



# Mobile Radio Networks

Networking and Protocols

Bernhard H. Walke

BIBLIOTHEQUE DU CERIST

# **Mobile Radio Networks**

## Networking and Protocols

To  
Antonie,  
Thomas and Christoph

1112195

# Mobile Radio Networks Networking and Protocols

**Bernhard H. Walke**

*Rheinisch-Westfälische Technische Hochschule, Aachen, Germany*

BIBLIOTHEQUE DU CERIST

**JOHN WILEY & SONS, LTD**

Chichester • New York • Weinheim • Brisbane • Singapore • Toronto



First published under the title Mobilfunknetze und ihre Protokolle, Band 1 und 2  
© B. G. Teubner Verlag, Stuttgart 1998

Copyright © 1999 by John Wiley & Sons Ltd,  
Baffins Lane, Chichester,  
West Sussex PO19 1UD, England

National 01243 779777  
International (+44) 1243 779777  
e-mail (for orders and customer service enquiries): cs-books@wiley.co.uk  
Visit our Home Page on <http://www.wiley.co.uk>  
or  
<http://www.wiley.com>

Reprinted February 2000

All rights reserved. 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 under the terms of the Copyright, Designs and Patents Act 1988 or under the terms of a licence issued by the Copyright Licensing Agency, 90 Tottenham Court Road, London W1P 9HE, UK, without the permission in writing of the Publisher, with the exception of any material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the publication

*Other Wiley Editorial Offices*

John Wiley & Sons, Inc., 605 Third Avenue,  
New York, NY 10158-0012, USA

WILEY-VCH GmbH, Pappelallee 3,  
D-69469 Weinheim, Germany

Brisbane • Singapore • Toronto

*Library of Congress Cataloging-in-Publication Data*

Walke, Bernhard

[Mobilfunknetze und ihre Protokolle, band 1 and 2. English]  
Mobile radio networks / Bernhard H. Walke.

p. cm.

Translation of: Mobilfunknetze und ihre Protokolle, band 1 and 2.

Includes bibliographical references and index.

ISBN 0 471 97595 8 (alk. paper)

1. Wireless communication systems. 2. Mobile communication  
systems. 3. Global system for mobile communications I. Title.

TK5103.2 W3513 1999

621.382 dc21

98 50609

CIP

*British Library Cataloguing in Publication Data*

A catalogue record for this book is available from the British Library

ISBN 0 471 97595 8

Typeset in from PostScript files supplied by the author.

Printed and bound in Great Britain by Biddles Ltd, [www.biddles.co.uk](http://www.biddles.co.uk)

This book is printed on acid-free paper responsibly manufactured from sustainable forestry, in which at least two trees are planted for each one used for paper production.

# Contents

<b>Preface</b>	<b>XVII</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Existing and New Networks and Services . . . . .	6
1.1.1 GSM/DCS 1800 System . . . . .	6
1.1.2 DECT . . . . .	9
1.1.3 Radio Networks as a Bypass to the Local Loop . . . . .	12
1.1.4 Wireless Local Area Networks (IEEE 802.11 WLAN, Wireless LAN, ETSI/HIPERLAN/1) . . . . .	12
1.1.5 Wireless Networks for Process Control . . . . .	13
1.1.6 Universal Mobile Telecommunications System UMTS .	13
1.1.7 Wireless Broadband Systems . . . . .	14
1.1.8 Mobile Satellite Radio . . . . .	14
1.1.9 Universal Personal Mobility . . . . .	17
1.2 Systems with Intelligent Antennas . . . . .	17
1.3 Mobile Radio Systems with Dynamic Channel Allocation . .	19
1.4 Other Aspects . . . . .	19
1.4.1 Self-Organizing 4th-Generation Systems . . . . .	19
1.4.2 Electromagnetic Environmental Compatibility . . . .	21
1.5 Historical Development . . . . .	21
<b>2 System Aspects</b>	<b>27</b>
2.1 Fundamentals of Radio Transmission . . . . .	27
2.1.1 Attenuation . . . . .	30
2.1.2 Propagation over Flat Terrain . . . . .	30
2.1.3 Multipath Fading . . . . .	33
2.1.4 A Statistical Description of the Transmission Channel .	35
2.1.5 Reflection . . . . .	38
2.1.6 Diffraction . . . . .	42
2.1.7 RMS Delay Spread . . . . .	42
2.1.8 Shadowing . . . . .	42
2.1.9 Interference Caused by Other Systems . . . . .	43
2.2 Models to Calculate the Radio Field . . . . .	43
2.2.1 Empirical Models . . . . .	43
2.2.2 Diffraction Models . . . . .	44
2.2.3 Ray Tracing Techniques . . . . .	44
2.2.4 The Okumura/Hata Model . . . . .	45
2.2.5 Radio Propagation in Microcells . . . . .	46

