

# WCDMA (UMTS) DEPLOYMENT HANDBOOK

**Planning and Optimization Aspects**

Editors

Christophe Chevallier  
Christopher Brunner  
Andrea Garavaglia  
Kevin P. Murray  
Kenneth R. Baker

*All of QUALCOMM Incorporated  
California, USA*



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# List of Contributors

The technical content of this book was developed by:

Kenneth R. Baker  
Christopher Brunner  
Patrick Chan  
Christophe Chevallier  
Andrea Forte  
Andrea Garavaglia  
Kevin P. Murray  
Sunil Patil

The content was edited by:

Diana Martin  
Lynn L. Merrill  
Donald Puscher

Figures were created by the content developers and by:

Max Campanella.

All from QUALCOMM Incorporated.



# Foreword

Mobile wireless communications has already dramatically affected our lives, and will continue to do so as usage, services, and coverage rapidly expand with the adoption of the Third Generation of cellular wireless, and the transition to Internet-protocol-based networks.

First Generation cellular networks used analog FM and circuit switching. Despite low voice capacity, uneven quality, limited roaming, and bulky, expensive handsets with limited battery life, the rapid increase of voice subscribers necessitated the adoption of digital transmission technology.

Second Generation (2G) networks, including TDMA-based GSM, PDC, IS-54, and CDMA-based IS-95, allowed rapid expansion of voice subscribers and the introduction of some data services, including short message service (SMS). These Second Generation digital technologies featured advanced coding and modulation, offering greater voice capacity and quality, and supporting digital control channels. The result? More robust and secure signals, smaller and lower-power handsets, enhanced roaming, and a rapid expansion of subscribers worldwide. Even with the limited data capabilities of 2G technology, it became clear that a next generation of cellular networks should focus on even greater capacity, high speed data, and increased reliance on packet switching.

Third Generation (3G) wireless, encompassing three forms of CDMA—CDMA2000®, including 1X and EV-DO; WCDMA, also called UMTS and 3GSM; and most recently TD-SCDMA—has been introduced by many operators and is rapidly gaining subscribers. Both plug-in cards and integral modems are supporting broadband mobile communications directly to laptops. An abundance of powerful handsets are now reaching the market, which support a wide variety of services including music, streamed and stored video, multiplayer games, multiparty instant messaging, and location-based services.

Such growth in usage and applications poses great challenges for the network operators, test equipment vendors, infrastructure manufacturers, and the technical staff that plan, deploy, and operate these networks. This book focuses on the knowledge needed to effectively deploy Wideband CDMA (WCDMA) networks, much of which has been either publicly unavailable or widely scattered across various journals and other sources. In gathering and distilling this knowledge in a readable and coherent form, the authors have achieved their goal of further speeding the deployment and optimization of WCDMA networks.

Third Generation cellular networks will enhance our lives in many ways, rapidly reaching every part of the world and supporting education, business, entertainment, health, and government. The demand for knowledgeable practitioners will continue to grow. This book should provide welcome assistance.

We have come a long way. I look forward to the excitement of further rapid change.

**Irwin Mark Jacobs**  
Chairman of the Board  
QUALCOMM Incorporated





# Preface

In our day-to-day activities, as part of the Engineering Services Group of QUALCOMM®, we consult with network operators throughout the world. In working with them, we have realized that operators repeatedly face the same four challenges: improving RF optimization, properly tuning system parameters, increasing the reliability of inter-system transitions, and providing better indoor coverage. These issues, among others, cannot be resolved simply by studying the communication standard; consequently, they have not been widely addressed in the literature.

In this book, using the experience we have gained from performing many network assessments, we focus on the day-to-day tasks and real world choices that confront operators. We have chosen to minimize paraphrasing of the standard. This is not to say that we disregard the ample documentation written by the Third Generation Partnership Project (3GPP), also known as the standard. We do refer to the standard throughout this book but rather than present its concepts in a dry manner, we introduce only the sections that readers can use to deepen their knowledge on specific topics. We selected these topics to help network planners and optimization engineers make a better transition from GSM to WCDMA while understanding how to perform the required tasks.

