Multicast in Third-Generation Mobile Networks
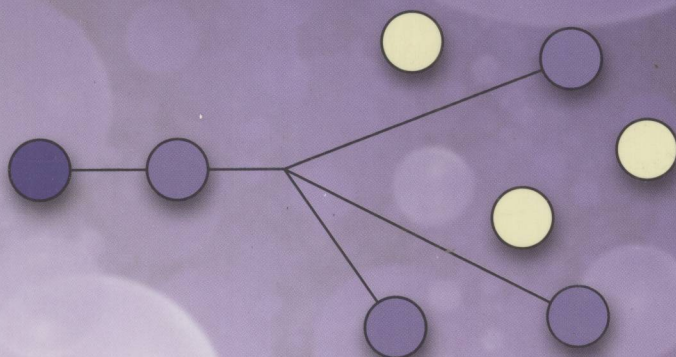
Services, Mechanisms and Performance

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WILEY

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Biography

Robert Rümmler

Robert Rümmler received his Bachelor and PhD degrees in electrical engineering from King's College, University of London, in 2000 and 2005 respectively. From 2001 to 2005 he worked as a research associate at the Centre for Telecommunications Research, King's College London, and contributed to several European research projects in the area of reconfigurability. He currently works as a consultant for Accenture AG, Zürich, Switzerland. His research interests are in multicast for third-generation networks, software-defined radio and end-to-end reconfigurability. He has authored many papers in refereed international conferences and journals. He is a member of the IEEE.

Alexander Gluhak

Alexander is currently a researcher at the Ericsson Ireland Research Centre. He received a Dipl.-Ing. (FH) in communications engineering from the University of Applied Sciences Offenburg, Germany, in 2002 and a PhD in mobile networks and systems from the University of Surrey, UK, in 2006. His research interests are in mobile multicast delivery, heterogeneous network architectures, and scalable context information infrastructures for next generation networks. He has won several awards for his research contributions, such as the Deutsche Telekom Award in 2002, the JSPS Research Fellowship Award in 2005 and the MobileVCE Research Award 2006.

A. Hamid Aghvami

Hamid Aghvami obtained his MSc and PhD degrees from King's College, The University of London, in 1978 and 1981 respectively. He joined the academic staff at King's in 1984. In 1989 he was promoted to Reader and in 1993 was promoted Professor in Telecommunications Engineering. He is presently the Director of the Centre for Telecommunications Research at King's. Professor Aghvami carries out consulting on digital radio communication systems for British and international companies. He has published over 480 technical papers and given invited talks all over the world on various aspects for personal and mobile radio communications as well as giving courses on the subject world

wide. He was a Visiting Professor at NTT Radio Communication Systems Laboratories in 1990 and and a Senior Research Fellow at BT Laboratories in 1998–1999. He was an Executive Advisor to Wireless Facilities Inc., USA in 1996–2002. He is the Managing Director of Wireless Multimedia Communications Ltd, his own consultancy.

He leads an active research team working on numerous mobile and personal communications projects for future-generation systems, these projects are supported both by the government and industry. He was a member of the Board of Governors of the IEEE Communications Society in 2001–2003. He is a distinguished lecturer of the IEEE Communications Society and has been member, Chairman, and Vice-Chairman of the technical programme and organizing committees of a large number of international conferences. He is also founder of the international conference on Personal Indoor and Mobile Radio Communications (PIMRC). He is a Fellow of the Royal Academy of Engineering, Fellow of the IET and Fellow of the IEEE.

Preface

This book investigates the deployment of multicast in third-generation mobile networks. Multicast is the delivery of data to a group of destinations simultaneously, using the most efficient strategy to deliver the data. The book gives an overview of the services that can be realized with multicast in third-generation networks, describes the mechanisms required to support these services and evaluates the performance of several mechanisms for multicast. The focus of this book is on multicast in Universal Mobile Telecommunication System (UMTS) and CDMA2000 networks, the dominant third-generation network standards. The authors hope to provide a good balance between describing the relevant mechanisms for multicast in third-generation networks, providing useful considerations and presenting specific research results.

