Chapter 6

Cross-Layer Optimization for Energy-Efficient QoS Support of Multimedia Streams

Carolina Blanch Perez del Notario
Interuniversity MicroElectronics Center (IMEC), Belgium

Sofie Pollin
Interuniversity MicroElectronics Center (IMEC), Belgium

Tong Gan
Interuniversity MicroElectronics Center (IMEC), Belgium

Claude Desset
Interuniversity MicroElectronics Center (IMEC), Belgium

Antoine Dejonghe
Interuniversity MicroElectronics Center (IMEC), Belgium

Bart Masschelein
Interuniversity MicroElectronics Center (IMEC), Belgium

ABSTRACT

A major limitation for wireless video communication on portable devices is the limited energy budget. For this reason, efficient usage of the scarce energy becomes a critical design constraint, in addition to meeting the Quality of Service constraints related to the video quality. In this chapter the authors focus on minimizing the energy cost of the two main energy consumers in the handheld wireless video device: the video encoding and wireless communication tasks. For this purpose, they present a cross-layer approach that explores the tradeoff between coding and communication energies. They then exploit the Rate-Distortion-Complexity tradeoffs and flexibility of the Scalable Video Codec. The results show that by adapting the codec configuration at runtime to the specific scenarios up to 50% of the total energy can be saved with marginal video quality loss. Moreover, the approach presented is of low complexity and easily deployable in practical systems.

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INTRODUCTION

Wireless video communication with portable devices has become the driving technology of many important applications such as personal communication, gaming and security. In this respect, both mobile communication protocols and video coding technologies have experienced rapid advances.

On the one hand, in the context of video coding technologies, several video compression standards have been developed within the past years such as MPEG-4 Part 10, H.264/Advanced Video Codec (AVC) or the most recent Scalable Video Codec (SVC). The purpose of the H.264/AVC project was to create a standard capable of providing good video quality at substantially lower bit rates than previous standards (e.g. half or less the bit rate of MPEG-2, H.263, or MPEG-4 Part 2), without increasing the complexity of design so much that it would be impractical or excessively expensive to implement. In a similar way, the Scalable Video Codec (SVC) has been developed as an extension of the H.264/AVC providing scalability aspects in the encoded video bitstream relying on a wide range of spatio-temporal and quality scalability. This higher flexibility comes also at the cost of an increased complexity or energy consumption.

In general, we can see that the trend in the evolution of video codecs aims at achieving higher compression degree and higher flexibility in terms of scalability and adaptability. Both features are highly valuable in mobile communications. First, bandwidth is a scarce resource and a high compression degree lowers the required bandwidth. Secondly, the variability of the available bandwidth together with the heterogeneity of devices and processing capabilities makes the bitstream scalability and adaptability a desired feature.

One obvious way to compress the video information is to reduce the target video quality. By allowing a coarser quantization the output rate is reduced at the cost of an increased video distortion. This exploits the inherent Rate – Distortion tradeoffs of video codecs. However, for a fixed target video quality, obtaining a higher compression degree generally requires the use of more complex coding tools, which increases the complexity of the coding process and with it its coding energy. This extends the Rate – Distortion tradeoff to a three-dimensional Rate – Distortion – Energy tradeoff, as shown in Figure 1.

On top of this, to avoid severe degradation of the end video quality when transmission errors occur, the video codec should provide a certain degree of error resilience or robustness. This is achieved at the cost of an increased redundancy, or in other words, increased output rate, which is translated again in terms of Rate-Distortion tradeoff.

On the other hand, the trend in the development of new wireless communication standards is to provide, among other aspects, higher bandwidth/data rate to the end users. This way, the new WLAN standard, 802.11n, aims to provide up to 600 Mbits/s with respect to the 54 Mbits/s provided by previous WLAN standard such as 802.11g. Achieving high data rate is indeed one of the key aspects of wireless communications. The available bandwidth is variable as it is dependent on the channel conditions during transmission and the distance between mobile terminal and base station. Given the error-prone nature of wireless channels, providing a certain Quality of Service (QoS) to the end user is another challenging task. This QoS is generally measured in terms of latency and Packet Error Rate (PER) as this can have a dramatic impact on the end video quality. Finally, when addressing wireless communications from battery-powered devices, energy consumption becomes also a critical issue. The required energy consumption is directly linked to the amount of transmitted data: the more bits transmitted, the higher the energy consumption is. On top of this, the required transmission energy depends on both distance between transmitter and receiver and experienced channel conditions. This way, guaranteeing a specific QoS under