This volume attempts to provide as many answers as possible to the complex questions that planners or engineers encounter in their daily activities. As we were writing, we had to make difficult choices about what to include. Without these choices, of course, we would still be writing. Here are the basic questions that we tried to answer in each chapter:

- **Introduction to UMTS networks.** What nodes are necessary in a WCDMA network? What are their basic functions? What is WCDMA anyway? What differentiates WCDMA from other technologies, such as GSM? What are the key terms and concepts of the technology?
- **RF planning and optimization.** What is a typical Link Budget for the different services offered in WCDMA? Is the Downlink or the Uplink limiting? What are the main factors that determine the coverage? How can the coverage of a WCDMA network be qualified?
- **Capacity planning and optimization.** What is the capacity of a WCDMA cell? How does soft handover affect the capacity of a WCDMA network? How do the different services affect the overall capacity? How can the capacity of the network be maximized? Will microcells affect the capacity of the network?
- **Initial parameter settings.** What are the most important parameters to focus on? What is a good starting point for each parameter? How can you verify the values that are broadcast, and where?
- **Service optimization.** How should the optimization process be started? What are the basic procedures that will affect all services? What should you look for to resolve

typical failures? What differs from one service to another? Do any parameters apply only to particular services?

- **Inter-system planning and optimization.** Why rely on other systems? When should you start looking at inter-system issues? What parameters are involved in inter-system changes? What are good starting points for their respective settings?
- **HSDPA.** What is HSDPA? What advantages does it offer compared to a WCDMA (Release 99) network? How does it differ? How and where should HSDPA be deployed? What parameters are available in HSDPA? How do these parameters affect the coverage and capacity of the entire network?
- **Indoor coverage.** Why is indoor coverage different? When should indoor coverage be provided? How can it be achieved and optimized?

By the time you have read this book, you will no doubt be ready to ask several more questions. Hopefully, with the aid of this book, you will have the skills to find the answers you need.

# Acknowledgments

Writing a book of this scope is a major undertaking, one that perhaps cannot be fully appreciated by those who have not wrestled with it. It cannot be achieved without a great deal of help. Adequately acknowledging all the people who have assisted us is difficult, even more so when an entire team has contributed to the effort, even if indirectly. With that in mind, we would like to acknowledge the entire Engineering Services Group of QUALCOMM Incorporated. In particular, we would like to acknowledge the initiators of this project: Dan Agre, Steve Anderson, Richard Costa, and Thomas Erickson. We would also like to thank those who have contributed by reviewing the material, within QUALCOMM and beyond: Jay Dills, Mauricio Guerra, Tony Guy, Pat Japenga, Ben Miller, Mukesh Mittal, Peter Rauber, Mustafa Saglam, Salil Sawhney, and Ralf Weber. Finally, we apologize to all of those we may have neglected to mention here.



# Acronyms

1xEV-DO	Code Division Multiple Access technology compliant with revision 0 of the IS-856 standard, Evolution-Data Optimized of CDMA2000 1X
2-D	Two-Dimensional
2G	Second Generation
3-D	Three-Dimensional
3G	Third Generation
3GPP	Third Generation Partnership Project
ACK	ACKnowledge
ACLR	Adjacent Channel Leakage Ratio
AGC	Automatic Gain Control
AICH	Acquisition Indicator Channel
AM	Acknowledged Mode
AM	Amplitude Modulation
AMC	Adaptive Modulation and Coding
AMR	Adaptive Multirate
ANSI	American National Standards Institute
AS	Access Stratum
AS	Active Set
ASET	Active Set
ASN.1	Abstract Syntax Notation One
ASU	Active Set Update
ASUC	Active Set Update Complete
ATM	Asynchronous Transfer Mode
AuC	Authentication Center
AUTN	Authentication Token
AWGN	Additive White Gaussian Noise
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BDA	Bidirectional Amplifier
BHCA	Busy Hour Call Attempts
BLE	Block Error
BLER	Block Error Rate
BMC	Broadcast/Multicast Control
BPL	Building Penetration Loss
BS	Base Station
BSC	Base Station Controller
BSIC	Base Station Identification Code
BSS	Base Station sub-System
BTS	Base Transceiver Station