The book is structured as follows. Chapters 1 to 3 provide an overview of cellular mobile communication systems, the fundamentals of multicast in IP networks and the most relevant aspects of third-generation mobile networks. Chapter 4 discusses some of the services that may be realized with multicast in third-generation networks. Chapters 5 to 7 explore the multicast capabilities of third-generation networks. The Multimedia Broadcast/Multicast Service (MBMS) standard for multicast in UMTS and the Broadcast/Multicast Service (BCMCS) standard for multicast in CDMA2000 networks are described in detail. Chapters 8 to 10 cover the performance of multicast in third-generation networks in terms of radio capacity, multicast routing cost to the network, as well as the efficiency of reliable multicast with respect to throughput and delay. Chapter 11 finally presents mechanisms for delivering multicast in a heterogeneous network environment in which third-generation mobile technology coexists with digital broadcast technology.

Chapter 1 introduces the main concepts of mobile cellular communication systems, describes some important fundamentals of data networking and briefly outlines how multicast can be achieved in data networks as well as in cellular mobile networks.

Chapter 2 introduces the fundamentals of IP multicast. The chapter first provides an overview of the IP multicast service model as well as multicast addressing, followed by a review of the mechanisms for multicast address assignment and session announcement. Group management and routing for IP multicast are then described in detail. As a more advanced topic, protocols and mechanisms for reliable multicast delivery are detailed. Also, congestion and flow control for IP multicast are briefly touched upon, followed by a brief introduction of solutions that support multicast in a mobile environment.

Chapter 3 describes the most important aspects of UMTS and CDMA2000 third-generation networks. The chapter describes the air interface, the radio and core networks of UMTS and CDMA2000, as well as several relevant procedures such as mobility and session management.

Chapter 4 provides an overview of mobile services that can be realized with multicast in third-generation networks. Several services that can be offered with multicast are described in the form of use cases. Several high-level requirements that the system must provide in order fully to support the described services are extracted from the use cases. In addition, the factors that have an influence on whether multicast services will be accepted by users and succeed in the marketplace are discussed.

Chapter 5 explores the multicast capabilities of third-generation networks. For both UMTS and CDMA2000 networks, the network extensions for MBMS and BCMCS that support the efficient delivery of multicast traffic are introduced. The modifications to the radio access and core network architecture for MBMS and BCMCS are outlined. The chapter also provides an overview of the different multicast service delivery phases within UMTS and CDMA2000 networks.

Chapter 6 describes the MBMS standard in detail. It explains the different procedures that are relevant for the management of MBMS bearer services and discusses practical issues in routing multicast packets on the bearer path. Additionally, the MBMS service layer and its mechanisms are described.

Chapter 7 focuses on the BCMCS standard. The chapter covers the BCMCS network layer as well as the bearer service architecture and its management. The chapter also describes the service layer of BCMCS in detail.

Chapter 8 analyses the capacity for performing multicast over the CDMA air interface. In CDMA, data transfer to a group may either take place on multiple point-to-point channels transmitted to individual multicast users separately or on a single point-to-multipoint channel that is broadcast over the entire cell. The chapter provides insight into the trade-offs between employing point-to-point and point-to-multipoint channels for multicast over the CDMA air interface.

Chapter 9 investigates the cost of packet delivery and location update cost of different mechanisms for multipoint data transfer in UMTS networks. Firstly, an alternative mechanism for performing multicast routing in UMTS networks is described. Then, cost expressions for the packet delivery and location update cost of several mechanisms for multipoint data transfer such as MBMS are derived. Finally, the performance trade-off between the proposed mechanism for routing multicast packets in UMTS is evaluated numerically and compared against that of MBMS and other viable mechanisms for multicast data transfer.

Chapter 10 investigates the performance of different reliability mechanisms for multicast. Reliability mechanisms that combine packet-based forward error correction with automatic repeat request are considered. The performance of these mechanisms, applied both to the radio link control layer as well as the application layer, are evaluated in terms of channel efficiency, residual packet error rate and delay.

