consistent, high-bandwidth and low-latency network connection to nomadic users, who often run into a scenario where there is insufficient bandwidth on any single network path to ensure delivery of a media (in particular video) stream from server to client.

The emerging wireless networking paradigm known as Mobile Networks [1] addresses the mobility requirements of groups of mobile nodes travelling together in unison. Mobile nodes in a mobile network no longer directly connect to the ISP. Instead, they connect to a local device (Mobile Router) within the mobile network that handles mobility on behalf of all nodes. Multihomed mobile networks offer multiple network access paths, which can be accessed and used simultaneously. To support video applications for resource-constrained users, H.264 Scalable Video Coding (SVC) [2] has recently been standardized as an extension to the H.264 Advanced Video Coding standard (AVC) [3]. Its scalable nature facilitates the adaptation of video streams in response to varying network conditions and terminal capabilities. Previously proposed algorithms [4, 5] aim to make best use of the aggregated bandwidth of multiple network paths, ensuring the delivery of MPEG2 and MPEG4 streams to client nodes. These schemes consider network path conditions and media stream characteristics when deciding which path(s) to use for streaming. Chebrolu and Rao [4] proposed the Earliest Delivery Path First (EDPF) algorithm, which uses path condition metrics of available bandwidth and end-to-end delay to estimate the arrival time of a packet, which is then sent on the path offering the earliest arrival time. This scheme addresses the problem of out-of-sequence packet delivery arising in multipath transmission where paths have different bandwidth and delay characteristics. Jurca and Frossard [5] proposed a scheme that considers a generic scalable video format and selectively drops packets that will be unusable at the decoder. However, no schemes have investigated the negative effect of path switching because of dynamic path selection among multiple available paths.

In this paper, we provide insight into the tradeoff between the benefits and costs of path selection and switching in multipath transmission; we explore an SVC-specific priority weighting scheme for packet prioritization; we demonstrate the significant quality improvement, and also identify the performance gaps for future development. We conducted the empirical performance evaluation in a realistic multihomed mobile networks testbed.

2. DESIGN AND IMPLEMENTATION

Our work designs and implements a streaming scheme specifically tailored for use of H.264/SVC in the multihomed mobile networks environment, as shown in Figure 1.
We extend the path selection schemes from [4, 5] by taking account of the previously unconsidered path switching costs induced in a realistic multihomed mobile network [6] and introducing an algorithm that trades off optimal bandwidth aggregation in favor of reduced path switching cost. Each time a path switching is invoked, a non-trivial switching delay will be added to the ongoing packets being delivered, resulting in a significant increase in the end-to-end delay and thus making some packets unusable at the decoder. Thus, in contrast to [4, 5], the proposed algorithm persistently uses the current path as long as it meets the instantaneous delivery requirement even when a better path comes up. By reducing the path switching frequency, we also mitigate out-of-sequence delivery following a path switching.

We then consider tunneling overheads and path switching delays in packet-delivery-time estimation for path selection. The packet encapsulation overheads are introduced by the Home Agent to Mobile Router tunnel in our testbed based on the Network Mobility protocol [1]. In our experiments, we observed that, when using a one SVC network abstraction layer (NAL) unit per RTP packet strategy the size of the RTP packet was normally much greater than the Ethernet maximum transmission unit of 1500 bytes. As these overheads are added to each fragment of the RTP packet, the overall bitstream size was increased by between 3% and 5%. By considering these overheads, we improve the preciseness of packet-delivery-time prediction and thus improve the decision-making in path selection. Those packets that would not arrive at the client on time or would be unusable due to unmet packet dependencies are dropped at the scheduler to prevent unnecessary use of the available bandwidth.

An SVC-specific packet prioritization scheme, which has not been included in previous schemes from the literature, is further integrated in this work. SVC has a three-dimensional scalability of spatial resolution, temporal resolution and quality. We utilize JSVM SVC codec [7] to provide per-packet prioritization. This assigns a weight based on the spatial, temporal and quality tuple, which describes a packet’s relative position in an SVC stream. This information is carried in each SVC NAL unit and is used to calculate a priority weighting when NAL unit is packetized for transmission. In our scheme, within each spatial layer, quality enhancements of the highest temporal layer have the lowest priority, while the lowest quality layer of the lowest temporal layer (temporal base layer quality_id = 0) has the highest priority.