---

CC	Call Control
CCCH	Common Control Channel
CCTrCh	Coded Composite Transport Channel
CDMA	Code Division Multiple Access
CDMA2000 1X	Code Division Multiple Access technology compliant with revision 0 or later of IS2000 standard
CE	Channel Element
CELL_DCH	Basic Connected state following a successful call origination, or termination
CFN	Connection Frame Number
CIO	Cell Individual Offset
cm	centimeters
CM	Connection Management
CM	Compressed Mode
CN	Core Network
CPCH	Common Packet Channel
CPICH	Common Pilot Channel
CPICH_ $E_c/N_0$	Pilot channel quality energy per chip over total received power spectral density
CPICH_RSCP	Receive signal code power of the Pilot channel
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CS	Circuit Switched
CTCH	Common Traffic Channel
DAS	Distributed Antenna System
dB	Decibel
dBc	Decibels below carrier power
dB <sub>i</sub>	Decibels Isotropic
dB <sub>m</sub>	Decibel referenced to 1 milliwatt
DCCH	Dedicated Control Channel
DCH	Dedicated Channel
DCR	Dropped Call Rate
DCS1800	Digital Cellular Standard for 1800 MHz band
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
DRAC	Dynamic Resource Allocation Control
DRX	Discontinuous Reception
DSCH	Downlink Shared Channel
DTCH	Dedicated Traffic Channel
DTX	Discontinuous Transmission
E1	European (CEPT) standard data rate of 2.048 Mbps
$E_b/N_t$	Energy per bit over the effective noise power spectral density
$E_c/I_{or}$	Energy per bit over the total transmit power spectral density
$E_c/N_0$	Energy per chip over total received power spectral density

---

EDGE	Enhanced Data rates for GSM Evolution
EFR	Enhanced Full Rate
EIR	Equipment Identity Register
EIRP	Effective Isotropically Radiated Power
EMR	Electromagnetic Radiation
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
FACH	Forward Access Channel
FAF	Floor Attenuation Factor
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FPLMTS	Future Public Land Mobile Telecommunication Systems
FTP	File Transfer Protocol
G	Geometry
Gbyte	Gigabyte
GERAN	GSM/EDGE Radio Access Network
GGSN	GPRS Gateway Support Node
GHz	GigaHertz
GIS	Geographic Information System
GMM	GPRS Mobility Management
GMSC	Gateway Mobile Switching Center
GoS	Grade of Service
GPRS	General Packet Radio Service
GPRS-CN	General Packet Radio Service, Core Network
GPS	Global Positioning System
GSM	Global System for Mobiles
GSM900	Global System for Mobile communication operating in the 900 MHz band
HARQ	Hybrid Automatic Repeat Request
HCS	Hierarchical Cell Structure
HLR	Home Location Register
HO	Handover
HORF	Handover Reduction Factor
HPA	High Power Amplifier
HPSK	Hybrid Phase Shift Keying
HSDPA	High Speed Downlink Packet Access
HS-DPCCH	High Speed Dedicated Physical Control Channel
HS-DSCH	High Speed Downlink Shared Channel
HS-SCCH	High Speed Shared Control Channel
HS-PDSCH	High Speed Physical Downlink Shared Channel
HTTP	HyperText Transfer Protocol
Hz	Hertz
IAF	Intra-Frequency
IC	Integrated Circuit
IE	Information Elements

---

IEEE	Institute of Electrical and Electronic Engineers
IEF	IntEr-Frequency
IMT-2000	International Mobile Telecommunications-2000
$I_{oc}/\hat{I}_{or}$	Ratio of other-cell interference to same-cell received power density
$I_{oc}/N_o$	Ratio of other-cell interference total received power spectral density
IP	Internet Protocol
IR	Incremental Redundancy
IRAT	Inter-Radio Access Technology
IS-95	Code Division Multiple Access technology compliant with Release 0 or later of the TIA-IS-95 standard
ISCR	Inter-System Cell Reselection
ISHO	Inter-System Handover
ISO	International Standards Organization
ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
Iub	Interface between RNC and Node B
K	Kelvin
k	Boltzmann constant ( $1.38 \times 10^{-23}$ Joules/Kelvin)
kbps	Kilobits Per Second
kHz	kiloHertz
km/hr	Kilometers per Hour
KPI	Key Performance Indicator
L3	Layer 3
LA	Location Area
LAN	Local Area Network
LAU	Location Area Update
LNA	Low-Noise Amplifier
LNF	Lognormal Fading
LOS	Line of Sight
MAC	Medium Access Control
MAPL	Maximum Allowable Path Loss
Mbps	Megabits per second
MB	Megabyte
MCM	Measurement Control Message
Mcps	Megachips per second
mErl	milli-Erlangs
MHz	MegaHertz
MIB	Master Information Block
MM	Mobility Management
MMS	Multimedia Messaging Service
MO	Mobile Originated
MOS	Mean Opinion Score
MoU	Minutes of Use
MPEG	Moving Picture Experts Group
MRM	Measurement Report Message
ms	Millisecond



