

# CONTENT NETWORKING IN THE MOBILE INTERNET

**WWW.**  
LINK AVAILABLE

**Sudhir Dixit    Tao Wu**

---

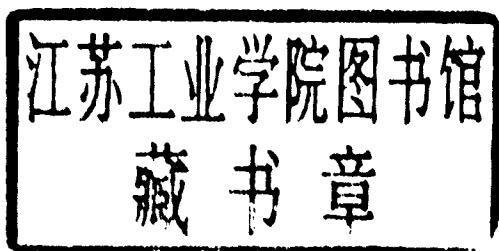
# CONTENT NETWORKING IN THE MOBILE INTERNET

---

Edited by

**SUDHIR DIXIT and TAO WU**

Nokia Research Center



 **WILEY-  
INTERSCIENCE**

A JOHN WILEY & SONS, INC., PUBLICATION

Copyright © 2004 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.  
Published simultaneously in Canada.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400, fax 978-646-8600, or on the web at [www.copyright.com](http://www.copyright.com). Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008.

**Limit of Liability/Disclaimer of Warranty.** While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services please contact our Customer Care Department within the U.S. at 877-762-2974, outside the U.S. at 317-572-3993 or fax 317-572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print, however, may not be available in electronic format.

***Library of Congress Cataloging-in-Publication Data:***

Dixit, Sudhir.

Content networking in the mobile Internet / Sudhir Dixit & Tao Wu.  
p. cm.

Includes bibliographical references and index.

ISBN 0-471-46618-2 (Cloth)

1. Wireless Internet. 2. Computer networks. I. Wu, Tao, 1971–. II.

Title.

TK5103.4885 D58 2004

004.67'8–dc22

2003025148

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

# PREFACE

---

When we initiated a research project on content delivery in Nokia Research Center in 1999, the technology world was at the height of its fascination with the Internet and the World Wide Web. The Internet backbone bandwidth just could not keep up with the exponential traffic growth, and from time to time, a major Website was brought down by overwhelming visits. At that time, content networking was attracting interest from industry and academia for its scalability, performance, and cost effectiveness. Many companies sprang up to meet the challenge by coming up with the idea of content delivery networks (CDNs) to deliver service level guarantees to the Internet service providers, enterprises, operators, and content providers. The buzzes were that the “content is king,” “it is all about user experience—the 8-second rule,” and so on. The joint ownership of the content and the infrastructure by some operators or service providers gave an impetus to CDNs so that they could differentiate their services from those of their competitors.

The last several years have witnessed dramatic changes in business and technology environment. The Web has clearly emerged as the interface of choice, and multimedia applications are rapidly gaining consumer pull and acceptance on handheld devices. As life becomes mobile and consumer and business devices become digital with wireless interconnectivity, mobility and context awareness are providing the much-needed value-add to build viable business models. Concurrently, Web performance is undergoing substantial improvement, thanks to increased capacity in the backbone, wide availability of broadband access, and, of course, content delivery technologies. However, as professionals and consumers alike start to access information and multimedia content anywhere and anytime, mobility, the varying characteristics of the wireless medium, and constrained handheld terminals bring even greater challenges to the evolving next-generation mobile services. And that is what this book is all

about—making Web and multimedia content and services available to mobile users with optimal user experience. Mobile content networking is still in its infancy, and we believe that what we have presented in this book is only the beginning of the story. Indeed, with the long-awaited arrival of the third-generation (3G) wireless technology, the increasing popularity of the wireless local area network (WLAN), and the emergence of numerous other short-range radio technologies, a new era of mobility services has just begun. We hope this book is helpful for anyone who is interested in mobile networks, content networking, and Web services in writing his/her own story.

In order to cover the breadth and depth of the topics covered in this book, we felt that this could be done judiciously and expeditiously only by bringing the various experts in their respective fields together to contribute to a book of this kind. Since content networking is an emerging area of research, this also helped all the contributing authors present their different points of view. The book is written in a style intended to provide a broad overview of the content networking technologies with special emphasis on the mobile Internet, and is aimed toward practicing engineers, graduate students, and researchers. It has been our objective to provide the material in one single place to enable quick learning of the fundamentals involved in an easy-to-read format.

