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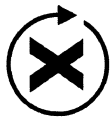

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Multimedia Systems

With 172 Figures

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Preface

Multimedia Applications and Systems are an increasingly common part of our everyday lives—emerging mobile terminals which can display pictures and video data, DVD players in the home, downloadable games, streaming in the Internet, radio stations on the World Wide Web—are just a few examples. These applications and systems are becoming an integral part of our heterogeneous computing and communication environment. Over the last decade, we have experienced an explosive growth of multimedia computing, communication, and applications (World Wide Web, conferencing, digital entertainment, etc.) which provide not just text and images but also video, audio, and other continuous media. In the future, all computers and networks will contain multimedia devices. They will also require appropriate processing and communication support to provide seamless and ubiquitous services and protocols for the relevant multimedia applications.

This book is one of three closely related volumes which aim to cover the whole area of multimedia technology and its applications: The first volume (*Ralf Steinmetz, Klara Nahrstedt, "Multimedia Fundamentals Volume 1: Media Coding and Content Processing", Prentice-Hall, 2002*) deals mainly with the fundamentals of media per se, and covers media-specific considerations such as individual media characteristics, media processing, and optical storage, content analysis, and processing. It includes coding, compression, and a detailed discussion of optical storage. The third volume (*Ralf Steinmetz, Klara Nahrstedt, "Multimedia Applications", Springer-Verlag 2004*) discusses multimedia database and document issues, programming of multimedia applications, multimedia security, human-computer interfaces, multimedia learning,

design and different types of applications. Taken together, our three books are intended to be the standard reference books on "multimedia fundamentals".

Do the individual volumes contain sufficient information which readers might need to make the most out of reading this book?

The present volume can be read (and understood) without detailed knowledge of media coding and content processing. However, a basic grasp of the notion of compression would certainly be very useful. Furthermore, it is of crucial importance that the readers have an introductory background in the areas of operating systems and networking systems.

In this book, we emphasize multimedia systems and networking to provide fundamental understanding what are the underlying concepts, mechanisms and frameworks that multimedia applications stand on. Chapter 2 on quality of service provides the basic definitions and concepts (1) to explain quality differentiation and quality-aware resource management, and (2) to present one of the most fundamental building blocks of multimedia systems. Chapter 3 on multimedia operating systems touches upon fundamentals in processor soft-real-time scheduling, based on earliest deadline first and rate-monotonic scheduling policies, as well as in memory and device management. Chapter 4 continues the discussion of multimedia operating systems and presents media servers, one of the most researched domains in multimedia operating systems. Topics range from multimedia file structure, file placement, overall storage organization, to disk management, disk scheduling, and caching policies. Chapter 5 describes basic concepts for multimedia transmission at the physical and Medium Access Control layers, presenting past and existing networking technologies (e.g., Gigabit Ethernet, ATM) that embed appropriate algorithms, protocols and services for multimedia communication. Chapter 6 on multimedia communication is the core chapter for multimedia-enabled protocols executing at the network IP and transport layers. The readers will find discussion on existing protocols, that have been modified to assist in multimedia communication such as the TCP protocol, as well as on new protocols such as IPv6 and RTP protocols. Chapter 7 continues the discussion of multimedia-enabling concepts in the protocol stack and presents group communication services and protocols at the session layer. Chapter 8 is the glue of the whole book because it describes the synchronization concepts and mechanisms across the whole multimedia system architecture. It ties together synchronization mechanisms at the operating system and network levels with synchronization mechanisms at the application and user levels to deliver the overall goal of a multimedia system—the best perceptual quality of multimedia data to the user.

Overall, the book covers a wide scope of multimedia system and networking concepts, due to its intended purpose of serving as a reference, or as an introductory book in an undergraduate multimedia systems class. It evolved from the third edition of

our book on multimedia technology, published in German in 2000 [Ste00]. (Figures from this book have been reused with the permission of Springer-Verlag). However, several sections of the English text depart from the corresponding material in the German edition. The present volume can be used by computer professionals who are interested in multimedia systems, or by instructors as a textbook for introductory multimedia courses in computer science and related disciplines.

To help instructors use this book, additional material is available on our Web site: `http://www.kom.tu-darmstadt.de/mm-book/`. Please enter `mm_book` and `mm_docs` for user name and password, respectively.