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MS	Mobile Station
MSC	Mobile Switching Center
MT	Mobile Terminated
mW	milliWatts
NA	Not Applicable
NAK	Negative Acknowledgement
NAS	Non-Access Stratum
NBAP	Node B Application Part
NF	Noise Figure, or Noise Factor
NLOS	Non-Line of Sight
ns	Nanosecond
NSS	Network and Switching sub-System
O&M	Operation and Maintenance
OA&M	Operations, Administration, and Maintenance
OBS	Obstructed (opposite of Line of Sight)
OMC	Operation and Maintenance Center
OOS	Out of Service
OVSF	Orthogonal Variable Spreading Factor
PA	Power Amplifier
PAMS	Perceptual Analysis Measurement System
PAR	Peak to Average Ratio
PC	Personal Computer
PCCH	Paging Control Channel
PCCPCH	Primary Common Control Physical Channel
PCH	Paging Channel
P-CPICH	Primary Common Pilot Channel
PDA	Personal Digital Assistant
PCU	Packet Control Unit
PDC	Personal Digital Cellular
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Downlink Shared Channel
PDP	Packet Data Protocol
PDU	Protocol Data Unit
PESQ	Perceptual Evaluation Speech Quality
PHY	Physical
PI	Page Indicator
PICH	Paging Indicator Channel
PLMN	Public Land Mobile Network
PO	Power Offset
PRACH	Physical Random Access Channel
PS	Packet Switched
PSC	Primary Scrambling Code
P-SCH	Primary Synchronization Channel
PSNR	Peak Signal-to-Noise Ratio
PSQM	Perceptual Speech Quality Measurement
PSTN	Public Switched Telephone Network

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QAM	Quadrature Amplitude Modulation
QCIF	Quarter Common Intermediate Format
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RA	Routing Area
RAB	Radio Access Bearer
RACH	Random Access Channel
RANAP	Radio Access Network Application Part
RAU	Routing Area Update
RB	Radio Bearer
RF	Radio Frequency
RLA	Received Signal Level Averaged
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Subsystems
ROT or RoT	Rise Over Thermal
RRC	Radio Resource Control
RSCP	Received Signal Code Power
RSSI	Received Signal Strength Indicator
RTT	Round Trip Time
RV	Redundancy Version
Rx	Receive
SCCPCH	Secondary Common Control Physical Channel
SCH	Synchronization Channel
sec	Second
SF	Spreading Factor
Sf_HORF	Softer Handover Reduction Factor
SGSN	Serving GPRS Support Node
SIB	System Information Block
SID	Silence Descriptor
SIM	Subscriber Identity Module
SINR	Signal-to-Interference-and-Noise Ratio
SIR	Signal-to-Interference Ratio
SM	Session Management
SNR	Signal-to-Noise Ratio
SPER	Sub-Packet Error Rate
SQCIF	Sub-Quarter Common Intermediate Format
SRB	Signal Radio Bearer
SRES	Signed Authentication Response
SSC	Secondary Scrambling Code
S-SCH	Secondary Synchronization Channel
T1	Trunk Level 1, Digital transmission line, data rate of 1.544 Mbps
TB	Transport Block
TBS	Transport Block Size
TCP/IP	Transmission Control Protocol/Internet Protocol
TDD	Time Division Duplex

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TDMA	Time Division Multiple Access
TFCI	Transport Format Combination Indicator
TFCS	Transport Format Combination Set
TFRC	Transport Format Resource Combination
TGCFN	Transmission Gap Connection Frame Number
TGD	Transmission Gap Distance
TGL	Transmission Gap Length
TGP	Transmission Gap Patterns
TGPL	Transmission Gap Pattern Length
TGPRC	Transmission Gap Pattern Repetition Count
TGPS	Transmission Gap Pattern Sequence
TGPSI	Transmission Gap Pattern Sequence Identifier
TGSN	Transmission Gap Slot Number
TM	Transparent Mode
TMA	Tower Mount Amplifier
TPC	Transmit Power Control
TRX	Transceiver
TSP	Transmit Status Prohibit
TSN	Transmission Sequence Number
TTI	Transmission Time Interval
TTT	Time-to-Trigger
TV	Television
Tx	Transmit
UARFCN	UTRA Absolute Radio Frequency Channel Number
UE	User Equipment
UL	Uplink
UM	Unacknowledged Mode
UMTS	Universal Mobile Telecommunications Systems
URA	UTRAN Registration Area
UTM	Universal Transverse Mercator
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network
UV	UltraViolet
VoIP	Voice over Internet Protocol
VLR	Visitor Location Register
VT	Video-Telephony
W	Watts
WAF	Wall Attenuation Factor
WCDMA	Wideband Code Division Multiple Access
WGS	World Geodetic System
WLAN	Wireless Local Area Network
WLL	Wireless Local Loop
YUV	Video format where luminance (Y) and chrominance (U and V) are a weighted function of R(ed) G(reen) B(lue) signal