We are indebted to the contributors of this book for their diligent work that made this book possible. Throughout this project they were very understanding and forthcoming with any revisions that we requested of them. We would like to thank Zhu Liu and Zhimei Jiang for their help and valuable suggestions during the course of the preparation of this book. We also thank the reviewers for their comments on the initial drafts, especially Mitri Abou-Rizk, Sadhna Ahuja, Mortaza Bargh, Srinivas Bindignavile, Dan Li, Zhu Liu, Gabor Fodor, Xia Gao, Yin-Ling Liong, Lili Qiu, and Haihao Wu.

We express our gratitude to the staff of John Wiley, especially Rosalyn Farkas, Val Moliere, and Kirsten Rohstedt, for guiding us through the labyrinth of the publication process. Their promptness and attention to details made editing this book so much easier.

Last, but not the least, we thank our families (Sudhir Dixit thanks his wife Asha and children Sapna and Amar, and Tao Wu thanks his wife Lingxuan) for their understanding and support, without which this book would not have been possible. They happily agreed to forsake valuable family time to let us work on this book. Thanks again!

Finally, we (the authors and editors) have tried our best to make each chapter quite complete in itself and its contents as accurate as possible. However, we are afraid that some errors and omissions may still have remained unnoticed. Any feedback intended to correct errors and improve the book would be highly appreciated.

*Boston, Massachusetts*  
(Email: [sudhir.dixit@ieee.org](mailto:sudhir.dixit@ieee.org))

SUDHIR DIXIT

*Boston, Massachusetts*  
(Email: [tao.wu@nokia.com](mailto:tao.wu@nokia.com))

TAO WU

*March 2004*

# ACRONYMS

---

2G	Second-generation cellular communications
3G	Third-generation cellular communications
3GPP	Third Generation Partnership Project
8PSK	Octagonal phase shift keying
8-VSB	Trellis-coded eight level vestigial sideband
AAA	Authentication, authorization, and accounting
ACK	Acknowledgments
ACME	Architecture for content delivery in the mobile environment
ADSL	Asymmetric digital subscriber line
ALC	Asynchronous layered coding
AMP	Asynchronous multicast push
AMPS	Advanced mobile phone system
AMR	Adaptive multirate (voice codec)
ANON	Active-networks overlay network
ATSC	Advanced Television System Committee
B2B	Business to business
BAN	Body area network
BEEP	Blocks extensible exchange protocol
BM-SC	Broadcast multicast service center
BSC	Base station controller
BST-OFDM	Band-segmented transmission OFDM
CAMEL	Customized applications for mobile network enhanced logic
CBS	Cell broadcast service
CDF	Cumulative distribution function
CDN	Content delivery network

CMP	Continuous multicast push
CN	Core network
COFDM	Coded OFDM
COPS	Common open policy service
CORBA	Common object request broker architecture
CPS	Content provisioning (or policy) system
CS	Circuit switch
DA	Duplicate avoidance
DAB	Digital audio broadcast
DHCP	Dynamic host configuration protocol
DNS	Domain name service
DR	Donated receiver
DRM	Digital rights management
DSL	Digital subscriber line
DSM	Distributed shared memory
DSSS	Direct-sequence spread spectrum
DVB	Digital video broadcast
DVB-H	DVB-handheld (a mobile optimized version of VB-T)
DVB-S	Satellite DVB
DVB-T	Terrestrial DVB
DUMRP	Distance vector multicast routing protocol
e-CS	E-commerce system
EDGE	Enhanced data rates for GSM evolution
ERS	Expanding-ring search
ESG	Electronic service guide
FEC	Forward error correction
FIB	Forwarding information base
FLO	Flexible layer one
FLUTE	File delivery over unidirectional transport
GERAN	GSM/EDGE RAN
GGSN	Gateway GPRS support node
GPRS	General packet radio service
GSM	Global system for mobile communications
GTP	GPRS tunneling protocol
HDML	Handheld Device Markup Language
HO	Handover/handoff
HSDPA	High-speed downlink packet access
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IETF	Internet Engineering Task Force
IGMP	Internet group management protocol
IMG	Internet media guide
IMS	IP multimedia system
IP	Internet protocol
IPDC	IP datacast

