COGNITIVE RADIO COMMUNICATIONS and NETWORKS

Principles and Practice

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Cognitive Radio Communications and Networks

Principles and Practice

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NEW YORK • OXFORD • PARIS • SAN DIEGO
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30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
525 B Street, Suite 1900, San Diego, California 92101-4495, USA
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK

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Library of Congress Cataloging-in-Publication Data
Cognitive radio communications and networks: principles and practice/edited by Alexander M. Wyglinski, Maziar Nekovee, and Y. Thomas Hou.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-12-374715-0 (alk. paper)
1. Cognitive radio networks. I. Wyglinski, Alexander M. II. Nekovee, Maziar. III. Hou, Y. Thomas.
TK5103.4815.C63 2010
621.384-dc22 2009040908

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.
For information on all Academic Press publications
visit our Web site at www.elsevierdirect.com

Printed in the United States of America
08 09 10 9 8 7 6 5 4 3 2 1

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To my parents, Ted and Barbara,
and my sisters, Laura and Joanne
AMW

To Laverne, Jack, and Sirous; to my father, Sirous,
and in memory of my mother, Parvin
MN

To my wife Tingting Jiang
YTH

Preface

Cognitive radio is the next disruptive radio communication and networking technology. It is currently experiencing rapid growth due to its potential to solve many of the problems affecting present-day systems. For instance, interest in cognitive radio by the industrial sector has been rapidly growing over the past couple of years, which has manifested into several forms, including:

- Regulatory agencies moving toward allowing the operation of cognitive radios in licensed television spectrum bands.
- Creation and eventual ratification of international wireless standards supporting secondary access of licensed spectrum.
- Incorporation of cognitive radio technology into existing standards.
- Active lobbying by various entities and coalitions for cognitive access to wireless spectral white spaces, including nonprofit organizations and various corporations.

Wireless device manufacturers (e.g., Motorola, Eriksson, and Nokia), telecommunication operators (e.g., BT, France Telecom), and chip makers (e.g., Intel) are all beginning to invest in this new technology, especially with respect to research and development. Outside the area of wireless communication, software-defined radio and cognitive radio technology are expected to have important applications in consumer electronics and the automotive industry. However, although there have been numerous publications, conferences, tutorials, short courses, and books in this area, there does not exist a single comprehensive textbook introducing this material to the communication networks generalist in a structured manner.

The foremost objective of this book is to educate wireless communication generalists about cognitive radio communication networks. The first two parts of this book introduce the reader to the wireless communication and networking theory involved in designing/implementing cognitive radio systems and networks. End-of-chapter questions give the reader the opportunity to apply what she or he has just learned to address problems arising in that chapter. Finally, the third part of this book, which contains numerous implementations, applications, and case studies, helps the reader synthesize the previous two parts by highlighting how these concepts fit in real-world problems.

The intended readership for this book is both wireless communication industry and public sector practitioners and researchers in electrical engineering, computer engineering, and computer science (including graduate students). Both groups are assumed to have a basic background in wireless communications and networks, although they lack any expertise in cognitive radio. This book is designed specifically to introduce communication generalists to the area of cognitive radio communications and networks via a structured approach.

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For the industry practitioner, our book provides a self-contained guide that caters to their immediate needs of learning new concepts and techniques in this emerging area. While the introductory sections bring the reader up to speed with the fundamentals of cognitive radio, the third part provides an up-to-date "handbook of cognitive radio technology," as it will be in the marketplace within a few years. Sample code and implementations allow researchers to gain a hands-on knowledge of cognitive radio technology, which is much appreciated in an industrial setting. Furthermore, by having specifically two chapters on the two emerging industry standards based on cognitive radio (IEEE 802.22 and IEEE SCC41), we believe that this book will be of definite benefit to the industry practitioners in this sector. The relevance of the book to this group is further increased by one of the editors and several of the contributors being from industrial research laboratories worldwide (e.g., BT, Motorola, Cisco, Philips, Intel, Broadcom).

For academic researchers, cognitive radio communications has been the subject of much recent research and is starting to become well-established. Nevertheless, cognitive radio networks are recognized as a highly challenging area, with many open research problems remaining to be explored. The cognitive radio networks part of our book is written by internationally leading experts in the field and caters to the needs of researchers in the field who require a basis in principles and challenges of cognitive radio networks (such as architecture, security, cooperation) from where they can explore new research directions in cognitive radio. Moreover, many academic institutions are beginning to offer courses on cognitive radio, software-defined radio, and advanced wireless systems engineering. At the moment, only a half dozen universities offer entire courses on cognitive radio or software-defined radio. However, numerous courses on advance wireless communications and networks exist worldwide, possessing at least a module on cognitive radio, which will eventually evolve into full courses in the near future as this area continues to grow.