# 1

## Introduction to UMTS Networks

Patrick Chan, Andrea Garavaglia and Christophe Chevallier

Since their inception, mobile communications have become sophisticated and ubiquitous. However, as the popularity of mobile communications surged in the 1990s, Second Generation (2G) mobile cellular systems such as IS-95 and Global System for Mobile (GSM) were unable to meet the growing demand for more network capacity. At the same time, thanks to the Internet boom, users demanded better and faster data communications, which 2G technologies could not support.

Third Generation (3G) mobile systems have evolved and new services have been defined: mobile Internet browsing, e-mail, high-speed data transfer, video telephony, multimedia, video-on-demand, and audio-streaming. These data services had different Quality of Service (QoS) requirements and traffic characteristics in terms of burstiness and required bandwidth. More importantly, the projected traffic for these types of data services was expected to surpass voice traffic soon, marking a transition from the *voice paradigm* to the *data paradigm*. Existing cellular technology urgently needed a redesign to maximize the spectrum efficiency for the mixed traffic of both voice and data services. Another challenge was to provide global roaming and interoperability of different mobile communications across diverse mobile environments.

Toward these ends, the International Telecommunication Union (ITU), the European Telecommunications Standards Institute (ETSI), and other standardization organizations collaborated on the development of the Future Public Land Mobile Telecommunication Systems (FPLMTS). The project was later renamed International Mobile Telecommunications-2000 (IMT-2000). The goal of the project was to achieve convergence of the disparate competing technologies by encouraging collaborative work on one globally compatible system for wireless communications.

Set to operate at a 2 GHz carrier frequency band, the new 3G mobile cellular communication system needed to be backward-compatible with the 2G systems while improving system capacity and supporting both voice and data services. The system was expected

to support both circuit switched (CS) and packet switched (PS) data services. For the PS domain, the supported data rates were specified for the various mobile environments:

- Indoor or stationary – 2 Mbps
- Urban outdoor and pedestrian – 384 kbps
- Wide area vehicular – 144 kbps

Of the various original proposals, the two that gained significant traction were based on Code Division Multiple Access (CDMA): CDMA2000 1X and Universal Mobile Telecommunication System (UMTS).

- CDMA2000 1X was built as an extension to cdmaOne (IS-95), with enhancements to achieve high data speed and support various 3G services. CDMA2000 1X further evolved to support even higher data rates with a data optimized version: CDMA2000 1xEV-DO [1].
- UMTS was based on the existing GSM communication core network (CN) but opted for a totally new radio access technology in the form of a wideband version of CDMA (Wideband CDMA: WCDMA). The Wideband Code Division Multiple Access (WCDMA) proposal offered two different modes of operation: Frequency Division Duplex (FDD), where Uplink (UL) and Downlink (DL) traffic are carried by different radio channels; and Time Division Duplex (TDD), where the same radio channel is used for UL and DL traffic but at different times. Evolution to support higher data rates was achieved with the recent introduction of High-Speed Downlink Packet Access (HSDPA) [2].

The goal of this book is to address the deployment aspects of the FDD version of the UMTS IMT-2000 proposal – namely WCDMA network planning and optimization. While it is accepted that deploying a WCDMA network requires a thorough knowledge of the standard, this book leaves that to other existing works such as Refs [3] and [4], and concentrates instead on the key aspects necessary to successfully deploy and operate a WCDMA network in a real-world scenario. For newcomers to this technology, however, this chapter describes the basic network topology and underlying concepts associated with the technology.

## 1.1 UMTS Network Topology

When deploying a WCDMA network, most operators already have an existing 2G network. WCDMA was intended as a technology to evolve GSM network toward 3G services. Paralleling that evolution, this chapter first discusses GSM networks, then highlights the changes that are necessary to migrate to Release 99 of the WCDMA specification. The discussion then moves on to Release 5 of the specification and the network changes needed to support HSDPA.

### 1.1.1 GSM Network Architecture

Figure 1.1 illustrates a GSM reference network [5], showing both the nodes and the interfaces to support operation in the CS and PS domains.