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978-0-521-88204-0 - Multimedia Networking: From Theory to Practice

Jenq-Neng Hwang

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Multimedia Networking

From Theory to Practice

This authoritative guide to multimedia networking is the first to provide a complete system design perspective based on existing international standards and state-of-the-art networking and infrastructure technologies, from theoretical analyses to practical design considerations.

The four most critical components involved in a multimedia networking system – data compression, quality of service (QoS), communication protocols, and effective digital rights management – are intensively addressed. Many real-world commercial systems and prototypes are also introduced, as are software samples and integration examples, allowing readers to understand the practical tradeoffs in the real-world design of multimedia architectures and to get hands-on experience in learning the methodologies and design procedures.

Balancing just the right amount of theory with practical design and integration knowledge, this is an ideal book for graduate students and researchers in electrical engineering and computer science, and also for practitioners in the communications and networking industry. Furthermore, it can be used as a textbook for specialized graduate-level courses on multimedia networking.

Jenq-Neng Hwang is a Professor in the Department of Electrical Engineering, University of Washington, Seattle. He has published over 240 technical papers and book chapters in the areas of image and video signal processing, computational neural networks, multimedia system integration, and networking. A Fellow of the IEEE since 2001, Professor Hwang has given numerous tutorial and keynote speeches for various international conferences as well as short courses in multimedia networking and machine learning at universities and research laboratories.

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**To my wife Ming-Ying, my daughter Jaimie, and my son Jonathan, for their
endless love and support.**

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Preface

With the great advances in digital data compression (coding) technologies and the rapid growth in the use of IP-based Internet, along with the quick deployment of last-mile wireline and wireless broadband access, networked multimedia applications have created a tremendous impact on computing and network infrastructures. The four most critical and indispensable components involved in a multimedia networking system are: (1) data compression (source encoding) of multimedia data sources, e.g., speech, audio, image, and video; (2) quality of service (QoS) streaming architecture design issues for multimedia delivery over best-effort IP networks; (3) effective dissemination multimedia over heterogeneous IP wireless broadband networks, where the QoS is further degraded owing to the dynamic changes in end-to-end available bandwidth caused by wireless fading or shadowing and link adaptation; (4) effective digital rights management and adaptation schemes, which are needed to ensure proper intellectual property management and protection of networked multimedia content.

This book has been written to provide an in-depth understanding of these four major considerations and their critical roles in multimedia networking. More specifically, it is the first book to provide a complete system design perspective based on existing international standards and state-of-the-art networking and infrastructure technologies, from theoretical analyses to practical design considerations. The book also provides readers with learning experiences in multimedia networking by offering many development-software samples for multimedia data capturing, compression, and streaming for PC devices, as well as GUI designs for multimedia applications. The coverage of the material in this book makes it appropriate as a textbook for a one-semester or two-quarter graduate course. Moreover, owing to its balance of theoretical knowledge building and practical design integration, it can serve also as a reference guide for researchers working in this subject or as a handbook for practising engineers.

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Abbreviations

AAC	advanced audio coding
AAC-LC	AAC low-complexity profile
AAC-SSR	AAC scalable sample rate profile
AC	access category
ACAP	advanced common application platform
ADPCM	adaptive delta pulse code modulation
ADSL	asymmetric digital subscriber line
ADTE	adaptation decision taking engine
AES	advanced encryption standard
AIFS	arbitration interframe space
AIFSN	arbitration interframe space number
AIMD	additive-increase multiplicative decrease
ALM	application-level multicast
AMC	adaptive modulation coding
AODV	ad hoc on-demand distance vector
AP	access point
AR	auto-regressive
ARF	autorate fallback
ARIB	Association of Radio Industries and Business
ARK	Add Round Key
ARQ	automatic repeat request
AS	autonomous system
ASF	advanced system format
ASO	arbitrary slice ordering
ATIS	Alliance for Telecommunications Industry Solutions
ATSC	Advanced Television Systems Committee
AVC	advanced video coding
BBGDS	block-based gradient descent search
BE	best-effort
BER	bit error rate
BGP	border gateway protocol
BIC	bandwidth inference congestion control
BIFS	binary format for scenes
BSAC	bit-sliced arithmetic coding
BSS	basic service set
BST-OFDM	band segmented transmission OFDM

