The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

The UMTS Network and Radio Access Technology

The UMTS Network and Radio Access Technology

Air Interface Techniques for Future Mobile Systems

Dr. Jonathan P. Castro

Orange Communications SA/AG, Switzerland

John Wiley & Sons, Ltd
Chichester New York Weinheim Brisbane Singapore Toronto

Copyright © 2001 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

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.

Neither the author(s) nor John Wiley & Sons Ltd accept any responsibility or liability for loss or damage occasioned to any person or property through using the material, instructions, methods or ideas contained herein, or acting or refraining from acting as a result of such use. The author(s) and Publisher expressly disclaim all implied warranties, including merchantability of fitness for any particular purpose. There will be no duty on the author(s) or Publisher to correct any errors or defects in the software.

Designations used by companies to distinguish their products are often claimed as trademarks. In all instances where John Wiley & Sons is aware of a claim, the product names appear in initial capital or capital letters. Readers, however, should contact the appropriate companies for more complete information regarding trademarks and registration.

Other Wiley Editorial Offices

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

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

John Wiley & Sons (Asia) Pte Ltd, 2 Clementi Loop #02-01,
Jin Xing Distripark, Singapore 129809

John Wiley & Sons (Canada) Ltd, 22 Worcester Road,
Rexdale, Ontario, M9W 1L1, Canada

John Wiley & Sons Australia, Ltd, 33 Park Road, Milton,
Queensland 4064, Australia

Library of Congress Cataloging-in-Publication Data

A catalogue record from the Library of Congress has been applied for

British Library Cataloguing in Publication Data

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

ISBN 0 471 81375 3

Produced in 10/12pt Times from the author's files by Deerpark Publishing Services, Ltd, Shannon.
Printed and bound in Great Britain by Biddles Ltd, Guildford and King's Lynn.
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.

The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

To:

My family for they endurance, and to my friends and colleagues for their understanding; because while putting together this book I stole too many precious moments from them.

And

To all the 3GPP contributors for their dedication to make the UMTS specifications a reality, without whom some of the contents of this book would not have been possible.

The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

Acknowledgements

It is impossible to acknowledge every one who had contributed in some way to the conception and realization of this book. Nonetheless, to the best of my ability I shall attempt to do so. I would thus thank Mark Hammond from John Wiley, who encouraged me to go ahead and undertake the idea of writing this book; and who also patiently motivated me to go forward when time was not on my side to complete the manuscript. I would also like to thank Mark's team, Sarah Hinton and Kirsten Evans for making all the practical arrangements to produce the book. Special thanks also to Lorna O'Brien who took the files to the finish.

My gratitude goes also to Orange Communications SA for providing a practical and stimulating environment to deploy 2G and prepare for 3G mobile networks. In particular I would like to thank the Orange UMTS Engineering team, who devoted extra time from their demanding tasks to join me in the 3G project to conceive a complete UMTS network. I am especially would like to be grateful to those in NSS and BSS Engineering for supporting my technical activities while I was writing this book and to those in Radio Planning for being there, to consolidate ideas and test assumptions. I would like also to thank my colleagues in Procurement who tirelessly joined the team to look at the investment side of the UMTS network elements and motivate and cheer the writing of this book. In addition, I am also grateful to Ericsson's, Nokia's, Alcatel's and other 3G suppliers' teams in Switzerland who joined the Orange UMTS team to consider the dimensioning, deployment (new and co-located sites) and configuration of forthcoming UMTS networks.

Last, but not least, I would also like to thank all those in the standardization bodies, e.g. (formerly SMG in ETSI), 3GPP, who despite all controversies or delays kept the specification work of UMTS on target to reach the milestones like R99 and go forward with future releases.

The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

CONTENTS

The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

PREFACE

The rapid growth in traffic volume and increase in new services has begun to change the configuration and structure of wireless networks. Thus, future mobile communications systems will be distinguished by high integration of services, flexibility and higher throughput.

To support such features, the efficient use of spectrum and optimum management of radio resources will be essential.