Chapter 11 takes a look at alternative technologies for mobile multicast delivery. Several wireless communication technologies such as DVB-H, MediaFlo, ISDB-T and T-DMB that are suitable for multicast service delivery are reviewed. The motivation and benefits of using these technologies for multicast service delivery are described. Also, the challenges

in providing multicast services in a heterogeneous network environment consisting of different network technologies are discussed. The chapter introduces a potential approach for achieving coordinated delivery of multicast services in a heterogeneous environment consisting of several wireless networks. Chapter 11 concludes the main body of this book.

Chapter 11 is followed by two appendices. Appendix A derives the closed-form expressions for the capacity of employing dedicated point-to-point and shared point-to-multipoint channels for multicast over the CDMA air interface. The numerical evaluation of these expressions is presented in Chapter 8. Appendix B derives the cost expressions for the packet delivery and location update cost of different mechanisms for performing multipoint data transfers in UMTS. These cost expressions are evaluated numerically in Chapter 6.

Each chapter is preceded by a short outline of the topics to be treated and closes with a summary and some intermediate conclusions. Readers may find the list of abbreviations and a list containing the mathematical symbols used throughout the book useful. The list of abbreviations and the list of symbols can be found after the acknowledgements. As far as acronyms are concerned, an effort has been made to write them out in full whenever they occur first in each chapter. Exceptions to this rule include regularly recurring acronyms and cases where acronyms are used in passing first and explicitly introduced soon after.

Acknowledgements

List of Abbreviations

3GPP	Third-Generation Partnership Project
3GPP2	Third-Generation Partnership Project 2
A	
AAA	Authentication, Authorization and Accounting
AAC	Advanced Audio Coding
AC	Asynchronous Control
ACK	Acknowledgement
AI	Acquisition Indicator
AICH	Acquisition Indicator Channel
ALC	Asynchronous Layered Coding
AMPS	American Mobile Phone System
AN	Access Network
AP-AICH	Access Preamble AICH
API	Access Preamble Indicator
APN	Access Point Name
ARP	Address Resolution Protocol
ARPU	Average Revenue Per User
ARQ	Automatic Repeat Request
ASIC	Application-Specific Integrated Circuit
ASM	Any Source Multicast
AT	Access Terminal
ATM	Asychronous Transfer Mode
B	
BAK	Broadcast Access Key
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BC/MC	Broadcast/Multicast
BCMCS	Broadcast/Multicast Service
BCMCS-C	BCMCS Controller
BGMP	Border Gateway Multicast Protocol
BGP	Border Gateway Protocol
BMC	Broadcast/Multicast Control
BM-SC	Broadcast/Multicast Service Centre

BPSK	Binary-Phase Shift-Keying
BS	Base Station
BSC	Base Station Controller
BSF	Bootstrapping Service Function
BSN	Broadcast Serving Node
BTS	Base Station Transceiver System

C

CBC	Cell Broadcast Centre
CBE	Cell Broadcast Entity
CBS	Cell Broadcast Service
CBT	Core-Based Trees
CCC	Content Casting Centre
CCCH	Common Control Channel
CCTrCH	Coded Composite Transport Channel
CD/CA-ICH	Collision Detection/Channel Assignment Indicator Channel
CDI	Collision Detection Indicators
CDI/CAI	Collision Detection/Collision Assignment Indicators
CDMA	Code-Division Multiple Access
CN	Core Network
CoA	Care of Address
CPCH	Common Packet Channel
CPHCH	Common Physical Channel
CPICH	Common Pilot Channel
CRC	Cyclic Redundancy Check
CS	Content Server
CSI	Channel State Information
CSICH	CPCH Status Indicator Channel
CTCH	Common Traffic Channel

D

DA	Destination Address
DAB	Digital Audio Broadcasting
D-AMPS	Digital AMPS
DB	Dynamic Broadcast
DCCH	Dedicated Control Channel
DCH	Dedicated Channel
DECT	Digital Enhanced Cordless Telecommunications
DMB	Digital Multimedia Broadcasting
DMSP	Designated Multicast Service Provider
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
DPHCH	Dedicated Physical Channel
DRC	Data Rate Control
DRNC	Drift RNC
DS	Direct-Sequence
DSCH	Downlink Shared Channel
DSP	Digital Signal Processing

