Preface

The Wireless Multimedia Communications Scene

Against the backdrop of the emerging third-generation wireless personal communications standards and broadband access network standard proposals, this book is dedicated to a range of topical wireless video communications aspects. The transmission of multimedia information over wireline based links can now be considered a mature area, where a range of interactive and distributive services are offered by various providers across the globe, such as Integrated Services Digital Network (ISDN) based on H.261/H.263 assisted videotelephony, video on demand services using the Motion Pictures Expert Group (MPEG) video compression standards, multimedia electronic mail, cable television and radio programs, and so on. A range of interactive mobile multimedia communications services are also realistic in technical terms at the time of writing, and their variety, quality, as well as market penetration are expected to exceed those of the wireline-oriented services during the next few years.

The wireless multimedia era is expected to witness a tremendous growth with the emergence of the third-generation (3G) personal communications networks (PCN) and wireless asynchronous transfer mode (WATM) systems, which constitute a wireless extension of the existing ATM networks. All three global 3G PCN standard proposals, which originated in the United States, Europe, and Japan, are based on Code Division Multiple Access (CDMA) and are capable of transmitting at bit-rates in excess of 2 Mbps. Furthermore, the European proposal was also designed to support multiple simultaneous calls and services. The WATM solutions often favor Orthogonal frequency Division Multiple Access (OFDM) as their modulation technique. Indeed, the Broadband Access Network (BRAN) standard also advocates OFDM. A range of WATM video aspects and mobile digital video broadcast (DVB) issues are also reviewed in Part IV of the book.

Research is also well under way toward defining a whole host of new modulation and signal processing techniques, and a further trend is likely to dominate this new era: namely, *the merger of wireless multimedia communications, multimedia consumer electronics, and multimedia computer technologies.* These trends are likely to hallmark the community's future research in the forthcoming years. This book is naturally limited in terms of its coverage of these aspects, simply because of space limitations. We endeavored, however, to provide the reader with a broad range of applications examples, which are pertinent to scenarios, such as transmitting low-latency interactive video as well as distributive or broadcast video signals over the existing second-generation (2G) wireless systems, 3G arrangements, and the forthcoming fourth-generation systems. We also characterized the video performance of

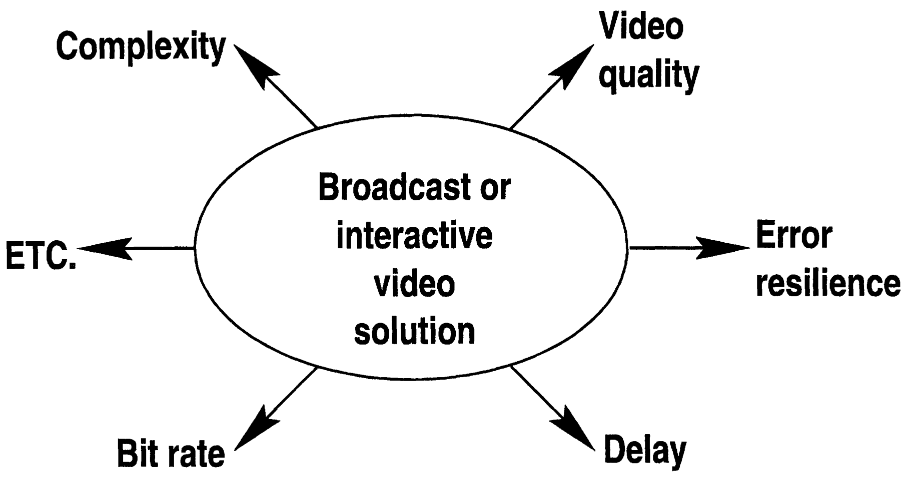

Figure 1: Contradictory system design requirements of various video communications systems.

a range of high bit-rate Local Area Network (LAN) type systems as well as various video broadcast systems, transmitting broadcast-quality video signals to mobile receivers, both within the home and farther afield, to demanding business customers on the move.

These enabling technologies facilitate a whole host of wireless services, such as videotelephony, electronic commerce, city guide, Internet access for games, electronic mail, and web browsing. Further attractive applications can be found in wireless in-home networks, DVB reception in busses, trains, cars, on board ships, and elsewhere — for example, using multimedia laptop PCs. Again, the book does not delve into the area of specific applications; rather it offers a range of technical solutions, which are applicable to various propagation and application environments.

We hope that the book offers you a range of interesting topics, sampling — and hopefully without gross aliasing errors, the current state of the art in the associated enabling technologies. In simple terms, finding a specific solution to a distributive or interactive video communications problem has to be based on a compromise in terms of the inherently contradictory constraints of video-quality, bit-rate, delay, robustness against channel errors, and the associated implementational complexity, as suggested by Figure 1. Analyzing these trade-offs and proposing a range of attractive solutions to various video communications problems are the basic aims of this book.