To meet these challenges standardization bodies like ETSI (now expanded to 3GPP), have selected the Wideband Code Division Multiple Access (WCDMA) and the hybrid Time Division – CDMA as the radio techniques for the Universal Mobile Telecommunication Systems (UMTS). Hence, UMTS conceived at the eve of this new millennium will without doubt have a large impact on future wideband mobile networks and serve as the leading platform for wireless multimedia communications.

The specification extracts in this book are intended to provide a concise reference for the many documents related to UMTS systems. After all, the whole UMTS specification set would probably exceed 4000 pages. Thus, it is hoped that the synthesis presented in this book will be useful in some way. In this context, in order to offer a complete source on the UMTS air interface and network issues, this book aims to present a description of the principles, methods and technology used in the standard specification. Different aspects of the UMTS multiple access and network configuration are presented; however, this concise and integrated volume, which embodies the main design elements, goes further. Thus, the content of this book follows structurally the specifications of the 3GPP recommendations to comply entirely with the concept, terminology, approach and style, and not just the technical essence.

In drafting the standards or UMTS technical specifications, the experts have tried to reduce the risk of ambivalent interpretation, and not necessarily ease the understanding for the common reader. The logic, constructive discussions and consensus behind the choices or equivalent solutions have not always been retained in the final specifications. Therefore, in some ways this book tries to present an objective unified view of the key aspects of UMTS. On the other hand, the area of UMTS is vast in content and detail, and not all within the scope of these writings. As a result, the book will allow us to understand the UMTS specifications and get a good grasp of its design, but the technical documents of formerly SMG, and now 3GPP, remain the official specifications with all their appropriate ownership and origin of contribution.

Since this book has been introduced in good faith as a useful reference for UMTS technology, the author does not take responsibility for any misuse or error while dealing

with the information provided. If for some reason some representations have been omitted due to time constraints or the dynamic changing process of the specifications, they will be revised and corrected for later reprints. Thus, the author welcomes any comments and suggestions for improvements or changes that could enhance further this contribution to UMTS.

The chapters in this book cover specific design details of the building blocks in the UMTS air interface, in particular the physical layer. It addresses the technical part of the specification for both the FDD and TDD modes. On the other hand, it also introduces the key criteria for network dimensioning and deployment of 3G systems assuming an evolution from 2G mobile networks from the providers' point of view. To illustrate the progressive steps of UMTS standards such as the evolution towards predominant packet switching oriented communications, this book also introduces the 'All IP Core Network' architecture concept for mobile multimedia.

Chapter 1 deals with concrete requirements for 3G mobile systems after summarizing the rapid growth of wireless communications and the Internet. It also outlines briefly enhancing technologies such as capacity increasing antennas, multi-user detection techniques, and software radio applications.

Chapter 2 presents the fundamentals of system analysis, e.g. multiple access options, which considers narrow-band and wide-band digital channels, as well as the background for the UTRA FDD and TDD modes. It covers signal processing aspects describing the principles of spread spectrum, modulation and spreading, the CDMA performance, PN sequences, power control and handovers. It presents the communications environments envisaged for UMTS operation and deployment. It also describes the channel models used to verify and justify the performance for the selected operating scenarios. It provides a summary of the mathematical formulation for the performance analysis results seen in the forthcoming chapters (e.g. Chapter 7).

Chapter 3 describes the UMTS development platform. It introduces its architecture top down, identifying the core and access network domains. It defines the UTRA identifiers and functions, e.g. system access control, radio channel ciphering and deciphering, mobility functions, and radio resource management and control functions. It also presents mobility management with its signaling connections and impact of mobility handling. Chapter 3 presents the UTRAN sychronization and UTRAN interfaces besides pointing out co-existing 2G/3G network issues. It also introduces the radio interface protocol architecture with its structure in terms of services and function layers. This chapter thus outlines the most relevant elements, which require technical description for design and implementation.