DTCH	Dedicated Traffic Channel
DTMC	Discrete-Time Markov Chain
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting Handheld
DVMRP	Distance-Vector Multicast Routing Protocol

E
EDGE	Enhanced Data Rates for Global Evolution
EPG	Electronic Programme Guide
ESG	Electronic Service Guide
ETSI	European Telecommunication Standards Institue
EV-DO	Evolution Data Only
EV-DV	Evolution Data Voice

F
FACH	Forward Access Channel
FDD	Frequency-Division Duplex
FDMA	Frequency-Division Multiple Access
FDT	File Delivery Table
FEC	Forward Error Correction
FH	Frequency-Hopping
FLUTE	File Delivery over Unidirectional Transport
FTP	File Transfer Protocol

G
GA	Group Address
GGSN	Gateway GPRS Support Node
GMMF	Group Membership Management Function
GPRS	General Packet Radio Service
GRE	Generic Routing Encapsulation
GSM	Global System for Mobile Communications
GTP	GPRS Tunnelling Protocol

H
HA	Home Agent
H-ARQ	Hybrid ARQ
HDLC	High-Level Data Link Control
HLR	Home Location Register
HRS	Home RADIUS Server
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol

I
IANA	Internet Assigned Numbers Authority
ID	Identifier
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IGW	Interworking Gateway

iid	independent and identically distributed
IMSI	International Mobile Subscriber Identity
IMT-2000	International Mobile Telecommunications 2000
IP	Internet Protocol
IPE	IP Encapsulation
ISDB-T	Integrated Services Digital Broadcasting Terrestrial
ISDN	Integrated Services Digital Network
ITU	International Telecommunications Union

K

| kbps | kilobits per second |

L

LAC	Link Access Control
LAN	Local-Area Network
LCT	Layered Coding Transport
LTE	Long-Term Evolution

M

MA	Multicast Agent
MAAA	Multicast Address Allocation Architecture
MAC	Medium Access Control
MASC	Multicast Address Set Claim
MBGP	Multicast Border Gateway Protocol
MBMS	Multimedia Broadcast/Multicast Service
Mbone	multicast backbone
MCCH	MBMS Control Channel
ME	Mobile Equipment
MF	Multicast Forwarder
MFTP	Multicast File Transfer Protocol
MGA	Multicast Group Address
MGC	Multicast Group Context
MGV-S	MBMS Key Generation and Validation Storage
MH	Mobile Host
MHA	Multicast Home Agent
MICH	MBMS Notification Indicator Channel
MIKEY	Multimedia Internet Keying
MIME	Multipurpose Internet Mail Extensions
MLD	Multicast Listener Discovery
MM	Mobility Management
MMA	Multicast By Multicast Agent
MMS	Multimedia Messaging Service
MOSPF	Multicast OSPF
M-PDP	Multicast Packet Data Protocol
MPE	Multi-Protocol Encapsulation
MPEG	Moving Pictures Expert Group
M-RAB	Multicast RAB
MRK	MBMS Request Key
MS	Mobile Station

MSC	Mobile Switching Centre
MSCH	MBMS Scheduling Channel
MSDP	Multicast Source Discovery Protocol
MSISDN	Mobile Subscriber ISDN Number
MSK	Multicast Service Key
MSR	Multicast Subscriber Record
MT	Mobile Terminal
MTCH	MBMS Traffic Channel
M-TEID	Multicast Tunnel Endpoint Identifier
MTK	MBMS Traffic Key
MUK	MBMS User Key

N

NACK	Negative Acknowledgement
NMF	Network Management Function
NMT	Nordic Mobile Telephone
N-PDU	Network PDU
NSAPI	Network Layer Service Access Point Identifier

O

OFDM	Orthogonal Frequency-Division Multiplexing
OMA	Open Mobile Alliance
OSI	Open Systems Interconnection
OSPF	Open Shortest Path First
OVSF	Orthogonal Variable Spreading Factor

