SoftCast: One-Size-Fits-All Wireless Video

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ABSTRACT

The focus of this demonstration is the performance of streaming video over the mobile wireless channel. We compare two schemes: the standard approach to video which transmits H.264/AVC-encoded stream over 802.11-like PHY, and SoftCast – a clean-slate design for wireless video where the source transmits one video stream that each receiver decodes to a video quality commensurate with its specific instantaneous channel quality.

Categories and Subject Descriptors: C.2 Computer-Communication Networks : Miscellaneous

General Terms: Algorithms, Design, Performance, Theory

Keywords: wireless networks, scalable video communications, joint source-channel coding

1. INTRODUCTION

Mobile video broadcast presents a significant challenge to conventional wireless design. With mobility, the channel quality can exhibit fast unpredictable variations [3,9]. Video codecs however operate over groups of pictures (GOP) and hence cannot instantaneously adapt the video rate to the channel bit rate. As a result, a mobile receiver suffers from video glitches and stales [2]. With multicast, different receivers experience different channel qualities (SNRs) and hence support different bit rates. The transmitter however has to pick a single transmission bit rate. As a result, the transmitter has to send at the lowest bit rate supported by all multicast receivers, which reduces everyone to the video quality of the worst multicast receiver.

This demo advocates SoftCast, an alternative design for wireless video streaming. SoftCast uses a novel encoding technique that allows it to broadcast a single stream from which each receiver can decode a video quality commensurate with its instantaneous channel quality. Thus, a mobile receiver need not suffer glitches and stales due to quickly varying channel quality; the received video quality naturally adapts to the channel quality without any effort from the source. Furthermore, different multicast receivers can be served with a single video broadcast, without reducing all receivers to the video rate supported by the worst receiver in the group. Moreover, SoftCast can support this performance without any receiver feedback.

SoftCast adopts a unified design for video compression and transmission over the wireless physical layer. SoftCast starts with video that is represented as a sequence of numbers, with each number representing a pixel luminance. Taking an end-to-end perspective, it then performs a sequence of transformations to obtain the final signal samples that are transmitted on the channel. The crucial property of SoftCast is that each transformation is linear. This property ensures that the signal samples transmitted on the channel are linearly related to the original pixel values. Thus, increasing channel noise progressively perturbs the transmitted bits in proportion to their significance for the video application, i.e., high-quality channels perturb only the least significant bits while low-quality channels still preserve the most significant bits. Each receiver therefore decodes the received signal into video whose quality is proportional to the quality of its specific instantaneous channel.

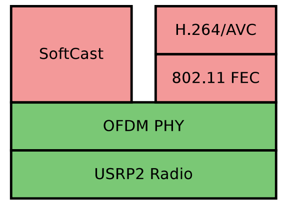

Figure 1 The architecture of the experiment. We compare the joint design of SoftCast to the standard design using H.264/AVC on top of the 802.11 FEC. Both schemes use the same OFDM PHY and the USRP2 radio front-end.

We have presented a preliminary design of SoftCast in [6]. Since then, we have enhanced SoftCast to perform inter-frame compression which allows it to exploit the correlation between subsequent frames in addition to the correlation of pixels in each individual frame. The new design also includes packet erasure protection and is refined to work with actual OFDM PHY (e.g., as provided by GNURadio [5]).

2. DEMONSTRATION

This demo shows live video streaming to mobile USRP software radio nodes. The demo shows the video performance of two schemes: SoftCast and the existing design which uses H.264/AVC (i.e., MPEG-4 part 10) over 802.11a/g PHY. In the experiment, a video sequence is streamed over the wireless channel to one or two mobile receivers. The spectators can freely move the nodes around and observe the live video feed on the laptop screen and how the channel conditions affect perceptible video quality.

The compared schemes share the low-level OFDM PHY implemented in GNURadio [5] as well as the USRP2 hardware, as shown in Fig. 1, thus experiencing *identical* channel conditions. This includes parameters such as: channel bandwidth and airtime, transmission power and receiver noise. The channel attenuation and fading is out of direct control, but can be influenced by changing node location (distance from the transmitter, walls, etc.).

We have implemented real-time SoftCast using the ATLAS

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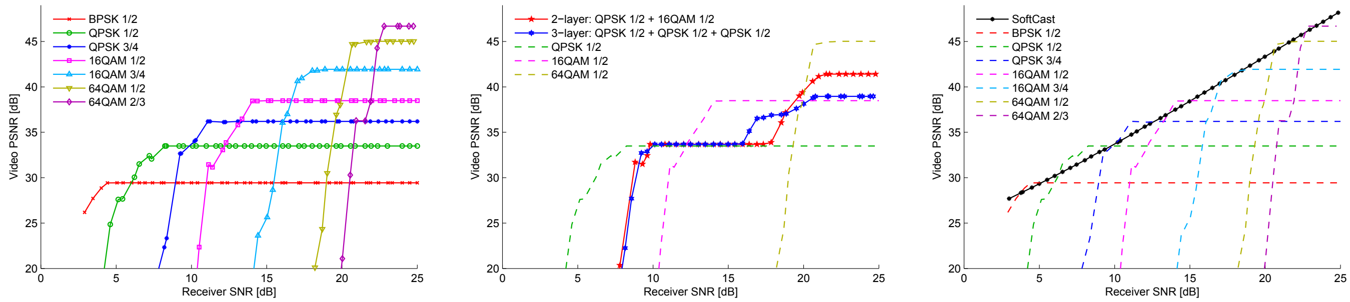