Many people have helped us to prepare this book: R. Ackermann, M. Bräuer, D. Dimitriu, J. Dittmann, A. El Saddik, M. Farber, S. Fischer, J. Geißler, N. Georganas, C. Griwodz, T. Hollmer, T. Kamps, T. Kunkelmann, J. Liang, A. Mauthe, A. Meissner, K. Reichenberger, J. Schmitt, K. Schork-Jakobi, C. Seeberg, A. Steinacker, N. Streitz, P. Tandler, H. Thimm, D. Tietze, M. Wessner, L. Wolf. Thank you!

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Contents

Introduction

Multimedia is probably one of the most overused terms of the 90s (for example, see [Sch97]). The field is at the crossroads of several major industries: computing, telecommunications, publishing, consumer audio-video electronics, and television/movie/broadcasting. Multimedia not only brings new industrial players to the game, but adds a new dimension to the potential market. For example, while computer networking was essentially targeting a professional market, multimedia embraces both the commercial and the consumer segments. Thus, the telecommunications market involved is not only that of professional or industrial networks—such as medium- or high-speed leased circuits or corporate data networks—but also includes standard telephony or low-speed ISDN. Similarly, not only the segment of professional audio-video is concerned, but also the consumer audio-video market, and the associated TV, movie, and broadcasting sectors.

As a result, it is no surprise when discussing and establishing multimedia as a discipline to find difficulties in avoiding fuzziness in scope, multiplicity of definitions, and non-stabilized terminology. When most people refer to multimedia, they generally mean the combination of two or more continuous media, that is, media that have to be played during some well-defined time interval, usually with some user interaction. In practice, the two media are normally audio and video, that is, sound plus moving pictures.

One of the first and best known institutes that studied multimedia was the Massachusetts Institute of Technology (MIT) Media Lab in Boston, Massachusetts. MIT has been conducting research work in a wide variety of innovative applications, including personalized newspapers, life-sized holograms, or telephones that chat with callers

[Bra87]. Today, many universities, large-scale research institutes, and industrial organizations work on multimedia projects.

From the user's perspective, "multimedia" means that information can be represented in the form of audio signals or moving pictures. For example, movement sequences in sports events [Per97] or an ornithological lexicon can be illustrated much better with multimedia compared to text and still images only, because it can represent the topics in a more natural way.

Integrating all of these media in a computer allows the use of existing computing power to represent information interactively. Then this data can be transmitted over computer networks. The results have implications in the areas of information distribution and cooperative work. Multimedia enables a wide range of new applications, many of which are still in the experimental phase. Think for a moment that the World Wide Web (WWW) took its current form only at the beginning of the 90s. On the other hand, social implications inherent in global communication should not be overlooked. When analyzing such a broad field as multimedia from a scientific angle, it is difficult to avoid reflections on the effects of these new technologies on society as a whole. However, the sociological implications of multimedia are not the subject of this book. We are essentially interested in the technical aspects of multimedia.

1.1 Interdisciplinary Aspects of Multimedia

If we look at applications and technologies, there is a strong interest in existing multimedia systems and their constant enhancement. The process of change that takes place in the background in various industrial sectors should not be underestimated:

- The telecommunications industry used to be interested primarily in telephony. Today, telephone networks evolve increasingly into digital networks that are very similar to computer networks. Switching systems used to be made up of mechanical rotary switches. Today, they are computers. Conventional telephones have been evolving into computers, or they even exist as pure software in the form of "IP telephony."
- The consumer electronics industry—with its "brown ware"—contributed considerably to bringing down the price of video technology that is used in computers. Optical storage technology, for example, emerged from the success of CD players. Today, many manufacturers produce CD drives for computers and hi-fi equipment or television sets and computer screens.
- The TV and radio broadcasting sector has been a pioneer in professional audio-video technology. Professional systems for digital cutting of TV movies are commercially available today. Some of these systems are simple standard computers equipped with special add-on boards. Broadcasters now transmit their

information over cables so it is only natural that they will continue to become information vendors over computer networks in the future.

- Most publishing companies offer publications in electronic form. In addition, many are closely related to movie companies. These two industries have become increasingly active as vendors of multimedia information.

This short list shows that various industries merge to form interdisciplinary vendors of multimedia information.