Chapter 4 describes the UTRA physical layer design and configuration, where we introduce all the building blocks in detail with their respective technical description and requirements. It covers dedicated common transport channels, configuration of FDD and TDD physical channels in the uplink and downlink with their spreading and coding characteristics. Spreading and modulation, including scrambling, multiplexing and channel coding are also discussed. The chapter presents the aforementioned characteris-

tics for the FDD and TDD separately for each mode or unified when the case applies to both.

Chapter 5 introduces the UTRA transmission system starting from the spectrum allocation, i.e. the UTRA frequency bands. It presents the radio transmission and reception aspects, describing transmitter and receiver characteristics for the User Equipment (UE) and the Base Station (BS). It describes the maximum output power and output power dynamics, out of synchronization output power handling, transmit on/off power. Details on the output RF spectrum emissions, such as occupied bandwidth and out band emission, spectrum emissions, adjacent channel leakage power ratio, spurious emissions, and transmit modulation and inter-modulation are given. The summary of examples includes a review of simulation scenarios for the co-existence of FDD/FDD when analyzing ACIR with macro-to-macro and macro-to-micro cases. Before presenting results the chapter also reviews propagation models.

Chapter 6 describes the UMTS service components. It covers the UMTS bearer architecture, concepts in quality of service for 3G systems, multimedia transmission and traffic classes in UMTS. The classes include conversational, streaming, interactive, and background types. Sensitivity to IP transmission impairments are also covered here. To provide an overview of potential applications in UMTS this chapter also summarizes service offerings and selected areas of service technology.

Chapter 7 introduces the factors that influence 3G network dimensioning. It discusses coverage and capacity trade-off in the FDD mode pointing out impacts from soft handover, power control and orthogonality deviations. It covers the analysis of parameters for multi-service traffic in PS and CS. It establishes service models starting from capacity projections, and service strategy. Cellular coverage planning issues, i.e. the coverage concept, radio network parameter assumptions for CS and PS, characteristics of CDMA cells (with its theoretical capacity and cell loading effects) constitute the essential parts of this chapter. Link budget principles for the forward and reverse links and their respective formulation are covered. In the latter part, these principles are applied to a field study. For completeness the chapter also describes briefly the dimensioning of the RNC in the UTRAN side. Chapter 7 also presents the dimensioning of the core network and transmission systems. In the last part, results of a field study are provided using hypothetical parameters to illustrate the concepts end-to-end. The illustrations correspond to dimensioning exercises carried out while optimizing 3G networks. However, the input and output values in this chapter do not necessarily reflect actual values that may be used directly while dimensioning a future UMTS network. Finally, to complete the assessment of UMTS network deployment within 2G networks like GSM, this chapter discusses briefly co-location and site sharing, as well as co-location of antenna systems.

Chapter 8 presents issues on resource and network management. It covers radio resource management and signalling, i.e. managing power (fast and low). The conceptual aspects of network management are covered from the network management system point of view. Initial considerations for network optimization are also covered.

Chapter 9 as a prelude to future predominantly PS domain networks, covers the conceptual architecture of UMTS Release 2000 or more specifically Release 4 and 5. It starts

with the evolution of R99 and discusses briefly the long term view and vision of the UMTS architecture. Then it describes the components of R00 with their corresponding interfaces or reference points. This chapter also presents an introduction to and considerations of mobility management, registration aspects, multimedia signalling, service platforms, QoS aspects, and transport issues such as the basic differences of Ipv4 and Ipv6.

The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

ACRONYMS

AAL2	ATM Adaptation Layer Type 2
AAL5	ATM Adaptation Layer Type 5
ATM	Asynchronous Transfer Mode
BHCA	Busy Hour Call Attempt
CAMEL	A version of IN standardised for the mobile environment
CCB	Customer Care and Billing
CDR	Call Detail Record
CPS	Call Processing Server
CSE	CAMEL Service Environment
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage power Ratio
ACS	Adjacent Channel Selectivity
AH	Address Handling
AI	Acquisition Indicator
AICH	Acquisition Indicator Channel
ALCAP	Access Link Control Application Part
AMR	Adaptive MultiRate (speech codec)
AP	Access Preamble
AP-AICH	Access Preamble Acquisition Indicator Channel
API	Access Preamble Indicator
ARQ	Automatic Repeat Request
ASC	Access Service Class
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BER	Bit Error Rate
BLER	Block Error Ratio
BMC	Broadcast/Multicast Control
BM-IWF	Broadcast Multicast Interworking Function
BS	Base Station
BSS	Base Station Subsystem
C-	Control-
CA	Channel Assignment

