UNIVERSAL PERSONAL COMMUNICATIONS

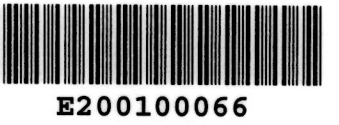
THIRD GENERATION MOBILE COMMUNICATION SYSTEMS

RAMJEE PRASAD
WERNER MOHR
WALTER KONHÄUSER
EDITORS

Third Generation Mobile Communication Systems

Ramjee Prasad
Werner Mohr
Walter Konhäuser

Editors



Artech House
Boston • London

Library of Congress Cataloging-in-Publication Data
Prasad, Ramjee.
Third generation mobile communication systems / Ramjee Prasad, Werner Mohr, Walter Konhäuser.
p. cm. — (Artech House universal personal communications library)
Includes bibliographical references and index.
ISBN 1-58053-082-6 (alk. paper)
1. Wireless communication systems. 2. Mobile communication systems — Standards. 3. Code division multiple access. 4. Time division multiple access. I. Mohr, Werner, 1955- II. Konhäuser, Walter. III. Title. IV. Series.

TK5103.2. P72 2000
621.3845—dc21

99-089511
CIP

British Library Cataloguing in Publication Data
Prasad, Ramjee
Third generation mobile communication systems. — (Artech House universal personal communications library)
1. Mobile communication systems
I. Title II. Mohr, Werner III. Konhäuser, Walter
621.3'845

ISBN 1-58053-082-6

Cover design by Dutton and Sherman

International Standard Book Number: 1-58053-082-6
Library of Congress Catalog Card Number: 99-089511

10 9 8 7 6 5 4 3 2

Third Generation Mobile Communication Systems

For a listing of recent titles in the *Artech House Universal Personal Communications Series*, turn to the back of this book.

Dedication

To
my wife Jyoti, to our daughter Neeli,
and to our sons Anand and Rajeev
Ramjee Prasad

To
my parents
Werner Mohr

To
my wife Tina and to our son Philipp
Walter Konhäuser

Preface

कर्मण्येवाधिकारस्ते मा फलेषु कदाचन ।
मा कर्मफलहेतुर्भूर् मा ते संगोऽस्त्वकर्मणि ॥

karmaṇy evādhikāras te
mā phaleṣu kadācana
mā karma-phala-hetur bhūr
mā te saṅgo 'stv akarmaṇi

You have a right to perform your prescribed duty, but you are not entitled to the fruits of action. Never consider yourself the cause of the result of your activities, and never be attached to not doing your duty.

The Bhagavad Gita (2.47)

This book is the output of the research and development contributions of several major players from industries, a network operator, research laboratories and universities, which were carried out during the European Advanced Communication Technology and Services (ACTS) Future Radio Wideband Multiple Access System (FRAMES) project. The main objective of the FRAMES project was to develop a radio interface proposal, which fulfills the requirements on terrestrial third generation mobile radio systems, and to contribute to the international standardization process. The FRAMES project was the only ACTS project dealing with the terrestrial communications of the Universal Mobile Telecommunications System (UMTS) radio interface.

Third Generation Mobile Communication Systems is the first book to take a comprehensive look at UMTS, providing an in depth description of all the elements required to understand and develop the third generation mobile radio systems and networks. Figure 1 illustrates the coverage of the book. Chapter 1 presents an overview of International Mobile Telecommunications – 2000 (IMT-2000) / UMTS). Chapter 2 explains the basic principles of Time Division – Code Division Multiple Access (TD-CDMA). The basic concept of Wideband CDMA