ISDB-T	Terrestrial integrated service digital broadcasting
ISO	International Organization for Standardization
ISP	Internet service provider
LAN	Local area network
LLC/SNAP	Logical link control/subnetwork attachment point
LSM	Limited scope multicast
m-t-m	multipoint-to-multipoint
m-t-p	multipoint-to-point
MAC	Media access control
MAN	Metropolitan area network
MBMS	Multimedia broadcast and multicast service
MLD	Multicast listener discovery protocol
MPE	Multiprotocol encapsulator/encapsulation
MPEG	Moving Picture Experts Group
MRF	Media resource function
MTU	Maximum transport unit
MUSE	Multiuse sensor enhancement
NACK	Negative ACK
NORM	NACK-oriented reliable multicast
OFDM	Orthogonal frequency-division multiplex
OMA	Open Mobile Alliance
OSI	Open systems interconnection
OSPF	Open shortest path first
p-t-m	Point-to-multipoint
p-t-p	Point-to-point
PAN	Personal area network
PC	Personal computer
PCV	Piggyback cache validation
PID	Packet identifier
PING	Packet Internet groper
PKI	Public key infrastructure
PLMN	Public land mobile network
POP	Point of presence
PPP	Point-to-point protocol
PS	Packet switch
PSI	Program service information
QAM	Quadrature amplitude modulation
QoS	Quality of service
RADIUS	Remote authentication dial-in user service
RAMP	Reliable adaptive multicast protocol
RAN	Radio access network
RB	Radio bearers
REST	Representative state transfer
RF	Radio frequency
RFC	Request for comment(s)



RIS	Rights issue server
RLC	Radio link control
RMT	Reliable multicast transport
RNC	Radio network controller
RP	Rendezvous point
RRC	Radio resource controller
RRM	Radio resource management
RTCP	RTP control protocol
RTSP	Real-time streaming transport
RTP	Real-time transport protocol
RTT	Roundtrip time
SA	System aspect
SAP	Session announcement protocol
SCE	Single-connection emulation
SDMS	Service and delivery management system
SDP	Session description protocol
SDPng	SDP next generation
SGSN	Serving GPRS support node
SI	Service information
SIR	Signal-to-interference ratio
SMS	Short message service
SMSC	SMS center
SOAP	Simple object access protocol
SRM	Scalable reliable multicast
SS	Service system
SSM	Single-source multicast
TAG	Technical Architecture Group
TCP	Transmission control protocol
TDMA	Time-division multiple access
TFCI	Transport format combination indication
TPC	Transmission power control
TR	Technical report
TS	Transport stream
TSG	Technical specification group
TTL	Time to live; transistor–transistor logic
UDDI	Universal description, discovery, and integration
UE	User equipment
UHF	Ultrahigh frequency
UMTS	Universal mobile telecommunications system
UTRA	Universal terrestrial radio access (previously UMTS)
UTRAN	Universal terrestrial RAN
URI	Uniform resource identifier
VoD	Video on demand
VoIP	Voice over Internet Protocol
W3C	World Wide Web Consortium

WAN	Wide area network
WAP	Wireless access protocol
WCCP	Web Cache Control Protocol (proprietary to Cisco)
WCDMA	Wideband code-division multiple access
WG	Working group
WLAN	Wireless LAN
WML	Wireless Markup Language
WWW	World Wide Web
XML	eXtensible Markup Language
XrML	eXtensible rights Markup Language

# CONTENTS

---

<b>PREFACE</b>	<b>xxv</b>
<b>ACRONYMS</b>	<b>xxvii</b>
<b>1 CONTENT NETWORKING IN THE MOBILE INTERNET</b>	<b>1</b>
<i>Sudhir Dixit and Tao Wu</i>	
1.1 Introduction / 1	
1.2 Content Networking in the Mobile Internet / 2	
1.3 Book Overview / 4	
1.3.1 Chapter 2: Mobile Internet Architecture Overview / 4	
1.3.2 Chapter 3: Protocols for the Web and the Mobile Internet / 5	
1.3.3 Chapter 4: Content Caching and Multicast / 5	
1.3.4 Chapter 5: Characterizing Web Workload of Mobile Clients / 5	
1.3.5 Chapter 6: ACME: A New Mobile Content Delivery Architecture / 5	
1.3.6 Chapter 7: Content Adaptation for the Mobile Internet / 6	
1.3.7 Chapter 8: Content Synchronization / 6	
1.3.8 Chapter 9: Multimedia Streaming in Mobile Wireless Networks / 6	
1.3.9 Chapter 10: Multicast Content Delivery for Mobiles / 6	