2.3	Cellular Systems . . . . .	47
2.3.1	Cluster Patterns and Carrier-to-Interference Ratio . . . . .	48
2.3.2	C/I Ratio and Interference-Reduction Factor . . . . .	49
2.3.3	Traffic Load and Cell Radius . . . . .	51
2.4	Sectorization and Spectral Efficiency . . . . .	52
2.4.1	Efficiency and Traffic Capacity . . . . .	53
2.4.2	The Effect of Sectorization with a Given Cluster Size . . . . .	54
2.4.3	Efficiency and Traffic Capacity with Sectorization and a Well-Chosen Cluster Size . . . . .	57
2.4.4	Sectorization with Shadowing . . . . .	58
2.5	The ISO/OSI Reference Model . . . . .	58
2.6	Allocation of Radio Channels . . . . .	62
2.6.1	Frequency-Division Multiplexing, FDM . . . . .	62
2.6.2	Time-Division Multiplexing, TDM . . . . .	63
2.6.3	Code-Division Multiplexing, CDM . . . . .	64
2.6.4	CDMA Technique for 2nd-Generation PLMNs . . . . .	67
2.6.5	Space-Division Multiplexing, SDM . . . . .	72
2.6.6	Hybrid Methods . . . . .	73
2.7	Fundamentals of Error Protection . . . . .	73
2.7.1	Error Protection in Radio Channels . . . . .	73
2.7.2	Error Detection . . . . .	75
2.7.3	Error Correction . . . . .	76
2.7.4	Error-Handling Methods by ARQ-Protocols . . . . .	80
2.7.5	Hybrid ARQ/FEC Methods . . . . .	87
2.8	Fundamentals of Random Access . . . . .	88
2.8.1	Slotted-ALOHA Access Methods . . . . .	88
2.8.2	Slotted-ALOHA with Random Access Frames . . . . .	97
2.8.3	Access Delay with Slotted-ALOHA . . . . .	102
2.8.4	Algorithms for Collision Resolution with S-ALOHA . . . . .	108
<b>3</b>	<b>GSM System . . . . .</b>	<b>121</b>
3.1	The GSM Recommendation . . . . .	121
3.2	The Architecture of the GSM System . . . . .	125
3.2.1	Functional Structure of the GSM System . . . . .	125
3.2.2	Interfaces of the GSM System . . . . .	135
3.3	The Interface at Reference Point $U_m$ . . . . .	136
3.3.1	Multiplex Structure . . . . .	137
3.3.2	Frequency Hopping (FH) . . . . .	141
3.3.3	Logical Channels . . . . .	142
3.3.4	Hierarchy of Frame Structures . . . . .	146
3.3.5	Combinations of Logical Channels . . . . .	146
3.3.6	Channel Combinations of a Cell Depending on Anticipated Cell Utilization . . . . .	153
3.3.7	Layer 1: Physical Transmission . . . . .	154
3.3.8	GSM Layer 2: Data Link . . . . .	164