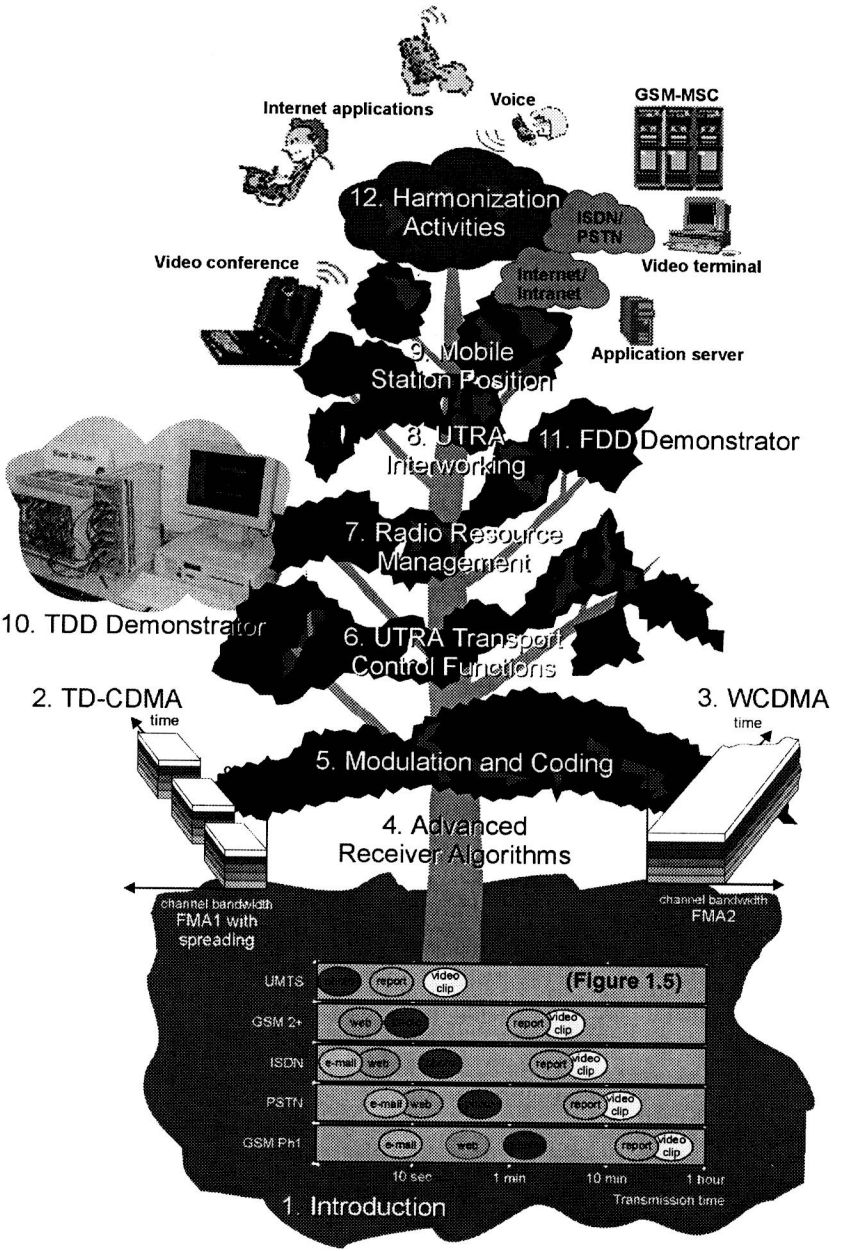


Figure 1 Illustration of the coverage of the book.

(WCDMA) is introduced in Chapter 3. Advanced receiver algorithms are covered in Chapter 4. Chapter 5 discusses modulation and coding techniques. UMTS Terrestrial Radio Access (UTRA) transport control functions are presented in detail in Chapter 6. Radio resource management is introduced in Chapter 7. Chapter 8 presents UTRA networking and mobile station positioning is presented in Chapter 9. Chapters 10 and 11 cover the Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) demonstrators developed during the FRAMES project, respectively. Finally the international harmonization activities are discussed in Chapter 12.

Thus this book delivers the basic principles and the analytical models for the UTRA TDD mode using TD-CDMA and for the UTRA FDD mode using WCDMA, allowing everyone to understand how these multiple access systems fulfill the UMTS requirements. Plus, several interesting topics are presented, viz. very advanced receiver algorithms, coding and modulation techniques, layer 2 issues including the UTRA architecture, protocol architectures, signaling protocols and Automatic Repeat Request (ARQ) schemes. Included is an examination of TDD and FDD mode compatibility with Global System for Mobile Communications (GSM) and the methods used for calculating mobile station location within the coverage area. With this new book one gets an integrated resource that examines the fundamentals and applications of today's most important mobile communication technologies.

FRAMES started in September 1995 before the detailed standardization activities in European Telecommunications Standardization Institute Special Mobile Group 2 (ETSI SMG2) began for the UMTS radio interface. During the first phase of the project we had serious discussions on the technical approach for the radio interface. This approach was also changed several times in this period. These technical discussions took place in the starting phase of a big project, where all partners were working to understand each other and their positions. Experience showed that this needs time when colleagues from different countries all over Europe, namely

- Austria
- Finland
- France
- Germany
- Portugal
- Spain
- Sweden
- Switzerland
- The Netherlands
- United Kingdom

and from different organizations as

- Manufacturers
  - Ericsson Radio Systems AB
  - Nokia Corporation
  - Siemens AG and Roke Manor Research
- Network operator
  - France Télécom – CNET
- SME
  - Integracion y Sistema de Medida
- Research Center and Academia
  - CSEM – Centre Suisse d'Electronique et de Microtechnique SA
  - Eidgenössische Technische Hochschule Zurich
  - Chalmers University of Technology AB
  - Delft University of Technology
  - Instituto Superior Técnico
  - Oulu Technical University
  - Royal Insitute of Technology
  - University of Kaiserslautern

started to cooperate.

