

Multimedia Communications

Applications, Networks, Protocols and Standards

Fred Halsall

Multimedia Communications by Fred Halsall addresses the main subject areas associated with multimedia communications (applications, networks, protocols, and standards) at a level that enables the reader to develop an in-depth understanding of the technical issues associated with this rapidly evolving subject. The book identifies the different types of multimedia applications, quantifies their communication requirements and describes the operation and protocols of the different kinds of networks that are used to support them.

FEATURES

- Covers all of the main subject areas associated with multimedia communications in one volume.
- Extensive use of detailed diagrams and worked examples for each major topic.
- Includes coverage of the main compression algorithms used with text, images, speech, audio and video.

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preface

Objectives

Multimedia communications embraces a range of applications and networking infrastructures. The term multimedia is used to indicate that the information/data relating to an application may be composed of a number of different types of media which are integrated together in some way. The different media types are text, images, speech, audio and video and some example applications are video telephony (speech and video), multimedia electronic mail (text, images and audio for example), interactive television (text, audio and video), electronic commerce (text, images, audio and video), Web TV (text, audio and video) and many others.

In practice, there are a number of different types of network that are used to provide the networking infrastructure. These include not only networks that were designed from the outset to provide multimedia communication services – normally referred to as broadband multiservice networks – but also networks that were designed initially to provide just a single type of service and it is as a result of advances in various technologies that these can now support a range of other (multimedia) services. For example, public (and private) switched telephone networks (PSTNs) were designed initially to provide a basic telephony service but they are now used to support a range of more advanced multimedia applications involving all of the different media types. Similarly, computer networks such as the Internet, which were designed initially to provide general data communication services such as electronic mail and file transfers, can now support a much richer set of multimedia applications.

In terms of the different types of media, text and images are generated and represented in a digital form. Speech, audio and video, however, are generated in the form of continuously varying – normally referred to as analog – signals. Hence in order to integrate all of the different media types together, it is necessary to first convert the various analog signals into a digital form. The integrated digital information stream can then be stored within a computer and transmitted over a network in a unified way. In addition, unlike text and images which are created in the form of a single block of digital information, since speech, audio and video are continuously varying signals, the digitization process can produce large volumes of information which carries on increasing with time. Hence in most multimedia applications, in

- Sun Microsystems. *Java Tutorial*. <http://java.sun.com/nav/read/tutorial/index.html>
- Netscape. *Java Script*. <http://home.netscape.com/eng/mozilla/2.0/handbook/javascript/>
- Dierks T. and Allen C. (1998). *The TLS Protocol*, January (RFC 2246)
- MasterCard (1999). *SET Secure Electronic Transaction*. <http://www.mastercard.com/shoponline/set/>
- Merkow M. et al. (1998). *Building SET Applications for Secure Transactions*. Wiley
- IEEE (1999). *IEEE Communications: Special Issue on Electronic Commerce*, September
- IEEE (1997). *IEEE Internet Computing: Special Issue on Electronic Commerce*, November
- IEEE (1997). *IEEE Spectrum: Special Issue on Technology and the Electronic Economy*, February.
- IEEE (1997). *IEEE Network: Special Issue on Network and Internet Security*, May

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