3.4	Signalling Protocols in the GSM Data Link Layer . . . . .	165
3.4.1	The LAPD <sub>m</sub> Protocol . . . . .	167
3.4.2	Services of the Physical Layer . . . . .	173
3.4.3	Influence of the Physical Layer on LAPD <sub>m</sub> . . . . .	173
3.4.4	LAPD <sub>m</sub> Services . . . . .	177
3.5	The Network Layer in GSM . . . . .	178
3.5.1	Connection Establishment . . . . .	179
3.5.2	Services of the CC Sublayer . . . . .	181
3.5.3	Services of the MM Sublayer . . . . .	183
3.5.4	Services of the RR Sublayer . . . . .	185
3.5.5	Format and Coding of a Layer-3 Message . . . . .	187
3.5.6	Routing of Layer-3 messages . . . . .	188
3.5.7	Primitives of the Sublayers . . . . .	190
3.6	GSM Handover . . . . .	191
3.6.1	Handover Causes . . . . .	191
3.6.2	GSM Recommendations . . . . .	191
3.6.3	Handover Preparation . . . . .	192
3.6.4	Measurement Reports . . . . .	198
3.6.5	Handover Decision . . . . .	200
3.6.6	Sample Algorithm GSM 05.08 . . . . .	205
3.6.7	Problems in the GSM Handover Process . . . . .	209
3.6.8	Intra-MSC Handover . . . . .	210
3.6.9	Intra-MSC Handover Protocol . . . . .	214
3.6.10	Inter-MSC Handover . . . . .	228
3.7	Location Update . . . . .	229
3.7.1	Roaming Support . . . . .	230
3.7.2	Numbering Plan for Roaming . . . . .	231
3.8	Connection Setup . . . . .	232
3.8.1	Mobile-Terminated Call . . . . .	232
3.8.2	Mobile-Originated Call . . . . .	234
3.9	Data Transmission and Rate-Adaptation Functions . . . . .	235
3.9.1	Rate Adaptation to Traffic Channel Performance . . . . .	236
3.9.2	Rate Adaptation in the Connection BTS/Transcoder to an MSC or MSC/IWF . . . . .	237
3.9.3	Layer-2 Relay Function and Radio Link Protocol . . . . .	237
3.9.4	Radio-Link Protocol (RLP) . . . . .	237
3.10	Services in the GSM Mobile Radio Network . . . . .	241
3.10.1	Service Introduction Phases . . . . .	242
3.10.2	Bearer Services . . . . .	242
3.10.3	Teleservices . . . . .	245
3.10.4	Supplementary Services . . . . .	250
3.10.5	Support for Value-Added Services . . . . .	250
3.11	Future Voice and Data Services in GSM . . . . .	255
3.11.1	ASCI—Advanced GSM Speech Call Items . . . . .	257
3.11.2	HSCSD—The High-Speed Circuit-Switched Data Service	260

3.11.3 GPRS The General Packet Radio Service . . . . .	265
3.12 Interworking Function (IWF) . . . . .	279
3.12.1 Gateway to the Public Switched Telephone Network . . . . .	279
3.12.2 Gateway to ISDN . . . . .	280
3.12.3 Gateway to the Public Switched Packet Data Network . . . . .	281
3.12.4 Gateway to the Public Switched Data Network . . . . .	281
3.12.5 Interworking Functions for Teleservices . . . . .	282
3.13 Security Aspects . . . . .	282
3.13.1 Authentication . . . . .	283
3.13.2 Confidentiality of User and Signalling Data . . . . .	283
3.13.3 Confidentiality of Subscriber Identity . . . . .	284
3.13.4 The Transport of Security-Related Information . . . . .	284
3.14 Closing Remarks . . . . .	285
3.15 ETSI/DCS 1800 Digital Mobile Radio Network . . . . .	292
3.16 GSM Abbreviations and Acronyms . . . . .	294
<b>4 Other Public Mobile Radio Systems</b>	<b>301</b>
4.1 Airline Telephone Network for Public Air-Ground Communication . . . . .	301
4.1.1 TFTS Cellular Network . . . . .	301
4.1.2 Frequency and Time-Multiplexing Channels . . . . .	302
4.1.3 Voice and Data Transmission . . . . .	303
4.1.4 Functional Characteristics . . . . .	303
4.1.5 Ground Stations and Frequency Plan . . . . .	305
4.2 The US Digital Cellular System (USDC) . . . . .	305
4.2.1 Technical Data on the USDC System . . . . .	306
4.3 CDMA Cellular Radio According to US-TIA/IS-95 . . . . .	307
4.3.1 Forward-Link . . . . .	308
4.3.2 Return-Link . . . . .	311
4.3.3 Experiences Gained with IS-95 CDMA Systems . . . . .	311
4.4 The Personal Digital Cellular System (PDC) of Japan . . . . .	315
4.4.1 Technical Data on the PDC System . . . . .	316
4.5 Comparison of some Second-Generation Cellular Systems . . . . .	317
<b>5 Third-Generation Cellular: UMTS</b>	<b>321</b>
5.1 UMTS (Universal Mobile Telecommunications System) . . . . .	323
5.2 FPLMTS; IMT 2000 . . . . .	326
5.3 Services for UMTS and IMT 2000 . . . . .	327
5.3.1 Carrier Services . . . . .	327
5.3.2 Teleservices . . . . .	328
5.3.3 Supplementary Services . . . . .	329
5.3.4 Value-Added Services . . . . .	330
5.3.5 Service Parameters . . . . .	330
5.3.6 Service-Specific Traffic Load . . . . .	331
5.4 Frequency Spectrum for UMTS . . . . .	331