- 1.3.10 Chapter 11: Security and Digital Rights Management for Mobile Content / 7
- 1.3.11 Chapter 12: Charging for Mobile Content / 7
- 1.3.12 Chapter 13: Algorithms and Infrastructures for Location-Based Services / 7
- 1.3.13 Chapter 14: Fixed and Mobile Web Services / 8
- 1.4 Concluding Remarks / 8

## **2 MOBILE INTERNET ARCHITECTURE OVERVIEW**

**9**

*Harri Holma and Antti Toskala*

- 2.1 Introduction / 9
- 2.2 Standardization Framework / 10
- 2.3 System Architecture and Core Network / 11
- 2.4 WCDMA Radio Access Network / 13
  - 2.4.1 WCDMA Radio Access Network Architecture / 13
  - 2.4.2 WCDMA Layer 2/3 Architecture and Principles / 14
  - 2.4.3 WCDMA Physical Layer / 18
  - 2.4.4 WCDMA beyond 2Mbps with HSDPA / 20
  - 2.4.5 Evolution of WCDMA / 21
    - 2.4.5.1 Enhanced Uplink Dedicated Channel / 22
    - 2.4.5.2 New Frequency Variants of WCDMA / 23
    - 2.4.5.3 Advanced Antenna Technologies / 23
    - 2.4.5.4 Multimedia Broadcast and Multicast Service / 24
- 2.5 GSM/GPRS/EDGE / 24
  - 2.5.1 GSM Principle / 24
  - 2.5.2 GSM Radio Access Network Architecture / 26
  - 2.5.3 GSM Service Creation Principle / 26
- 2.6 IS-95 Radio Access / 27
- 2.7 GSM/EDGE and WCDMA Operator Performance / 29
- 2.8 GSM/EDGE and WCDMA End-User Performance / 31
- References / 33

## **3 PROTOCOLS FOR THE WEB AND THE MOBILE INTERNET**

**35**

*Mitri Abou-Rizk*

- 3.1 Introduction / 35
- 3.2 History of the World Wide Web / 35

3.3	The Web Today /	37
3.4	The Future Web /	37
3.5	HyperText Transfer Protocol /	38
3.5.1	Definition and General Operation /	38
3.5.2	HTTP Evolution /	39
3.5.2.1	<i>HTTP/0.9</i> /	40
3.5.2.2	<i>HTTP/1.0</i> /	41
3.5.3	HTTP/1.1 /	44
3.5.3.1	<i>Formats of the Request and Response Messages for HTTP/1.1</i> /	45
3.5.3.2	<i>New Request Methods and Definitions</i> /	45
3.5.3.3	<i>Persistent Connections</i> /	46
3.5.3.4	<i>Chunked Encoding</i> /	47
3.5.3.5	<i>Content Negotiations</i> /	47
3.5.3.6	<i>Byte-Range Operation</i> /	48
3.5.3.7	<i>Authentication</i> /	48
3.5.3.8	<i>Caching</i> /	48
3.5.3.9	<i>Headers</i> /	50
3.5.4	Conclusion /	66
3.6	Wireless Access Protocol (WAP) /	66
3.6.1	Introduction /	66
3.6.2	WAP Evolution /	66
3.6.2.1	<i>WAP 1.0 Architecture</i> /	67
3.6.2.2	<i>WAP 1.0 Components</i> /	69
3.6.3	WAP 2.0 /	78
3.6.3.1	<i>Introduction</i> /	78
3.6.3.2	<i>WAP 2.0 Architecture and Overview</i> /	78
3.6.3.3	<i>WAP 2.x Components</i> /	80
3.6.4	Future of WAP /	83
	References /	84