CA	certification authority
CABAC	context-adaptive binary arithmetic coding
CAST	Carlisle Adams and Stafford Tavares
CATV	cable TV
CAVLC	Context-Adaptive Variable Length Coding
CBR	constant bitrate
CBT	core-based tree
CCIR-601	Consultative Committee on International Radio, Recommendation 601
CD	compact disc
CD-I	CD-interactive
CDMA	code-division multiple access
CDN	content delivery network
CELP	code-excited linear prediction
CIF	common intermediate format
CLC	cross-layer congestion control
CLUT	color look-up table
CMMB	China Mobile Multimedia Broadcasting
CMS	content management system
COFDM	coded orthogonal frequency-division multiplex
COPS	common open policy service
CPE	customer premise equipment
CPU	central processing unit
CQ	custom queuing
CQICH	channel quality indication channel
CRC	cyclic redundancy check
CS-ACELP	conjugate structure – algebraic code-excited linear prediction
CSI	channel-state information
CSMA/CA	carrier sense multiple access with collision avoidance
CSMA/CD	carrier sense multiple access with collision detection
CTS	clear to send
CW	contention window
CWA	contention window adaptation
DAB	digital audio broadcasting
DAM	digital asset management
DBS	direct broadcast satellite
DCC	digital compact cassette
DCF	distributed coordination function
DCI	digital cinema initiative
DCT	discrete cosine transform
DES	data encryption standard
DFS	distributed fair scheduling
DI	digital item
DIA	digital item adaptation
DID	digital item declaration
DIDL	digital item declaration language
DiffServ	differentiated services

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DIFS	DCF interframe space
DII	digital item identification
DIM	digital item method
DIMD	doubling increase multiplicative decrease
DIML	digital item method language
DIP	digital item processing
DIXO	digital item extension operation
DL	downlink
DLNA	digital living network alliance
DRM	digital rights management
DSC	digital still camera
DSCP	differentiated service code point
DSL	digital subscriber line
DTV	digital TV
DVB	digital video broadcasting
DVB-H	digital video broadcasting – handheld
DVB-T	digital video broadcasting – terrestrial
DVD	digital versatile disk
DVMRP	distance-vector multicast routing protocol
EBCOT	embedded block coding with optimized truncation
EBU	European Broadcasting Union
EDCA	enhanced distributed channel access
EDTV	enhanced definition TV
ertPS	extended-real-time polling service
ESS	extended service set
ETSI	European Telecommunication Standards Institute
EV-DO	evolution-data only
FATE	fair airtime throughput estimation
FDD	frequency-division duplex
FDDI	fiber distributed data interface
FDMA	frequency-division multiple access
FEC	forward error correction
FIFO	first-in first-out
FMO	flexible macroblock ordering
FTP	file transfer protocol
FTTH	fiber to the home
GIF	graphics interchange format
GOP	group of pictures
GPRS	general packet radio service
GSM	global system for mobile
GUI	graphical user interface
HCCA	HCF controlled channel access
HCF	hybrid coordination function
HD-DVD	high-definition digital versatile disk
HDTV	high-definition TV
HFC	hybrid fiber cable

HHI	Heinrich Hertz Institute
HSDPA	high speed downlink packet access
HSUPA	high speed uplink packet access
HTTP	hypertext transfer protocol
IANA	Internet Assigned Numbers Authority
IAPP	inter access-point protocol
ICMP	Internet control message protocol
IDEA	international data encryption algorithm
IEC	International Electrotechnical Commission
IETF	Internet engineering task force
IGMP	Internet group management protocol
IIF	IPTV interoperability forum
IMT-2000	International Mobile Telecommunications 2000
IntServ	integrated services
IP	intellectual property
IP	Internet protocol
IPMP	intellectual property management and protection
IPTV	Internet protocol TV
IPv4	Internet protocol Version 4
IPv6	Internet protocol Version 6
ISBN	International Standard Book Number
ISDB-T	integrated services digital broadcasting – terrestrial
ISDN	integrated services digital network
ISMA	International Streaming Media Alliance
ISO	International Organization for Standardization
ISP	Internet service provider
ISPP	interleaved single-pulse permutation
ISRC	International Standard Recording Code
ITS	intelligent transportation system
ITU-T	International Telecommunication Union
iTV	interactive TV
JBIG	Joint Bi-level Image experts Group
JP3D	JPEG2000 3D
JPEG	Joint Photographic Experts Group
JPIP	JPEG2000 Interactive and Progressive
JPSEC	JPEG2000 Secure
JPWL	JPEG2000 Wireless
JVT	Joint Video Team
LAN	local area network
LD-CELP	low-delay code-excited linear prediction
LLC	logical link control
LPC	linear predictive coding
LSA	link-state advertisement
LSP	line spectral pairs
LTE	long-term evolution
LTP	long-term prediction