5.5	Demands on the Radio Interface . . . . .	337
5.5.1	Operating Environment . . . . .	338
5.5.2	Services . . . . .	338
5.5.3	Mobility . . . . .	339
5.5.4	Protocols . . . . .	340
5.6	Basics of the UMTS Radio Interfaces . . . . .	340
5.6.1	Wideband CDMA . . . . .	341
5.7	UMTS Terrestrial Radio Access Network Logical Architecture . . . . .	348
5.7.1	Radio Interface Protocol Architecture . . . . .	348
5.7.2	FDD Mode . . . . .	349
5.7.3	TDD Mode . . . . .	352
5.7.4	Transport Channels . . . . .	355
5.7.5	Agreement Reached on UMTS Radio Interface (UTRA) for Third-generation Mobile System . . . . .	356
5.8	Handover in UMTS . . . . .	357
5.8.1	Network-Supported Handover . . . . .	358
5.9	Limitations of UMTS . . . . .	360
<b>6</b>	<b>Trunked Mobile Radio and Packet Data Radio</b>	<b>365</b>
6.1	The MPT 1327 Trunked Mobile Radio System . . . . .	366
6.2	MODACOM . . . . .	370
6.2.1	Services in the MODACOM Network . . . . .	371
6.2.2	The MODACOM Network Structure . . . . .	371
6.2.3	Technical Data . . . . .	372
6.2.4	Different Connection Possibilities in the MODACOM Radio Data Network . . . . .	373
6.2.5	Roaming and Handover . . . . .	376
6.3	The TETRA Trunked Mobile Radio System . . . . .	377
6.3.1	Technical Data on the TETRA Trunked Radio System . . . . .	378
6.3.2	Services of the TETRA Trunked Radio System . . . . .	379
6.3.3	Architecture of the TETRA Standard . . . . .	382
6.3.4	The Voice+Data Protocol Stack . . . . .	385
6.3.5	The Packet Data Optimized Protocol Stack . . . . .	417
6.3.6	List of Abbreviations for Trunked Radio . . . . .	434
<b>7</b>	<b>Paging Systems</b>	<b>439</b>
7.1	Paging Service “Cityruf” . . . . .	441
7.2	Euromessage . . . . .	444
7.3	RDS Paging System . . . . .	445
7.4	ERMES . . . . .	445
7.4.1	The Services of the ERMES Paging System . . . . .	446
7.4.2	ERMES Network Architecture . . . . .	447
7.4.3	Technical Parameters of the ERMES Paging System . . . . .	448
<b>8</b>	<b>Cordless Telephone Systems</b>	<b>453</b>