Since this book covers a wide range of topics in cognitive radio communications and networks, we arranged the presentation of the topics covered by this book such that each chapter gradually builds upon the knowledge and information of the previous chapters. As a result, someone with a basic understanding of communication systems and networks can learn about the topics covered in this book in a step-by-step approach, either in a classroom environment or via self-education. Moreover, communication engineers who already have an understanding of some of the material covered in the book can easily skip ahead to topics of interest. Finally, the chapters have been grouped together into three thematically related parts in order to provide better structure for the reader with respect to the topics covered: Radio Communications, Networks, and Implementation; Applications; and Case Studies. Note that the final chapter of this book provides an all-encompassing vision on the evolution and future directions for cognitive radio by Joseph Mitola III, the father of both software-defined radio and cognitive radio.

This book is made possible by the extensive support of numerous individuals throughout the duration of this project. First, we are deeply indebted to our contributors, who all share in our vision of educating wireless communication generalists about cognitive radio communication networks by producing well-written, informative, and high-quality chapters. Second, we would like to thank our publishers at Elsevier, especially Tim Pitts and Melanie Benson, for their hard work, guidance, and encouragement during the creation of this book. Third, we owe our special thanks to the following colleagues for taking the time to review the manuscript of this book at various stages of this project (in alphabetical order): Alireza Attar, David Cavalcanti, Si Chen, Natasha Devroye, Oliver Holland, Santosh Kawade, Devin Kelly, Michael Leferman, Shiwen Mao, Sai Shankar Nandagopala, Timothy Newman, Srikanth Pagadarai, Przemysław Pawełczak, Rangarao Venkatesha Prasad, Di Pu, Yi Shi, Jingkai Su, David Taubenheim, William Webb, Kai-Kit Wong, Liguang Xie, and Qing Zhao. Fourth, we would like to thank Honggang Zhang, Frederick Martin, and Rajarathnam Chandramouli, with whom we worked with much pleasure in organizing the Second International Conference on Cognitive Radio Oriented Wireless Communication and Networks (CrownCom 2007), for bringing us together in Orlando, Florida, USA, where the idea for this book was born. Finally, we would like to thank our families for their support and encouragement.

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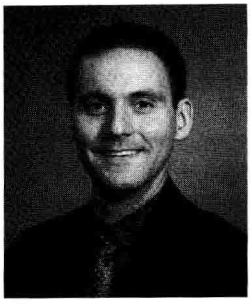

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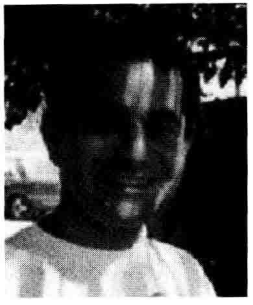

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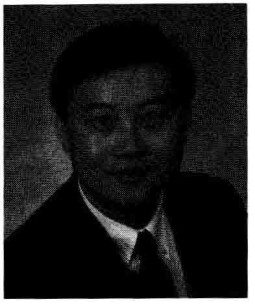

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Alexander M. Wyglinski is an Assistant Professor of Electrical and Computer Engineering at Worcester Polytechnic Institute (WPI), Director of the WPI Limerick Project Center, and Director of the Wireless Innovation Laboratory (WI Lab). He received his Ph.D. from McGill University in 2005, his M.S.(Eng.) from Queens University at Kingston in 2000, and his B.Eng. from McGill University in 1999, all in electrical engineering. Professor Wyglinski's current research interests include wireless communications, wireless networks, cognitive radios, software-defined radios, transceiver optimization algorithms, dynamic spectrum access networks, spectrum sensing techniques, machine learning techniques for communication systems, and signal processing techniques for digital communications. He is a member of the IEEE, IEEE Communications Society, IEEE Signal Processing Society, IEEE Vehicular Technology Society, IEEE Women in Engineering, Eta Kappa Nu, and Sigma Xi.

Maziar Nekovee leads cognitive radio research at BT (British Telecom) and is also involved in leading a number of large EU and International collaborative R&D projects on cognitive radio networks and secondary/dynamic spectrum access. These projects involve altogether over 30 industrial and academic partners from Europe, China, India, and the United States. They intend to bring very close to market the cognitive radio technology as well as researching long-term directions of the technology. Dr. Nekovee received his BSc. and MSc. (cum laude) in electrical engineering from Delft University of Technology in The Netherlands in 1990 and his Ph.D. in theoretical and computational physics from the University of Nijmegen in The Netherlands in 1995. His research cuts across several disciplines and currently focuses on theory, modeling, simulations, and development of complex networked systems, including cognitive and cooperative radio networks, wireless vehicular communication networks, and complex social and biological networks.

Dr. Nekovee is the recipient of a prestigious Industry Fellowship from the U.K.'s Academy of Science, the Royal Society, and an Honorary Senior Fellow at University College London.

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