P

PCCH	Paging Control Channel
P-CCPCH	Primary Common Control Physical Channel
PCE	Power Control Error
PCF	Packet Control Function
PCH	Paging Channel
PCN	Packet Core Network
PCPCH	Physical Common Packet Channel
P-CPICH	Primary Common Pilot Channel
PDA	Personal Digital Assistant
PDC	Personal Digital Cellular
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PDP	Packet Data Protocol
PDSCH	Physical Downlink Shared Channel
PDSN	Packet Data Serving Node
PDU	Packet Data Unit
PGM	Pretty Good Multicast
PHS	Personal Handphone System
PI	Paging Indicator
PICH	Paging Indicator Channel
PID	Packet Identifier
PIM	Protocol-Independent Multicast

PIM-DM	Protocol-Independent Multicast Dense Mode
PIM-SM	Protocol-Independent Multicast Sparse Mode
PLMN	Public Land Mobile Network
PMM	Packet Mobility Management
PPP	Point-to-Point Protocol
PRACH	Physical Random Access Channel
PS	Packet-Switched
PSS	Packet-Switched Streaming
PSTN	Public Switched Telephone Network
PTM	Point-To-Multipoint
PTP	Point-to-Point

Q

QoE	Quality of Experience
QoS	Quality of Service
QPSK	Quadrature-Phase Shift-Keying

R

RA	Routing Area
RAB	Radio Access Bearer
RACH	Random Access Channel
RADIUS	Remote Authentication Dial-In User Service
RANAP	Radio Access Network Application Part
RBMoM	Range-Based Mobile Multicast
RF	Radio Frequency
RK	Registration Key
RLC	Radio Link Control
RLP	Radio Link Protocol
RM	Resource Manager
RMTP	Reliable Multicast Transport Protocol
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RP	Rendezvous Point
RPB	Reverse-Path Broadcast
RPC	Reverse Power Control
RPM	Reverse-Path Multicasting
RRC	Radio Resource Control
RSS	Really Simple Syndication
RTCP	Real-Time Transport Control Protocol
RTP	Real-Time Protocol
RTSP	Real-Time Streaming Protocol
RTT	Radio Transmission Technology

S

SAP	Session Announcement Protocol
SB	Static Broadcast
SC	Sychronous Control
S-CCPCH	Secondary Common Control Physical Channel
SCF	Session Control Function

SCH	Sychronization Channel
S-CPICH	Secondary CPICH
SDP	Session Description Protocol
SDU	Service Data Unit
SF	Spreading Factor
SGSN	Serving GPRS Support Node
SI	Status Indicators
SIP	Session Initiation Protocol
SIR	Signal-to-Interference Ratio
SK	Short-Term Key
SM	Session Management
SMS	Short Message Service
SRBP	Signalling Radio Burst Protocol
SRM	Scalable Reliable Multicast
SRNC	Serving RNC
SRTP	Secure Real-Time Transport Protocol
SSM	Source-Specific Multicast

T

TACS	Total Access Communication System
TAM	Technology Acceptance Model
TCP	Transmission Control Protocol
TDD	Time-Division Duplex
TDMA	Time-Division Multiple Access
T-DMB	Terrestrial Digital Multimedia Broadcast
TD-SCDMA	Time-Division Synchronous Code-Division Multiple Access
TEID	Tunnel Endpoint Identifier
TFC	Transport Format Combination
TFCI	Transport Format Combination Identifier
TG	Transmission Group
TI	Transaction Identifier
TK	Temporary Key
TMGI	Temporary Mobile Group Identity
TOI	Transmission Object Identifier
TRPB	Truncated Reverse-Path Broadcasting
TS	Transport Stream
TSI	Transport Session Identifier
TS-MUX	Transport Stream Multiplex
TTI	Transmission Time Interval
TTL	Time-To-Live

U

UDP	User Datagram Protocol
UE	User Equipment
UHF	Ultrahigh-Frequency
UIM	User Identity Module
UMB	Ultra Mobile Broadband
UMTS	Universal Mobile Telecommunications System
URA	UTRAN Registration Area