8.1	CT2/CAI and Telepoint . . . . .	454
8.2	Technical Parameters of CT2/CAI . . . . .	455
<b>9</b>	<b>DECT</b>	<b>459</b>
9.1	Possible Applications of DECT Systems . . . . .	460
9.1.1	DECT Fixed Networks . . . . .	460
9.1.2	Data Storage . . . . .	465
9.2	The DECT Reference System . . . . .	466
9.2.1	Logical Grouping of DECT systems . . . . .	466
9.2.2	Physical Grouping of DECT Systems . . . . .	468
9.2.3	DECT Authentication Module (DAM) . . . . .	469
9.2.4	Specific DECT Configurations . . . . .	469
9.3	The DECT Reference Model . . . . .	472
9.3.1	An Overview of Services and Protocols . . . . .	472
9.3.2	Physical Layer (PHL) . . . . .	472
9.3.3	Medium-Access Control (MAC) Layer . . . . .	474
9.3.4	Data Link Layer . . . . .	475
9.3.5	Network Layer . . . . .	475
9.3.6	Management of the Lower Layers . . . . .	476
9.4	Detailed Description of Services and Protocols . . . . .	476
9.4.1	Physical Layer (PHL) . . . . .	476
9.4.2	Medium-Access Control (MAC) Layer . . . . .	479
9.4.3	Data Link Control Layer (DLC) . . . . .	492
9.4.4	Network Layer . . . . .	501
9.5	Dynamic Channel Selection . . . . .	513
9.5.1	Blind Time Slots . . . . .	513
9.5.2	Channel Selection and the Near/Far Effect . . . . .	518
9.6	Speech Coding Using ADPCM . . . . .	519
9.7	Handover . . . . .	520
9.7.1	Bearer Handover . . . . .	521
9.7.2	Connection Handover . . . . .	522
9.7.3	External Handover . . . . .	523
9.7.4	Handover Criteria . . . . .	523
9.8	Protocol Stacks for Multicell Systems . . . . .	524
9.9	The DECT Network Gateway Unit . . . . .	525
9.9.1	Signalling Data . . . . .	525
9.9.2	User Data . . . . .	526
9.10	Security in DECT . . . . .	527
9.10.1	User Identification . . . . .	527
9.10.2	Portable Access Rights Key (PARK) . . . . .	527
9.10.3	IPUI . . . . .	528
9.10.4	TPUI . . . . .	529
9.10.5	Authentication of a Mobile Station . . . . .	529
9.10.6	Authentication of a Base Station . . . . .	530

9.10.7	Equivalent Authentication Between Mobile and Base Stations . . . . .	530
9.10.8	Ciphering of User and/or Signalling Data . . . . .	530
9.11	ISDN Services . . . . .	531
9.11.1	End System and Intermediate System . . . . .	531
9.12	DECT Relays . . . . .	534
9.12.1	Outdoor Applications . . . . .	534
9.12.2	Indoor Applications . . . . .	536
9.12.3	Relay Concept . . . . .	537
9.12.4	Setting up a Relay Station . . . . .	539
9.12.5	Performance Evaluation Parameters . . . . .	545
9.13	Traffic Performance of DECT systems . . . . .	546
9.13.1	Equipment and Interference-Limited Capacity . . . . .	547
9.13.2	Estimating the Capacity of DECT Systems . . . . .	547
9.14	Capacity of DECT RLL Systems with Several Operators . . . . .	550
9.14.1	Using a Higher Density of Base Stations . . . . .	550
9.14.2	Use of More than One Transceiver per Base Station . . . . .	551
9.14.3	Channel Reservation . . . . .	551
9.14.4	Problems Anticipated through Mutual Interaction . . . . .	551
9.14.5	Separating Competing Operators in the Spectrum . . . . .	553
9.15	DECT Abbreviations . . . . .	554
9.16	Integration of DECT Systems into GSM900/1800 . . . . .	556
9.16.1	Details on Integration of DECT into GSM 900/1800 . . . . .	556
9.16.2	Interworking Unit DECT-GSM . . . . .	571
9.16.3	Dual-Mode Units for DECT-GSM . . . . .	578
<b>10</b>	<b>Wireless Local Loop Systems</b> . . . . .	<b>583</b>
10.1	Technologies for WLL Systems . . . . .	584
10.1.1	Cellular Mobile Radio Networks . . . . .	585
10.1.2	Digital Cordless Radio Networks . . . . .	586
10.1.3	Digital PMP Systems . . . . .	587
10.2	Different WLL Scenarios . . . . .	587
10.3	Direct User Connection in Access Network . . . . .	590
<b>11</b>	<b>Personal Handyphone System (PHS)</b> . . . . .	<b>591</b>
11.1	Development of the Personal Handyphone System in Japan . . . . .	591
11.2	System Overview . . . . .	592
11.2.1	Personal Station (PS) . . . . .	593
11.2.2	Cell Station (CS) . . . . .	593
11.3	PHS Radio Characteristics . . . . .	593
11.3.1	Speech Coding . . . . .	593
11.3.2	Modulation . . . . .	594
11.3.3	Access Method . . . . .	594
11.3.4	Slot Structure . . . . .	596
11.3.5	Radio-Frequency Band . . . . .	598

