

Chapter 18

Cross-Layer Techniques for Reliable Wireless Video Communication

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ABSTRACT

Designing wireless video communication system is a challenging task due to high error rates of wireless channels, limited and dynamically varying bandwidth availability, and low energy and complexity requirements of portable multimedia devices. Scalable video coders having excellent rate-distortion performance are most suited to cope with time varying bandwidth of wireless networks, but encoded bits are extremely sensitive to channel errors. This chapter presents a reliable video communication system exploring opportunities offered by various network layers for improved overall performance, while optimizing the resources. More specifically, cross-layer approach for Unequal Error Protection (UEP) of scalable video bitstream is the main theme of this chapter. In UEP, the important bits are given a higher protection compared to the other bits. Conventionally, UEP is achieved by using Forward Error Correction (FEC) at the application layer. However, UEP can also be provided at the physical layer using hierarchical modulation scheme. In this chapter, the authors discuss cross-layer design methodology for UEP that rely on interaction between the application layer and the physical layer to achieve reliable and high quality end-to-end performance in wireless environments. The discussion is mainly focused for wavelet coded video, but it is applicable to other embedded bitstreams as well.

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INTRODUCTION

In recent years, wireless communications and networking have experienced unprecedented growth. Video communication over wireless networks is envisioned for a vast range of applications, such as videotelephony, videoconferencing, telemedicine, surveillance, security monitoring, disaster rescue, environment monitoring, gaming, and entertainment, wildlife activity monitoring, and multimedia systems in consumer electronics (Al-Mualla, 2002). However, the issues of limited and dynamically varying bandwidth and error prone nature of the wireless channels, limited processing power, and battery life of the portable multimedia devices, and network heterogeneity make the video delivery over wireless networks a difficult and challenging task (Etoh, 2005).

Compressed video bitstream is extremely sensitive to bit errors, and therefore, not suitable for error prone and dynamically varying wireless channels. A variety of solutions have been proposed to cope with these challenges (Wang, 1998; Girod, 2000). These include *Forward Error Correction (FEC)*, retransmission using Automatic Repeat Request (ARQ), error resilient coding, *hierarchical modulation*, *joint source-channel coding*, scalable coding with transport prioritization, multiple-description coding, and error concealment by post processing etc. Traditionally, these solutions are employed at various network layers (such as application, transport, Media Access Control [MAC], and physical layers) separately and independently. Although, the decoupled layered protocol reduces network design complexity, however, independently optimized protocol paradigm is not well suited for wireless networks due to dynamically varying bandwidth and error rates, user mobility, high interferences, limited power, and complexity (van der Schaar, 2007). *Cross-layer design* methodologies that rely on interaction among different protocol layers hold great promises for addressing these challenges and for providing reliable and

high-quality end-to-end performance in wireless multimedia communications (Shakkottai, 2003; van der Schaar, 2005).

In recent years, *cross-layer designs* for *wireless video communication* have been widely reported in literature. Researchers have pursued *cross-layer design* from the perspectives of reliable communication (van der Schaar, 2003; Xu, 2004; Choi, 2004; Barmada, 2006; Pei, 2007; Maani, 2010), end-to-end Quality-of-Service (QoS) requirements (Kumwilaisak, 2003; Zhang, 2005; Melodia, 2010), rate-adaptation (Haratcherev, 2006), resource allocation (Katsaggelos, 2005), scheduling (Anton-Haro, 2006; Li, 2010), and optimization (Khan, 2006; Foh, 2007; Zhang, 2010), etc. However, the main focus of this chapter is on the opportunities offered by cross-layer for error protection to enable reliable *wireless video communication*. The idea is to jointly explore the error protection strategies at various network layers, in order to improve the transmission efficiency in terms of protection, bandwidth, and resource consumption.

VIDEO CODING: AN OVERVIEW

Digital video signals generally involve huge amount of data in raw or uncompressed form. For example, a relatively low resolution QCIF (Quarter Common Intermediate Format) video have uncompressed data rate of about 6 Mbps (megabits/second). On the other hand, HDTV (High Definition Television) resolution video sequences have uncompressed data rate of about 1.5 Gbps (gigabits/sec). Given the vast data volumes, and limited bandwidth of wireless channels, it is obvious that the most essential requirement for wireless video is high compression efficiency. Moreover, growing network heterogeneity and varying resolution of display devices coupled with time varying characteristics of the wireless channels requires video coder to be equipped with

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