Video over Wireless Systems

Over the past decade second-generation (2G) wireless systems have been installed throughout the world and in some countries about half of the population possesses a mobile telephone. These systems typically exhibit a higher spectral efficiency than their analog counterparts and offer a significantly wider range of services, such as data,

Video Format	Luminance Dimensions	No. of Pels per Frame	Uncompressed Bit-Rate (Mbit/s)			
			10 frame/s		30 frame/s	
			Gray	Color	Gray	Color
SQCIF	128 x 96	12 288	0.983	1.47	2.95	4.42
QCIF	176 x 144	25 344	2.03	3.04	6.09	9.12
CIF	352 x 288	101 376	8.1	12.2	24.3	36.5
4CIF	704 x 576	405 504	32.4	48.7	97.3	146.0
16CIF	1408 x 1152	1 622 016	129.8	194.6	389.3	583.9
CCIR 601	720 x 480	345 600	27.65	41.472	82.944	124.416
HDTV 1440	1440 x 960	1 382 400	110.592	165.888	331.776	497.664
HDTV	1920 x 1080	2 073 600	165.9	248.832	497.664	746.496
SQCIF: Sub-Quarter Common Intermediate Format QCIF: Quarter Common Intermediate Format CIF: Common Intermediate Format HDTV: High Definition Television						

Table 1: Various video formats and their uncompressed bit-rate. Upon using compression 10-100 times lower average bit-rates are realistic.

fax, e-mail, short messages, and high-speed circuit switched data. However, because of their relatively low bit-rates, the provision of interactive wireless videotelephony has been hindered. Potentially there are two different options for transmitting video over the 2G systems, namely, over their data channel, or — provided that the standards can be amended accordingly — by allocating an additional speech channel for video transmissions. Considering the second option first, the low-rate speech channel of the 2G systems constrains the achievable bit-rate to such low values that the spatial video resolution supported is limited to the 174 × 144-pixel Quarter Common Intermediate Format (QCIF) or to the 128 × 96-pixel Sub-QCIF (SQCIF) at a video-frame scanning rate of 5 to 10 frames/s.

The range of standard video formats is summarized in Table 1, along with their uncompressed bit-rates at frame scanning rates of both at 10 and 30 frames/sec for both gray and color video signals. This table indicates the extremely wide range of potential bit-rate requirements. Clearly, the higher resolution formats can be realistically used only, for example, in the context of high-rate WATM systems.

The Cordless Telephone (CT) schemes of the second generation typically have a 32 kbit/s speech rate, which is more readily amenable to interactive videotelephony. For the sake of supporting a larger video-frame size, such as the 352 x 288-pixel Common Intermediate Format (QCIF), higher bit-rates must be supported, which is possible over the Digital European Cordless Telecommunications (DECT) system upon linking a number of slots at a rate in excess of 500 kbps.

By contrast, the data channel of the 2G systems can often offer a higher data rate than that of the speech channel, for example, by linking a number of time-slots, as was proposed in the DECT scheme or in the high-speed circuit switched data (HSCSD) mode of the Global System of Mobile communications known as GSM. CT schemes typically refrain from invoking channel coding, since they typically operate over benign channels. Hence, they do not employ channel interleavers, which is advantageous in video delay terms but disadvantageous in terms of error resilience. The data transmission mode of cellular systems, however, typically exhibits a high interleaving delay, which helps increase the system's robustness against channel errors. This is advantageous in terms of reducing the channel-induced video impairments but may result in "lip-synchronization" problems between the speech and video output signals.

Both the speech and data channels of the 2G systems tend to support a fixed constant bit-rate. However, the existing standard video codecs, such as the H.263 and MPEG2 codecs, generate a time-variant bit-rate. This is because they endeavor to reduce the bit-rate to near the lowest possible bit-rate constituted by the entropy of the source signal. Since this is achieved by invoking high-compression variable-length coding schemes, their time-variant bitstream becomes very sensitive to transmission errors. In fact, a single transmission error may render the video-quality of an entire video-frame unacceptable. Hence, the existing standard-based video codecs, such as the H.263 and MPEG2 schemes, require efficient system-level transport solutions in order to address the above-mentioned deficiencies. (This issue will be discussed in more depth in Part IV of the book). An alternative solution is invoking constant-rate proprietary video codecs, which — to a degree — sacrifice compression efficiency for the sake of an increased robustness against channel errors. This philosophy is pursued in Part II of the book, which relies on much of the compression and communications theory, as well as on the various error correction coding and transmission solutions presented in Part I.