Many hardware and software components in computers have to be properly modified, expanded, or replaced to support multimedia applications. Considering that the performance of processors increases constantly, storage media have sufficient capacities, and communication systems offer increasingly better quality, the overall functionality shifts more and more from hardware to software. From a technical viewpoint, the time restrictions in data processing imposed on all components represent one of the most important challenges. Real-time systems are expected to work within well-defined time limits to form fault-tolerant systems, while conventional data processing attempts to do its job as fast as possible.

For multimedia applications, fault tolerance and speed are the most critical aspects because they use both conventional media and audio-video media. The conventional data (e.g., control information, metadata) must be delivered in a reliable fashion in order to assist audio-video data. The data of both media classes needs to get from the source to the destination as fast as possible, i.e., within a well-defined time limit. However, in contrast to real-time systems and conventional data processing, the elements of a multimedia application are not independent from one another. In other words, they must be integrated and synchronized. This means that in addition to being an integrated system, composed of various components from both data types, there has to be some form of synchronization between these media.

Our goal is to present the multimedia application and systems from an integrated and global perspective. However, as outlined above, multimedia applications and systems include many areas, hence we have decided to split the content about multimedia system fundamentals into three books. The first book deals with media coding and content processing (*Ralf Steinmetz, Klara Nahrstedt, "Media Coding and Content Processing", Prentice Hall 2002*). The second book describes media processing and communication (*Ralf Steinmetz, Klara Nahrstedt, "Multimedia Systems", Springer Verlag 2004*). The third book presents topics such as multimedia documents, security, and various applications (*Ralf Steinmetz, Klara Nahrstedt, "Multimedia Applications and Security", Springer Verlag 2004*).

1.2 Contents of This Book

This book is on *Multimedia Systems*, dealing with media processing and communication, and presenting fundamentals in multimedia operating systems and networking. The primary objective is to provide a comprehensive panorama of multimedia processing and communication technologies, and their integration. Understanding of the close relationship among the wide range of disciplines and components that make up a multimedia system is a key design principle towards successful building of a multimedia system and their applications.

The book is structured as a *reference book*, so that it allows fast familiarization with all issues concerned. However, it can be also used in educational process as an introductory book for an undergraduate multimedia systems class in computer science and related disciplines. It is important to stress that the readers will enjoy the book more and it will be helpful to them if they would have solid introductory background on concepts in media coding as well as in general purpose operating systems and networking.

1.3 Organization of This Book

As mentioned above, this book as an integral part of a comprehensive overview and practical view on multimedia technologies. Figure 1-1 shows the global view of the most important multimedia fields spanning across the three volumes. The overall organization attempts to explain the largest dependencies between the components involved in terms of space and time. We distinguish between:

- *Basics*: One of the most important aspects is a media-specific consideration, in addition to the computer architecture for multimedia systems.
- *Systems*: This group of multimedia fields relates system areas such as processing, storage, and communication, and their relevant interfaces.
- *Services*: The multimedia fields such as content analysis, document handling, security and others represent important multimedia functions that rely and are implemented on the basis of system components.
- *Applications*: The group of multimedia fields such as design, learning and user interfaces studies the type and design of applications and the interface between users and multimedia applications and systems.

In this book, we present the basics of multimedia processing and communication in the *system* and *services* multimedia fields (see Figure 1-1), concentrating on quality of service, soft-real-time scheduling, media servers, multimedia-enabling network technologies and communication protocols, and their overall integration through appropriate synchronization mechanisms.