CAI	Channel Assignment Indicator
CBC	Cell Broadcast Centre
CBR	Constant Bit Rate
CBS	Cell Broadcast Service
CC	Call Control
CCC	CPCH Control Command
CCCH	Common Control Channel
CCF	Call Control Function
CCH	Control Channel
CCPCH	Common Control Physical Channel
CCTrCH	Coded Composite Transport Channel
CD	Collision Detection
CD/CA-ICH	Collision Detection/Channel Assignment Indicator Channel
CDI	Collision Detection Indicator
CDMA	Code Division Multiple Access
CFN	Connection Frame Number
Chip Rate	Chip rate of W CDMA system, equals to 3,84 M chips per second
CN	Core Network
CPCH	Common Packet channel
CPICH	Common Pilot Channel
CRC	Cyclic Redundancy Check
CS	Circuit Switched
CSCF	Call State Control Function
CSICH	CPCH Status Indicator Channel
CTCH	Common Traffic Channel
CW	Continuous Wave (un-modulated signal)
DC	Dedicated Control (SAP)
DCA	Dynamic channel allocation
DCCH	Dedicated Control Channel
DCH	Dedicated Channel, which is mapped into Dedicated Physical Channel.
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPCH_Ec	Average energy per PN chip for DPCH
DPDCH	Dedicated Physical Data Channel
DRNC	Drift Radio Network Controller
DRNS	Drift RNS
DRX	Discontinuous Reception

DS-CDMA	Direct-Sequence Code Division Multiple Access
DSCH	Downlink Shared Channel
DSMA-CD	Digital Sense Multiple Access - Collison Detection
DTCH	Dedicated Traffic Channel
DTX	Discontinuous Transmission
EDGE	Enhanced Data Rates for GSM Evolution
EFR	Enhanced Full Rate speech codec
Ec/No	Received energy per chip divided by the power density in the band
FACH	Forward Link Access Channel
FAUSCH	Fast Upink Signalling Channel
FBI	Feedback Information
FCS	Frame Check Sequence
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FDR	False transmit format Detection Ratio
FEC	Forward Error Control
FER	Frame Error Rate
FTP	File Transfer Protocol
FSW	Frame Synchronization Word
Fuw	Frequency of unwanted signal.
GC	General Control (SAP)
GF	Galois Field
GGSN	Gateway GPRS support node
GMSC	Gateway MSC
GP	Guard Period
GPRS	General Packet Radio System
GSM	Global System for Mobile Communication
GTP	GPRS Tunnelling Protocol
HLR	Home Location register
HO	Handover
HSS	Home Subscriber Server
IC	Interference Cancellation
ICGW	Incoming call gateway
IETF	Internet engineering task force
IMSI	International Mobile Subscriber identity
IN	Intelligent network
Ioc	The power spectral density of a band limited white noise source.
Ior	The total transmit power spectral density of the DL at the BS antenna connector

IP	Internet Protocol
ISDN	Integrated services digital network
ISI	Inter-symbol interference
ITU	International Telecommunication Union
JD	Joint Detection
kbps	kilo-bits per second
L1	Layer 1 (physical layer)
L2	Layer 2 (data link layer)
L3	Layer 3 (network layer)
LAC	Link Access Control
LAI	Location Area Identity
LCS	Location Services
LLC	Logical Link Control
LAN	Local Area Network
MA	Multiple Access
MAC	Medium Access Control
Mbps	Mega bit per second
Mcps	Mega Chip Per Second
ME	Mobile Equipment
MER	Message Error Ratio
MF	Matched filter
MGCF	Media Gateway Control Function
MGW	Media Gateway Function
MM	Mobility Management
MPEG	Motion picture expert group
MRF	Multimedia Resource Function
MS	Mobile Station
MT	Mobile Terminated
MUD	Multiuser detection
MUI	Mobile User Identifier
NAS	Non Access Stratum
NBAP	Node B Application Protocol
NRT	Non-Real Time
Nt	Notification (SAP)
OVSF	Orthogonal Variable Spreading Factor (codes)
PAD	Padding
PC	Power Control
PCCC	Parallel Concatenated Convolutional Code