At the time of writing, the standardization of 3G systems is approaching completion in Europe, the United States, and Japan. These systems, which are characterized in Part I of the book, along with their 2G counterparts, were designed to further enrich the range of services supported. They are more amenable to interactive wireless videotelephony, for example, than their 2G conterparts. This book aims to propose a range of video system solutions that bridge the evolutionary avenue between the second- and third-generation wireless systems.

Part I of the book provides an overview of the whole range of associated transmission aspects of the various video systems proposed and investigated. Specifically, Chapter 1 summarizes the necessary background on information, compression, and communications theory. This is followed by the characterization of wireless channels in Chapter 2. The impairments produced by these channels can be counteracted by the channel codecs of Chapters 3 and 4. Various modulation and transmission schemes are the topic of Chapter 5. We then provide a discussion of video traffic modeling and evaluate the proposed model's performance in the context of various statistical multiplexing and multiple access schemes in Chapter 6. The effects of co-channel interferences — which represent the most dominant performance-limiting factor of multiple access-based cellular systems — are described in Chapter 7. Dynamic channel allocation schemes — which rely on knowledge of co-channel interference and the multiple access scheme employed — are the topic of Chapter 8. The video transmission capabilities of 2G wireless systems are discussed in Chapter 9. These elaborations are followed by an in-depth discussion of various CDMA schemes in Chapter 10, including a variety of novel residual number system-based CDMA schemes and on the global 3G CDMA proposals, which concludes Part I of the book.

Part II is dedicated to a host of fixed but arbitrarily programmable rate video codecs based on fractal coding, on the discrete cosine transform (DCT), on vector quantized (VQ) codecs, and quad-tree-based codecs. These video codecs and their associated quadrature amplitude modulated (QAM) video systems are described in Chapters 11–14. Part III book focusses on high-resolution video coding, encompassing Chapters 15 and 16.

Part IV presents Chapters 17–21, which characterize the H.261 and H.263 video codecs, constituting one of the most important representatives of the family of state-of-the-art hybrid DCT codecs. Hence, the associated findings of these chapters can be readily applied in the context of other hybrid DCT codecs, such as the MPEG family, including the MPEG2 and MPEG4 codecs. Chapters 17–21 also portray the interactions of these hybrid DCT video codecs with reconfigurable multimode QAM transceivers. The book concludes in Chapter 21 by offering a range of system design studies related to wideband burst-by-burst adaptive TDMA/TDD, OFDM, and CDMA interactive as well as distributive mobile video systems and their performance characterization over highly dispersive transmission media.

Motivation

The rationale of this book has already been outlined from a technical perspective. Another important motivation of the book is to bring together two seemingly independent research communities, namely, the video compression and the wireless communications communities, by bridging the philosophical difference between them. These philosophical differences are based partially on the contradictory requirements portrayed and discussed in the context of Figure 1. Specifically, while a range of exciting developments have taken place in both the image compression and wireless communications communities, most of the video compression research has been cast in the context of wireline-based communications systems, such as ISDN and ATM links. These communications systems typically exhibit a low bit error rate (BER) and a low packet- or cell-loss rate. For example, ATM systems aim for a cell-loss rate of 10^{-9}. Thus, the error-resilience requirements of the video codecs were extremely relaxed.

In the increasingly pervasive wireless era, however, such extreme transmission integrity requirements are simply unrealistic, because they impose unreasonable constraints on the design of wireless systems, such as, for example, WATM systems. For example, the ATM cell-loss rate of 10^{-9} could only be maintained over wireless links at a high implementational cost, potentially invoking Automatic Repeat Requests (ARQs). ARQs, however, would increase the system delay, potentially precluding real-time interactive video communications, unless innovative design principles are invoked. Again, all these trade-offs are the subject of this book.

Part I of the book seeks to provide background for readers who require an overview of wireless communications, potentially, for example, video compression experts. Part II assumes a sound knowledge of the issues treated in Part I of the book, while offering an effortless introduction to the associated video compression aspects. Wireless experts may therefore skip Part I and begin reading Part II of the book. Part III focuses exclusively on video compression. Hopefully, readers from both the video compression and wireless communications communities will find Part IV informative and fun to read, since it integrates the knowledge base of both fields, aiming to design improved video systems.

It is our hope that the book underlines the range of contradictory system design trade-offs in an unbiased fashion and that you will be able to glean information from it in order to solve your own particular wireless video communications problem. Most of all however we hope that you will find it an enjoyable and relatively effortless reading, providing you with intellectual stimulation.

Lajos Hanzo, Peter J. Cherriman, and Jürgen Streit
Department of Electronics and Computer Science
University of Southampton