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MAC	media access control
MAF	minimum audible field
MAN	metropolitan area network
MBS	Multicast and broadcast service
Mbone	multicast backbone
MCF	medium-access coordination function
MCL	mesh connectivity layer
MCU	multipoint control unit
MD5	message digest 5
MDC	multiple description coding
MDCT	modified discrete cosine transform
MELP	mixed-excitation linear prediction
MFC	Microsoft Foundation Class
MIMO	multiple-input multiple-output
MMP	multipoint-to-multipoint
MMR	mobile multi-hop relay
MMS	Microsoft Media Server
MOS	mean opinion score
MOSPF	multicast open shortest path first
MPC	multiple-pulse coding
MPDU	MAC protocol data unit
MPE-FEC	multiprotocol encapsulated FEC
MPEG	Moving Picture Experts Group
MPLS	multiprotocol label switching
MRP	multicast routing protocol
MSDU	MAC service data unit
MSE	mean squared error
MVC	multi-view video coding
NAL	network abstraction layer
NAT	network address translation
NAV	network allocation vector
NGN	next generation network
nrtPS	non-real-time polling service
OC-N	optical carrier level N
OFDM	orthogonal frequency-division multiplex
OFDMA	OFDM access
OLSR	optimized link-state routing
OS	operating system
OSPF	open shortest path first
OTT	one-way trip time
OWD	one-way delay
P2P	peer-to-peer
PAL	phase alternating line
PARC	Palo Alto Research Center
PCF	point coordination function
PCM	pulse code modulation

PDA	personal digital assistant
PER	packet error rate
PES	packetized elementary stream
PGP	pretty good privacy
PHB	per-hop behavior
PHY	physical layer
PIFS	PCF interframe spacing
PIM	protocol-independent multicast
PIM-DM	protocol-independent multicast-dense mode
PIM-SM	protocol-independent multicast-sparse mode
PKC	public key cryptography
PKI	public key infrastructure
PLC	packet loss classification
PLR	packet loss rate
PLM	packet-pair layered multicast
PMP	point-to-multipoint
PNA	progressive network architecture
POTS	plain old telephone service
PQ	priority queuing
PSI	program specific information
PSNR	peak signal-to-noise ratio
PSTN	public-switched telephone network
QAM	quadrature amplitude modulation
QMF	quadrature mirror filter
QoE	quality of experience
QoS	quality of service
QPSK	quadrature phase-shift keying
RBAR	receiver-based autorate
RC	Rivest Cipher
RCT	reversible color transform
RDD	rights data dictionary
RDT	real data transport
RED	random early detection/discard/drop
REL	rights expression language
RIP	routing information protocol
RLC	receiver-driven layered congestion control
RLC	run-length code
RLM	receiver-driven layered multicast
ROTT	relative one-way trip time
RPE	regular pulse excitation
RPF	reverse path forwarding
RSVP	resource reservation protocol
RTCP	real-time transport control protocol
RTP	real-time transport protocol
rtPS	real-time Polling Service
RTS	request to send

List of abbreviations

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RTSP	real-time streaming protocol
RTT	round-trip time
RVLC	reversible variable-length code
SAD	sum of absolute differences
SAN	storage area network
SBR	spectral band replication
SCM	superposition coded multicasting
SDM	spatial-division multiplex
SDMA	space-division multiple access
SDK	software development kit
SDP	session description protocol
SDTV	standard definition TV
SECAM	sequential color with memory
SFB	scale factor band
SHA	secure hash algorithm
SIF	source input format
SIFS	short interframe space
SIP	session initiation protocol
SKC	secret key cryptography
SLA	service-level agreement
SLTA	simulated live transfer agent
SMCC	smooth multirate multicast congestion control
SMIL	synchronized multimedia integration language
SMPTE	Society for Motion Picture and Television Engineers
SPL	sound pressure level
SRA	source rate adaptation
SSP	stream synchronization protocol
STB	set-top box
STP	short-term prediction
STS-N	SONET Telecommunications Standard level N
SVC	scalable video coding
TBTT	too busy to talk
TCP	transmission control protocol
TDAC	time-domain aliasing cancellation
TDD	time-division duplex
TDMA	time-division multiple access
T-DMB	terrestrial digital multimedia broadcasting
TFRC	TCP-friendly rate control
TIA	Telecommunication Industry Association
TOS	type of service
TPEG	Transport Protocol Experts Group
TTL	time to live
UAC	user agent client
UAS	user agent server
UDP	user datagram protocol
UED	usage environment description

UGS	unsolicited grant service
UL	uplink
UMB	ultra-mobile broadband
UMTS	universal mobile telecommunications system
URI	uniform resource identifier
URL	uniform resource locator
VBR	variable bitrate
VCD	video CD
VCEG	Video Coding Experts Group
VCL	video coding layer
VDSL	very-high-bitrate digital subscriber line
VFW	Video for Windows
VLBV	very-low-bitrate video
VO	video object
VoD	video on demand
VoIP	voice over IP
VOP	video object plane
VQ	vector quantization
VRML	virtual reality modeling language
VSF	vestigial sideband
VSELP	vector-sum-excited linear prediction
WAN	wide area networks
WCDMA	wideband CDMA
WEP	wired equivalent privacy
WFQ	weighted fair queuing
Wi-Fi	wireless fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	wireless local area network
WMN	wireless mesh network
WMV	Windows Media Video
WNIC	wireless network interface card
WPAN	wireless personal area network
WRALA	weighted radio and load aware
WRED	weighted random early detection
WT	wavelet transform
WWW	World Wide Web
XML	extensible markup language
XrML	extensible rights markup language
XOR	exclusive OR