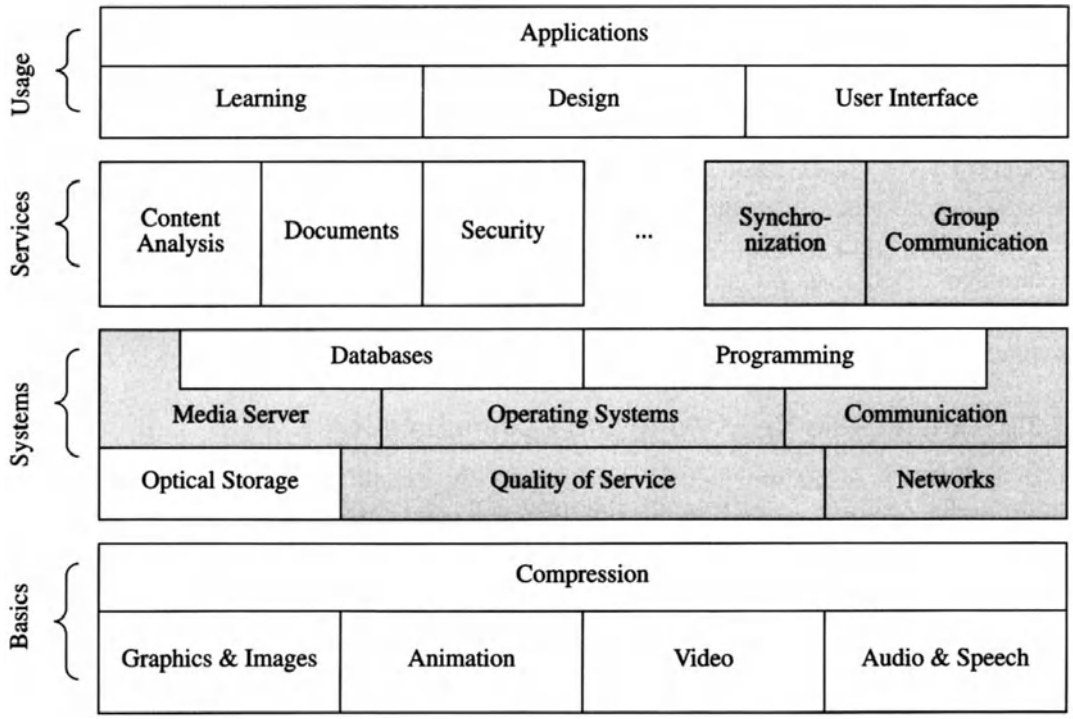

Figure 1-1 Global presentation of most important fields, as discussed in this book.

The book covers four major areas: (1) basic concepts in *quality of service* which present fundamentals for further investigation of system and service components in operating system and networks, (2) algorithms, policies and frameworks in *multimedia operating systems* to schedule and store multimedia data, (3) services and protocols in *multimedia networks and communication* to transmit multimedia streams, and (4) *synchronization* of media streams and various system and service components to achieve the best end-to-end perceptual quality for the user.

1.3.1 Quality of Service

The information on quality of service will cover basic concepts and definitions of qualities in different layers of multimedia systems, and various operations to manipulate quality parameters such as negotiation of quality parameters, routing of information according to quality requirements, and quality translation and transformation operations. Once quality of service concept is introduced, it allows us to talk about service differentiation in multimedia systems and networks via a quality-aware resource management. We will describe resource management concepts such as admission control., resource reservation, rate control and resource adaptation to prepare the reader for further multimedia operating system and networking concepts.

1.3.2 Multimedia Operating Systems

Multimedia support in operating systems is one of the crucial prerequisites for a successful multimedia system. At the processor level, this book investigates soft-real-time scheduling concepts and algorithms, including earliest deadline scheduling, processor-level reservation, task admission control, and various experimental scheduling systems. The multimedia support in OS is also examined with respect to memory and buffer management approaches, caching policies and device management. Extensive discussion is dedicated to media servers ranging from multimedia file structure and file management to disk scheduling, data placement, and overall storage management.

1.3.3 Multimedia Networking and Communication

Discussion on multimedia networking covers the protocol stack starting with multimedia-enabling concepts at the physical and MAC layers, continuing with fundamental services and protocols at the network and transport layer, and closing with extensive analysis of group communication at the session layer.

The multimedia-enabling concepts at the lower networking layers are presented via past or existing networking technologies. For example, analysis of the token concept in Token Ring and FDDI network technologies allows us to discuss the end-to-end delay control. On the other hand, the ATM technology allows us to present network level QoS parameters, service class concept, and connection-oriented networks with differentiated support of end-to-end QoS.

This book analyzes existing Internet network and transport protocols for their multimedia suitability and presents new services and protocols for multimedia transmission support. Examples of improved protocols are multimedia-enabled versions of the TCP protocol and rate-control/error control augmented versions of the UDP protocol. Examples of new protocols include IPv6 and RTP (Real-Time Transport Protocol).

The group communication at the session layer introduces important concepts such as conference control, session management, session control, and experimental systems that provide group communications such as MBone.

1.3.4 Synchronization

The synchronization area represents the glue of multimedia systems, integrating all system components in a meaningful and successful framework. We revisit various low level per-medium synchronization mechanisms that exist at the operating system and network level such as scheduling, and traffic shaping to stress their importance in the overall synchronization scheme. However, the main emphasize is on higher level synchronization mechanisms among different media, clear specification of user level synchronization requirements such as lip synchronization, and pointer synchronization.