Chapter 21
Cross-Layer Joint Optimization of Multimedia Transmissions over IP Based Wireless Networks

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ABSTRACT

The traditional approach consisting in separately optimizing each module of a transmission chain has shown limitations in the case of wireless communications where delay, power limitation and error-prone channels are experienced. This is why modern designers focus on a more integrated strategy to establish the heterogeneous 21st century networks, such as 3G (i.e. UMTS) system and its evolutions (i.e. Beyond 3G or 4G like LTE or future 5G systems). Indeed, it was shown in several studies that optimal allocation of user and system resources could be effectively achieved with the co-operative optimization of communication system components. In this chapter, an innovative Joint-Source Channel Coding and Decoding (JSCC/D) system is described and its performance over an IPv6-based Network infrastructure is assessed. A particular focus is put on the application controller, the key component to realize the adaptation strategies. Conclusions and considerations about the system implementation are also proposed, and the interest of a possible extension to a point-to-multipoint scenario is explained.

INTRODUCTION

Following the path opened by GSM systems, the under-deployment 3G (*i.e.* UMTS) system and its evolutions are leading to more and more configurable, dependable, adaptable, intelligent, secure but also complex wireless solutions. Aiming at handling digital data of different nature (text, voice, image, video...) that will be used in various contexts (home, office, on the move...) these systems rely on inner software that make them more and more efficient and easy to use. However, the gap between what the actual systems propose and what the users envision and could use still remains. The lack is particularly noticeable in the domains of heterogeneous networks and systems interconnection (*i.e.* in beyond 3G, future 4G or even 5G networks), but also in the flexible management of resources and

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in the Quality of Service (QoS) and bandwidth optimization domains.

Noticeable progresses were made throughout the last decades of 20th century to individually optimize each module in modern communication systems. Still, although excellent results were obtained, the separate approach following Shannon's well known theorem has shown limitations in the case of wireless communications. Working on a more integrated strategy, for instance via optimal allocation of user and system resources is the key challenge for modern designers. Following the already known approach of JSCC or Joint-Source Channel Coding (Massey, 1978), strategies are and have been developed where the source coding, channel coding, modulation, ciphering, and, possibly, network parameters are jointly determined to yield the best end-to-end system performance.

For the user, such an approach should result in greatly enhanced perceived quality for multimedia communication, potentially allowing the development of currently too complex, expensive and/or time consuming video over wireless systems. The realization of a system operating under JSCC/D paradigm is however not simple: in particular, the delivering of the control and signaling information between the system components is a key point, as it affects the overall design and operation of the system. As a matter of fact, in the ISO model, only the modules at the sender and receiver sides that are at the same layer (*i.e.* peer entities) can communicate with each other. On the contrary cross-layer communication implies that the different layers can communicate in order to allow the system to adapt to the network changes and to increase the overall performance. When adding the condition of realizing an exchange of control and signaling messages in a backward compatible manner, the complexity of designing a JSCC/D system is obvious.

In this chapter, the case-study of the system proposed within the framework of the FP6 IST PHOENIX project[1] (Martini & Mazzotti, 2007; Lamy-Bergot & Panza, 2008) is presented and discussed. The pursued goal was to develop a scheme for point-to-point multimedia communications, offering the possibility to let the application world (source coding, ciphering) and the transmission world (channel coding, modulation) to talk to each other over an IPv6 protocol stack (network world), so that they can jointly develop an end-to-end optimized wireless communication link. To reach the goal, three main axes were identified, following the path of first to enhance each module of the chain while ensuring compatibility with overall optimization, of second to propose optimization strategies between several modules and finally to define the corresponding global network architecture necessary to realize the system. Said another way, the IST PHOENIX project goals were:

- To design innovative schemes to enable end-to-end joint optimization over wireless links. This includes the development of flexible channel coding and modulation schemes, the adaptation of existing source coding schemes with respect to their ability for the JSCC and the development of new ones specifically optimized for this purpose.
- To establish efficient and adaptive optimization strategies that jointly control the coding blocks and realistically take into account the system limitations and specifications, such as the presence of ciphering, the presence of one or several wireless hops, …
- To build a global network architecture based on joint optimization for future wireless systems. This also implies the support of transparent network communications, which allow applying the optimization strategies in any kind of fully IP-based network.