11.3.6 Frequency Allocation . . . . .	598
11.3.7 Microcellular Architecture . . . . .	598
11.3.8 Handover . . . . .	600
11.4 PHS Radio Channel Structures . . . . .	601
11.4.1 Logical Control Channels (LCCH) . . . . .	601
11.4.2 Service Channels . . . . .	602
11.5 Network Operations . . . . .	604
11.5.1 Radio-Frequency Transmission Management (RT) . . . . .	604
11.5.2 Mobility Management (MM) . . . . .	604
11.5.3 Call Control (CC) . . . . .	606
11.5.4 Protocol Model . . . . .	608
11.5.5 Call Establishment . . . . .	608
11.5.6 Communication Phase . . . . .	613
11.6 Network Interfaces/Technologies . . . . .	614
11.6.1 Private Communication System Application . . . . .	614
11.6.2 Public PHS . . . . .	614
11.6.3 Wireless Local Loop (WLL) . . . . .	615
11.7 Standards and References . . . . .	615
<b>12 Wireless Broadband Systems and Wireless ATM</b>	<b>617</b>
12.1 European Research in Broadband Systems . . . . .	617
12.1.1 MBS . . . . .	618
12.1.2 Wireless Broadband Communications in the ACTS Programme . . . . .	619
12.1.3 ATMmobil . . . . .	622
12.1.4 The Role of the ATM Forum in the Standardization of Wireless ATM Systems . . . . .	622
12.1.5 The ETSI Contribution to W-ATM Standardization . . . . .	623
12.2 Services in Broadband ISDN . . . . .	623
12.2.1 ATM as a Transmission Technology in B-ISDN . . . . .	625
12.2.2 Structure of an ATM Cell . . . . .	625
12.2.3 ATM Switching Technology . . . . .	626
12.2.4 ATM Reference Model . . . . .	627
12.2.5 ATM Classes of Service . . . . .	629
12.2.6 Functions and Protocols of the AAL . . . . .	630
12.3 Architecture of the ATM Radio Interface . . . . .	631
12.3.1 The Radio Access System as a Distributed ATM Multiplexer . . . . .	631
12.3.2 Frequencies and Frequency Etiquette for W-ATM Systems . . . . .	632
12.3.3 Protocol Stack for the ATM Radio Interface . . . . .	634
12.3.4 Channel Access . . . . .	636
12.3.5 The LLC Layer . . . . .	638
12.3.6 Dynamic Capacity Allocation with Packet-Oriented Radio Interfaces . . . . .	639
12.3.7 Channel Concept for a Packet-Oriented Radio Interface . . . . .	641