PCCH	Paging Control Channel
PCCPCH	Primary Common Control Physical Channel
PCH	Paging Channel
PCPCH	Physical Common Packet Channel
PCS	Personal Communications System
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Downlink Shared Channel
PDSCH	Physical Dedicated Shared Channel
PDP	Packet Data Control
PDU	Protocol Data Unit
PhCH	Physical Channel
PHY	Physical layer
PhyCH	Physical Channels
PI	Paging Indicator
PICH	Paging Indicator Channel
PICH	Page Indicator Channel
PN	Pseudo Noise
PPM	Parts Per Million
PRACH	Physical Random Access Channel
PSC	Primary Synchronisation Code
PSCH	Physical channel
PSTN	Public Switched Telephone Network
PU	Payload Unit
PUSCH	Physical Uplink Shared Channel
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RAB	Radio Access Bearer
RACH	Random Access Channel
RAI	Routing Area identity
RANAP	Radio Access Network Application Part
RB	Radio Bearer
RF	Radio Frequency
RL	Radio Link
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RNS	Radio Network Subsystem
RNSAP	Radio Network Subsystem Application Part

RNTI	Radio Network Temporary Identity
RRC	Radio Resource Control
RRM	Radio Resource Management
RSC	Recursive Systematic Convolutional Coder
RSCP	Received Signal Code Power
RSSI	Received Signal Strength Indicator
RT	Real Time
RTP	Real Time Protocol
RU	Resource Unit
RX	Receive
SAB	Service Area Broadcast
SAP	Service Access Point
SCCC	Serial Concatenated Convolutional Code
SCCP	Signalling Connection Control Part
S-CCPCH	Secondary Common Control Physical Channel
SCH	Synchronisation Channel: Primary + Secondary synchronisation channels
SDP	Session Description Protocol
SDU	Service Data Unit
SF	Spreading Factor
SFN	System Frame Number
SHCCH	Shared Channel Control Channel
SI	Status Indicator
SIR	Signal to Interference Ratio
SMS	Short Message Service
SN	Sequence Number
SNR	Signal to Noise Ratio
SPD	Serving Profile Database
SRNC	Serving Radio Network Controller
SRNS	Serving Radio Network Subsystem
SSC	Secondary Synchronisation Code
SSCH	Secondary Synchronisation Channel
SSDT	Site Selection Diversity Transmission
SSDT	Site Selection Diversity TPC
STD	Selective Transmit Diversity
STTD	Space Time Transmit Diversity
TA	Timing Advance
TCH	Traffic Channel
TDD	Time Division Duplex

TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TF	Transport Format
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TFI	Transport Format Indicator
TMSI	Temporary Mobile Subscriber Identity
TPC	Transmit Power Control
TrBk	Transport Block
TrCH	Transport Channel
T-SGW	Transport Signalling Gateway Function
TSTD	Time Switched Transmit Diversity
TTI	Transmission Time Interval
TX	Transmit
TxAA	Transmit Adaptive Antennas
U-	User-
UE	User Equipment
UL	Uplink (Reverse link)
UMTS	Universal Mobile Telecommunications System
URA	UTRAN Registration Area
USCH	Uplink Shared Channel
USIM	UMTS Subscriber Identity Module
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
VBR	Variable Bit Rate
WCDMA	Wide-band Code Division Multiple Access

The UMTS Network and Radio Access Technology: Air Interface Techniques for Future Mobile Systems
Jonathan P. Castro
Copyright © 2001 John Wiley & Sons Ltd
Print ISBN 0-471-81375-3 Online ISBN 0-470-84172-9

INDEX