## **4 CONTENT CACHING AND MULTICAST**

**87**

*Dan Li*

4.1	Web-Based Applications /	87
4.1.1	Information Dissemination /	87
4.1.1.1	<i>Static Content</i> /	88
4.1.1.2	<i>Dynamic Content</i> /	88
4.1.1.3	<i>Streaming Media</i> /	89

4.1.2	Information Exchange /	90
4.2	Scalable Content Delivery via Multicast and Caching /	91
4.3	IP Multicast and Reliable Multicast /	93
4.3.1	Challenges Facing Reliable Multicast /	94
4.3.2	NAK-Based Recovery /	95
4.3.3	Distributed Recovery /	95
4.3.4	Router-Assisted Recovery /	98
4.3.5	FEC-Based Recovery /	100
4.3.6	State of the Art /	102
4.4	Application Layer Multicast /	103
4.4.1	Rationale for Application Layer Multicast /	104
4.4.2	Why We Still Need IP Multicast /	108
4.4.3	Functions of Application Layer Multicast /	110
4.4.4	Building the Distribution Tree /	112
4.4.5	State of the Art /	116
4.5	Web Proxy Caching /	117
4.5.1	Basics of Proxy Caching /	117
4.5.2	Content Delivery /	118
4.5.3	Cache Consistency /	120
4.5.4	Cache Cooperation /	122
4.5.5	Limitations of Previous Work /	125
4.6	Summary /	126
	References /	127

## **5 CHARACTERIZING WEB WORKLOAD OF MOBILE CLIENTS**

**135**

*Atul Adya, Paramvir Bahl, and Lili Qiu*

5.1	Overview of Web Workload Characterization /	136
5.1.1	Motivation for Workload Characterization /	136
5.1.2	Types of Analysis /	137
5.2	Overview of Previous Work /	137
5.2.1	Wireline User Workload Characterization /	137
5.2.1.1	Content Analysis /	138
5.2.1.2	User Behavior Analysis /	139
5.2.1.3	System Load Analysis /	140
5.2.2	Wireless User Workload Characterization /	140
5.2.2.1	Analysis of WAP Traffic at Bell Mobility's PCS /	141

	5.2.2.2	<i>Analysis of a Metropolitan Area Wireless Network</i>	/ 141
	5.2.2.3	<i>Wireless LAN Study</i>	/ 141
5.3		Server Architecture and Data Gathering	/ 142
	5.3.1	Server Architecture	/ 143
	5.3.2	Description of Data Logs	/ 144
	5.3.3	Types of Accesses	/ 144
5.4		Characterizing Web Browsing Workload	/ 145
	5.4.1	Content Analysis	/ 145
		5.4.1.1 <i>Content Size</i>	/ 146
		5.4.1.2 <i>Popular Content Categories</i>	/ 146
		5.4.1.3 <i>Document Popularity</i>	/ 148
	5.4.2	User Behavior Analysis	/ 149
		5.4.2.1 <i>Load Distribution of Different Users</i>	/ 150
		5.4.2.2 <i>Distribution of Wireless User Sessions</i>	/ 153
		5.4.2.3 <i>Temporal Stability</i>	/ 155
		5.4.2.4 <i>Spatial Locality</i>	/ 158
	5.4.3	System Load Analysis	/ 160
	5.4.4	Summary of Browse Log Analyses	/ 161
5.5		Characterizing Notification Workload	/ 163
	5.5.1	Content Analysis	/ 164
		5.5.1.1 <i>Notification Message Size and Its Implications</i>	/ 164
		5.5.1.2 <i>Popular Categories</i>	/ 164
		5.5.1.3 <i>Message Popularity Analysis and Its Implications</i>	/ 167
	5.5.2	User Behavior Analysis	/ 168
		5.5.2.1 <i>Load Distribution of Different Users</i>	/ 169
		5.5.2.2 <i>Spatial Locality</i>	/ 169
	5.5.3	System Load	/ 171
	5.5.4	Summary of Notification Log Analyses	/ 172
5.6		Correlation between Web Browsing and Notification	/ 174
	5.6.1	Correlation in the Amount of Usage	/ 174
	5.6.2	Correlation in Popular Content Categories	/ 176
	5.6.3	Summary	/ 178
5.7		Comparison between Workload of Wireline Web and Mobile Web	/ 178
	5.7.1	Comparison in Web Content	/ 178