12.3.8 Dynamic Channel Selection for W-LANs . . . . .	643
12.4 Mobility Support for W-ATM Systems . . . . .	644
12.4.1 Radio Handover . . . . .	645
12.4.2 Network Handover . . . . .	646
<b>13 Wireless Local Area Networks</b> . . . . .	<b>655</b>
13.1 Standards . . . . .	656
13.2 Technical Characteristics of HIPERLAN/1 . . . . .	657
13.3 Network Environments for HIPERLAN/1 . . . . .	658
13.3.1 HIPERLAN Applications . . . . .	658
13.3.2 Network Topologies . . . . .	659
13.4 HIPERLAN Reference Model . . . . .	661
13.5 HIPERLAN-MAC Sublayer . . . . .	662
13.5.1 Tasks of the MAC Sublayer . . . . .	662
13.5.2 MAC Services . . . . .	665
13.5.3 HIPERLAN-MAC Protocol . . . . .	668
13.6 HIPERLAN-CAC Sublayer . . . . .	675
13.6.1 Tasks of CAC Sublayer . . . . .	675
13.6.2 CAC Services . . . . .	676
13.6.3 HIPERLAN-CAC Protocol . . . . .	680
13.7 The Physical Layer . . . . .	686
13.7.1 Tasks . . . . .	686
13.7.2 Services of the Physical Layer . . . . .	686
13.7.3 Transmission Rates and Modulation Procedures . . . . .	687
13.7.4 Packet Structure . . . . .	688
13.7.5 Receiver Sensitivity . . . . .	688
13.8 HIPERLAN Parameters . . . . .	690
13.9 Scope and Purpose of WLAN IEEE 802.11 . . . . .	692
13.9.1 Architecture of IEEE 802.11 Networks . . . . .	693
13.9.2 Services of IEEE 802.11 Networks . . . . .	694
13.10 IEEE 802.11 MAC Sublayer . . . . .	696
13.10.1 Address Mapping . . . . .	696
13.10.2 MAC Services . . . . .	697
13.10.3 MAC Protocol . . . . .	699
13.10.4 Synchronization . . . . .	704
13.10.5 Power-Saving Mode . . . . .	705
13.11 IEEE 802.11 Physical Layer Specification . . . . .	707
13.11.1 Scope . . . . .	707
13.11.2 Physical Layer Service Definition . . . . .	707
13.11.3 Frequency Hopping Spread Spectrum . . . . .	708
13.11.4 Direct Sequence Spread Spectrum . . . . .	710
13.11.5 Infrared . . . . .	711
13.12 W-LAN Abbreviations and Acronyms . . . . .	712
<b>14 Mobile Satellite Communication</b> . . . . .	<b>715</b>

14.1 Fundamentals . . . . .	715
14.1.1 Application Areas . . . . .	715
14.1.2 Satellite Organizations . . . . .	725
14.1.3 Satellite Orbits . . . . .	725
14.1.4 Elevation Angles and Coverage Zones . . . . .	726
14.1.5 Frequency Regulation for Mobile Satellites . . . . .	727
14.2 Geostationary Satellite Systems . . . . .	728
14.2.1 Inmarsat-A . . . . .	731
14.2.2 Inmarsat-B . . . . .	732
14.2.3 Inmarsat-C . . . . .	732
14.2.4 Inmarsat-Aero . . . . .	733
14.2.5 Inmarsat-M . . . . .	733
14.3 Non-Geostationary Satellite Systems . . . . .	733
14.3.1 ICO . . . . .	734
14.3.2 IRIDIUM . . . . .	736
14.3.3 Globalstar . . . . .	738
14.3.4 TELEDESIC . . . . .	739
14.3.5 Odyssey . . . . .	743
14.4 Antennas and Satellite Coverage Zones . . . . .	743
14.4.1 Antennas . . . . .	745
14.4.2 Satellite Coverage Area and Cell Structure . . . . .	746
14.4.3 Radio Propagation . . . . .	748
14.4.4 Power Control . . . . .	752
14.5 Interference in the Satellite Radio Network . . . . .	753
14.5.1 Co-Channel Interference . . . . .	753
14.5.2 Uplink Carrier-to-Interference Ratio . . . . .	754
14.5.3 Downlink Carrier-to-Interference Ratio . . . . .	755
14.5.4 Model of a Land Mobile Satellite Channel . . . . .	755
14.6 Handover in Mobile Radio Satellite Systems . . . . .	758
14.6.1 Frequency of Handovers . . . . .	760
14.6.2 Types of Handover . . . . .	761
14.7 Satellites to Link Wireless Access Networks to a Fixed Network	766
14.7.1 Simple Fictional WLL System . . . . .	767
14.8 Abbreviations and Acronyms . . . . .	769
<b>15 UPT—Universal Personal Telecommunication</b>	<b>773</b>
15.1 Classification of Telecommunications Services . . . . .	773
15.2 Extended Service Features in ISDN and GSM . . . . .	775
15.2.1 Supplementary and Value-Added Services in ISDN . .	776
15.2.2 Supplementary and Value-Added Services in GSM . .	777
15.3 The UPT Service for Universal Personal Telecommunication .	778
15.3.1 Existing Studies of the UPT Service . . . . .	779
15.3.2 Further Development of UPT . . . . .	779
15.3.3 Phase 1—Scenario with Limited UPT Functionality .	779
15.3.4 Phase 2—Scenario with UPT Basic Functionality . .	780