We constructed a realistic hardware-based mobile network testbed and implemented an end-to-end SVC streaming framework including encoding, prioritization, packetisation, scheduling, selective dropping, multipath transmission, reception and decoding. Packet priority schemes are added to the stream pre-processing component of our framework. The major processes are shown in Figure 2. The streamer is a media-aware network element (MANE) and the two core routers (CR1 and CR2) run wide-area network emulation to provide two available paths to a multihomed mobile router and the mobile network (not shown).

The focus is evaluating our SVC-specific multipath streaming scheme, and comparing it with a typical existing scheme for generic scalable video [5], and an “ideal” single high-bandwidth path to identify performance gaps for further improvement. The single path scheme used is a slimmed-down version of our multipath scheme, where we still calculate the estimated packet arrival time and drop unusable packets. The “ideal” single path has a bandwidth equivalent to the aggregated bandwidth through multiple paths, and thus no path switching costs are incurred.

3. TESTING AND RESULTS

The Bus and Soccer test sequences were encoded using the JSVM software [7] with frame rates of 15, 30 and 60 fps. Spatial resolutions were 352×288 and 704×576 respectively. Each was encoded with a single spatial layer, multiple temporal layers and multiple quality layers. Test sequences had two versions, one where packets were marked using the priority weightings previously from [5] and one using the SVC scalability scheme. The tests were conducted over a single path with bandwidths ranging from 50% to 110% of the stream requirement, and then repeated using multipath transmission with aggregated bandwidths in the same range. Each multipath test was also repeated using bandwidth split ratios of 1:1 (equal path scenario) and 5:1 (high differential path scenario). Two types of single path were used. In our “ideal” single path, server and client are connected by a single wired path with no intermediate nodes and no added end-to-end latency. In our “functional” single path, we simply route all traffic through one Home Agent to Mobile Router tunnel on our testbed. This path is configured with variable end-to-end delays in the same way as our multiple paths. Figure 3 shows that the SVC scalability scheme offers a consistent improvement in PSNR (typically 1.1 dB) over the generic scheme [5]. This holds true for both our ideal single path and in the case of multipath streaming.
Figure 4 demonstrates that the number of packets delivered to the client in multipath streaming is considerably less than that in a single path scenarios, where there is no path switching overhead. It can also be seen that high differential paths deliver many more packets than equal paths, which have a higher path switching frequency (and added delay) due to the ping-pong path selection. Each path switching introduces a delay, which induces the dropping of following packets since they will no longer meet their decoding deadline. The inclusion of an SVC specific prioritization scheme shows that although the number of packets delivered in each case is broadly similar, the better prioritization of which packets to drop leads to a significant improvement in PSNR.

Furthermore, to complement the above results comparing ideal single path and multipath SVC streaming, a set of different experiments have been carried out to demonstrate the fact that our multipath scheme is able to provide an improved PSNR when no single sufficient path is available. In these experiments, we utilize our “functional” single path that is subject to all of the losses and delays that may be encountered in a “real” multihomed mobile network. The end-to-end delay and available bandwidth on both the “functional” single path and the multiple paths changes dynamically throughout the duration of the testing sequence. The observed improvements shown in Figure 5 justify the approach that exploits multipath transmission when no single path can meet the bandwidth requirement.

4. CONCLUSIONS

We show that our path selection and scheduling algorithm is able to effectively deliver H.264/SVC encoded streams over multiple paths in mobile networks and that it provides an acceptable quality of received video. Adding an SVC specific prioritization scheme to our algorithm demonstrates a significant improvement in PSNR of 1.1 dB over the previously proposed scheme used in [4] and [5]. However, it still does not realize our ultimate goal of matching the performance of a single ideal high-bandwidth path. Figure 6 shows the performance window of our multipath algorithm and highlights the performance gap that has yet to be bridged to achieve comparable performance with an “ideal” path. By analysis of test results, we have established that the remaining performance gap is primarily due to the relatively high delay introduced by path switching operations in multihomed mobile networks. The upper performance bound of our current scheme is reached when paths are diverse in nature and the path switching frequency is lowest. Our future work will concentrate on reduction of the delay introduced by each path switching operation and thus further improve the performance.

5. REFERENCES