- 5.7.2 Comparison in User Behavior / 179
- 5.7.3 Comparison in System Load / 179
- 5.8 Summary / 179
- References / 180

## **6 ACME: A NEW MOBILE CONTENT DELIVERY ARCHITECTURE**

**183**

*Tao Wu, Sadhna Ahuja, and Sudhir Dixit*

- 6.1 Introduction / 183
- 6.2 Mobile Content Delivery Techniques and Related Work / 186
  - 6.2.1 Content Delivery for the Internet / 186
    - 6.2.1.1 Network Scaling / 187
    - 6.2.1.2 End-System Acceleration / 187
    - 6.2.1.3 Content and Protocol Optimization / 188
  - 6.2.2 Content Delivery for the Mobile Internet / 189
  - 6.2.3 Related Work / 189
- 6.3 ACME Performance Analysis / 191
  - 6.3.1 System Description / 191
  - 6.3.2 ACME Performance in a Slotted ALOHA System / 191
    - 6.3.2.1 Performance of Baseline / 192
    - 6.3.2.2 Performance of ACME / 193
    - 6.3.2.3 Comparison / 194
  - 6.3.3 ACME in CDMA Networks / 196
- 6.4 Exploiting User Interest Correlation with ACME / 197
  - 6.4.1 The Algorithm / 197
  - 6.4.2 Traces / 198
  - 6.4.3 Simulations / 198
- 6.5 ACME in Radio Resource Management / 201
- 6.6 Conclusions / 201
- References / 202

## **7 CONTENT ADAPTATION FOR THE MOBILE INTERNET**

**205**

*Stephane Coulombe, Oskari Koskimies, and Guido Grassel*

- 7.1 Motivation for Adaptation / 205
- 7.2 Multimedia Content Types / 207
  - 7.2.1 Media Content / 207
    - 7.2.1.1 Textual Content / 207
    - 7.2.1.2 Audiovisual Content / 208
  - 7.2.2 Presentation Content / 210



	7.2.2.1	<i>Stylesheets</i>	/ 210
	7.2.2.2	<i>Device-Independent Presentation Content</i>	/ 214
	7.2.3	Application Data	/ 214
	7.2.4	Procedural Code	/ 215
7.3		Types of Adaptation	/ 216
	7.3.1	Format Adaptation	/ 216
	7.3.2	Characteristics Adaptation	/ 217
	7.3.3	Appearance Adaptation	/ 217
	7.3.4	Size Adaptation	/ 219
	7.3.5	Encapsulation Adaptation	/ 221
7.4		Methods of Adaptation	/ 221
	7.4.1	Multimedia Transcoding	/ 221
	7.4.1.1	<i>Multimedia Transcoding Architecture</i>	/ 221
	7.4.1.2	<i>Transcoding of Audiovisual Content</i>	/ 222
	7.4.1.3	<i>Transcoding of Nonaudiovisual Content</i>	/ 223
	7.4.1.4	<i>Transcoding of Procedural Code</i>	/ 224
	7.4.1.5	<i>Advantages and Drawbacks of Transcoding</i>	/ 224
	7.4.2	Content Selection	/ 225
	7.4.2.1	<i>The Infopyramid</i>	/ 225
	7.4.2.2	<i>The Customizer</i>	/ 226
	7.4.2.3	<i>The Infopyramid Creation Process</i>	/ 227
	7.4.2.4	<i>Advantages and Drawbacks of Content Selection</i>	/ 227
	7.4.2.5	<i>Separating Content and Its Representation</i>	/ 228
	7.4.3	Rendering at the Client	/ 228
	7.4.4	Hybrid Approaches	/ 230
7.5		Capabilities and Metadata	/ 230
	7.5.1	Capabilities	/ 231
	7.5.1.1	<i>User-Agent Information</i>	/ 231
	7.5.1.2	<i>Composite Capability/Preference Profiles (CC/PP)</i>	/ 231
	7.5.1.3	<i>UAProf</i>	/ 233
	7.5.1.4	<i>Subscriber Databases</i>	/ 233
	7.5.2	Metadata	/ 236
7.6		Adaptation Architectures	/ 237
	7.6.1	Location of Adaptation	/ 237