(a) Conventional Design (b) Layered SVC with Hierarchical QAM (c) SoftCast

Figure 2 Approaches to Wireless Video: Fig. (a) plots the space of video qualities obtained with the conventional design which uses MPEG-4 over 802.11. Each line refers to a choice of transmission bit rate (i.e., modulation and FEC). Fig. (a) shows that for any choice of bit rate, the conventional design experiences a performance cliff. Fig. (b) plots 2-layer video in red and 3-layer video in blue. For reference, the dashed lines are the three equivalent single-layer MPEG-4 videos. The figure shows that layered video makes the cliffs milder but each new layer introduces overhead and reduces the maximum video quality. Fig. (c) shows SoftCast (in black) and single-layer MPEG-4. It shows that SoftCast video quality scales with channel quality.

linear algebra package [1]. SoftCast encodes the video from pixels directly into OFDM frequency bin samples. H.264 implementation is provided by libx264 [11]. The H.264-encoded bitstream is then using 802.11 FEC, developed with Spiral [8], and modulated using GNURadio signal processing blocks.

The experiment shows that SoftCast's performance is robust to unpredictable channel conditions in mobile scenarios and scales gracefully with multiple receivers. Each receiver observes video quality commensurate with its instantaneous channel quality, without glitches or stales. This adaptation happens naturally in response to the noise (or interference) level in received signal, and neither requires receiver feedback nor sender adaptation.

3. EXPERIMENTAL RESULTS

Fig. 2 graphically displays the characteristics of the different video encoding and transmission schemes. This figure presents three graphs; each graph plots the video quality at the receiver as a function of the channel quality. All schemes use exactly the same transmission power and the same channel bandwidth over the same period of time.

Fig. 2(a) illustrates the realizable space of video qualities for conventional MPEG-based approaches. Each line refers to a particular choice of transmission bit rate, i.e., a particular choice of forward error correction code and a modulation scheme. The video codec encodes the video at the same rate as the channel transmission bit rate. The effective compression ratio of the video codec changes from 33× at the lowest rate to 3.7× at the highest rate. Fig. 2(a) shows that for any selection of transmission bit rate (i.e., modulation and FEC) the conventional design experiences a performance cliff, that is there is a critical SNR, below which the video is not watchable, and above that SNR the video quality does not improve with improvements in channel quality.

Fig. 2(b) illustrates the video qualities obtained by layered video coding. The video is encoded using the JSVM reference implementation for scalable video coding (SVC) [7]. The physical layer transmits the video using hierarchical modulation over OFDM, an inner convolutional code and an outer Reed-Solomon code following the recommendations in [4]. The figure shows two solid lines, the red line encodes the video into two layers while the blue line encodes the video into three layers. For reference, the figure also shows in dashed lines the single layer MPEG-4 videos that span the range of channel SNRs spanned by the layers in the layered video. The figure shows that layered video transforms the performance cliff of the conventional design to a few milder cliffs. Layering however causes extra overhead [10] and thus increases the size of the video. Given a particular bit rate budget, the video codec has to reduce the quality of the layered video in comparison with the single layer video to ensure that the videos have the same size and can be streamed at the same bit rate. As a result, the enhancement layer of the 3-layer video has a lower quality than the corresponding layer in 2-layer video, which has a lower quality than the corresponding single layer video.

Fig. 2(c) illustrates the video qualities obtained with SoftCast. Since SoftCast maps pixels to channel samples in the real field, it has no notion of bit rate. Unlike the conventional or layered design, where the channel noise determines the maximum reliable (layer) bit rate, in SoftCast it directly translates to distortion in the video pixels. Therefore SoftCast's video quality is proportional to the channel quality and stays competitive with the envelope of all of MPEG curves.

4. REFERENCES

[1] Automatically tuned linear algebra software. `http://math-atlas.sourceforge.net/`.

[2] G. Bai and C. Williamson. The Effects of Mobility on Wireless Media Streaming Performance. In *Proceedings of Wireless Networks and Emerging Technologies*, pages 596–601, july 2004.

[3] J. Camp and E. W. Knightly. Modulation rate adaptation in urban and vehicular environments: cross-layer implementation and experimental evaluation. In *MOBICOM*, 2008.

[4] ETSI. *Digital Video Broadcasting; Framing structure, channel coding and modulation for digital terrestial television*, Jan 2009. EN 300 744.

[5] The GNU software radio. `http://gnuradio.org/trac`.

[6] S. Jakubczak, H. Rahul, and D. Katabi. One-size-fits-all wireless video. In *HotNets*, 2009.

[7] SVC reference software. `http://ip.hhi.de/imagecom_G1/savce/downloads/SVC-Reference-Software.htm`.

[8] Spiral project: Viterbi decoder software generator. `http://www.spiral.net`.

[9] M. Vutukuru, H. Balakrishnan, and K. Jamieson. Cross-Layer Wireless Bit Rate Adaptation. In *ACM SIGCOMM*, Aug 2009.

[10] M. Wien, H. Schwarz, and T. Oelbaum. Performance analysis of SVC. *IEEE Trans. Circuits and Systems for Video Technology*, 17(9), Sept. 2007.

[11] x264 - a free H.264/AVC encoder. `http://www.videolan.org/developers/x264.html`.