The technical discussions in the first phase have been determined by the different interest of partners. However, FRAMES defined in that period the FMA scheme, which combined TDMA and CDMA based techniques. In December 1996 FRAMES participated in the ETSI SMG2 Workshop on UMTS in Sophia Antipolis with two presentations to present the first time publicly the FMA scheme. This was the starting point of the standardization process in ETSI SMG. In January 1997 a first Long-term Research Workshop was organized in Gothenburg. During 1997 we presented a lot of joint contributions to the international standardization. In 1997 we again had serious technical discussions in the standardization bodies. This is understandable due to the different interests of the different partners, which cannot be solved by a research project. However, the project contributed significantly to the international consensus building process. Despite all discussions FRAMES presented the FMA scheme in the ITU IMT-2000 Workshop in September 1997 in Toronto again with two deeply technical presentations.

January 1998 was a very important period for FRAMES. The ETSI decision on the UTRA concept on January 29, 1999 with WCDMA in the paired bands based on FMA2, and with TD-CDMA in the unpaired bands based on FMA1 with spreading was finally a big success for FRAMES. FMA1 without spreading was adopted in the U.S. for the high speed mode in UWC-136. From that point of view FRAMES had a big impact on the UMTS and IMT-2000 standardization. In 1998 FRAMES partners participated extensively in the standardization process with many contributions, which have been prepared in the framework of the project. FRAMES adopted the ETSI decision and focused its work on the optimization of the UTRA concept. UTRA TDD was mainly developed in the project. During 1998 FRAMES performed two successful workshops, one in Beijing, China, and one in Yokosuka, Japan. In addition, during the project's lifetime we did a large number of presentations and wrote several publications. Therefore, FRAMES is well-known internationally.

In January 1999 an open workshop was organized in Delft to present our results. We invited other ACTS projects as well as the European Commission. FRAMES was invited to workshops organized by other ACTS projects namely OnTheMove in Singapore in September 1997 and RAINBOW in December 1998 in Torino. In the last phase of the project, mainly during 1999, we concentrated our effort on the demonstrator, which is finally integrated. Joint trials with RAINBOW took place and in September 1999 and CNET performed trials and measurements. Beginning in November 1999 an Open Day was organized at France Télécom - CNET to present the demonstrator.

With respect to the difficult environment as different partner interests and the ongoing international standardization process, FRAMES was a very successful project with a significant contribution to and impact on the Third Generation Mobile Radio Systems.

All this was only possible because all colleagues worked together, respecting the interests of their organizations. It was a very good experience to cooperate in such an environment. We always could talk to each other and we were able to find reasonable solutions. The international workshops and the book, which was prepared by the FRAMES project, showed our ability to cooperate.

The relation to the European Commission was very trustful and fair. Discussions and negotiations have been needed in difficult situations. We were always able to find suitable solutions for the European Commission and the project.

We have tried our best to make each chapter quite complete in itself. This book will help in finding the solution in deploying the Third Generation Mobile Communications Systems IMT-2000 / UMTS. Any remarks to improve the text and correct any errors would be highly appreciated.

Acknowledgments

The material in this book originates from the FRAMES project and contributions to the international standardization process. Therefore, we would like to thank all the colleagues involved in the project for their support and cooperation that made success possible. This success is not only in completing the project successfully, but also finalizing the book as an additional part of the project. We hope that our personal relations remain and possibly we will cooperate in other projects or international bodies in the future.

FRAMES was partly funded by the European Union. We thank especially Dr. Joao Schwarz Dasilva and Mr. Bartolomé Arroyo-Fernandez from the European Commission for their continuous support. We would like to acknowledge the contributions of our colleagues from Siemens AG, Roke Manor Research Limited, Ericsson Radio Systems AB, Nokia Corporation, Technical University of Delft, University of Oulu, France Télécom CNET, CSEM – Centre Suisse d'Electronique et de Microtechnique SA, Eidgenössische Technische Hochschule Zürich, University of Kaiserslautern, Chalmers University of Technology AB, the Royal Institute of Technology, Instituto Superior Técnico and Integracion y Sistema de Medida.

Ljupco Jorguseski from Delft University of Technology / KPN Research helped to prepare the complete manuscript, freeing us from the enormous editorial burden. He was supported by Albena Mihovska and Martijn Kuipers from the Center for PersonKommunikation, Aalborg University, Denmark.

Last but not least, Per-Olof Anderson from Ericsson Radio Systems AB is greatly acknowledged for giving his support to finish this book as the technical manager of the FRAMES project.

Ramjee Prasad
Werner Mohr
Walter Konhäuser

December 1999

Contents