15.3.5 Phase 3—Scenario with Extended UPT Functionality . . . . .	780
15.3.6 Service Features of UPT in Phase 1 of its Introduction . . . . .	780
15.4 Business Relationship between UPT Users and Providers . . . . .	781
15.4.1 Charging—New Concepts in the Introduction of UPT . . . . .	783
15.4.2 Example of Registration of a UPT Subscriber . . . . .	783
15.4.3 Options for Authentication . . . . .	785
15.5 UPT Service Profile . . . . .	785
15.6 Requests to UPT-Supported Networks . . . . .	787
15.7 PSCS as a Further Development of UPT . . . . .	788
15.8 Numbering and Dialling . . . . .	789
15.8.1 ISDN, PSTN . . . . .	789
15.8.2 Public Mobile Telephone Network—GSM . . . . .	791
15.8.3 UPT . . . . .	791
15.9 Intelligent Networks and Their Value-Added Services . . . . .	796
15.9.1 The Functional Principle of an Intelligent Network . . . . .	796
15.9.2 Description of Services in Intelligent Networks . . . . .	797
15.9.3 The Intelligent Network Applications Protocol . . . . .	800
15.9.4 UPT in the IN Layer Model . . . . .	800
<b>16 The Future is Wireless</b> . . . . .	<b>805</b>
16.1 A Typical Day in the Year 2000 . . . . .	805
16.2 Wireless Communication in the Year 2005 . . . . .	806
16.3 Closing Remarks . . . . .	807
<b>Appendix</b> . . . . .	<b>809</b>
<b>A Queuing and Loss Systems</b> . . . . .	<b>809</b>
A.1 The Queuing System M/M/ $n-\infty$ . . . . .	809
A.1.1 State Process as Special Birth-and-Death Process . . . . .	809
A.1.2 Characteristic Performance Parameters . . . . .	810
A.2 The Queuing-Loss System M/M/ $n-s$ . . . . .	812
A.2.1 State Process as a Special Birth-and-Death Process . . . . .	813
A.2.2 Characteristic Values . . . . .	813
<b>B Standards and Recommendations</b> . . . . .	<b>817</b>
B.1 International Standards Organizations . . . . .	817
B.1.1 ISO . . . . .	818
B.1.2 ITU . . . . .	818
B.1.3 IEC . . . . .	823
B.1.4 INTELSAT/INMARSAT . . . . .	823
B.1.5 ATM Forum . . . . .	823
B.2 European Standards Organizations . . . . .	824
B.2.1 CEN/CENELEC . . . . .	824
B.2.2 CEPT . . . . .	824
B.2.3 ETSI . . . . .	826

B.2.4	ECMA . . . . .	833
B.2.5	EBU . . . . .	833
B.2.6	EUTELSAT . . . . .	833
B.2.7	ESA . . . . .	834
B.3	National Standards Organizations . . . . .	835
B.4	Quasi-Standards . . . . .	835
B.4.1	Company Standards . . . . .	835
B.4.2	User Standards . . . . .	836
<b>C</b>	<b>International Frequency Allocations</b>	<b>837</b>
<b>D</b>	<b>The Frequencies of European Mobile Radio Systems</b>	<b>841</b>
<b>E</b>	<b>The GSM Standard</b>	<b>843</b>
<b>Index</b>		<b>849</b>