

# WIRELESS COMMUNICATIONS AND NETWORKS

## SECOND EDITION

**William Stallings**



Upper Saddle River, NJ 07458

Vice President and Editorial Director, ECS:

*Marcia J. Horton*

Publisher: *Alan Apt*

Associate Editor: *Toni D. Holm*

Editorial Assistant: *Patrick Lindner*

Vice President and Director of Production and

Manufacturing, ESM: *David W. Riccardi*

Executive Managing Editor: *Vince O'Brien*

Managing Editor: *Camille Trentacoste*

Production Editor: *Rose Keman*

Cover Photo: *Brand X Pictures*

Director of Creative Services: *Paul Belfanti*

Art Director: *Heather Scott*

Cover Designer: *Tamara Newnam*

Managing Editor, AV Management

and Production: *Patricia Burns*

Art Editor: *Gregory Dulles*

Manufacturing Manager: *Trudy Piscioti*

Manufacturing Buyer: *Lynda Castillo*

Marketing Manager: *Pamela Hersperger*

Marketing Assistant: *Barrie Reinhold*



© 2005, 2002 Pearson Education, Inc.

Pearson Prentice Hall

Pearson Education, Inc.

Upper Saddle River, NJ 07458

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Pearson Prentice Hall® is a trademark of Pearson Education, Inc.

The author and publisher of this book have used their best efforts in preparing this book. These efforts include the development, research, and testing of the theories and programs to determine their effectiveness. The author and publisher make no warranty of any kind, expressed or implied, with regard to these programs or the documentation contained in this book. The author and publisher shall not be liable in any event for incidental or consequential damages in connection with, or arising out of, the furnishing, performance, or use of these programs.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN: 0-13-191835-4

Pearson Education Ltd., *London*

Pearson Education Australia Pty. Ltd., *Sydney*

Pearson Education Singapore, Pte. Ltd.

Pearson Education North Asia Ltd., *Hong Kong*

Pearson Education Canada, Inc., *Toronto*

Pearson Educación de México, S.A. de C.V.

Pearson Education—Japan, *Tokyo*

Pearson Education Malaysia, Pte. Ltd.

Pearson Education Inc., *Upper Saddle River, New Jersey*

*As always,  
for my loving wife  
and her constant companions  
Geoffroi and Helma*

# CONTENTS

---

## Preface xi

### Chapter 1 Introduction 1

- 1.1 Wireless Comes of Age 2
- 1.2 The Cellular Revolution 3
- 1.3 The Global Cellular Network 4
- 1.4 Broadband 5
- 1.5 Future Trends 5
- 1.6 The Trouble with Wireless 7
- 1.7 Outline of the Book 7
- 1.8 Internet and Web Resources 10

## PART ONE TECHNICAL BACKGROUND 13

### Chapter 2 Transmission Fundamentals 14

- 2.1 Signals for Conveying Information 15
- 2.2 Analog and Digital Data Transmission 22
- 2.3 Channel Capacity 27
- 2.4 Transmission Media 31
- 2.5 Multiplexing 36
- 2.6 Recommended Readings and Web Sites 40
- 2.7 Key Terms, Review Questions, and Problems 41
- Appendix 2A Decibels and Signal Strength 43

### Chapter 3 Communication Networks 46

- 3.1 LANs, MANs, and WANs 47
- 3.2 Switching Techniques 49
- 3.3 Circuit Switching 50
- 3.4 Packet Switching 54
- 3.5 Asynchronous Transfer Mode 60
- 3.6 Recommended Readings and Web Sites 65
- 3.7 Key Terms, Review Questions, and Problems 66

### Chapter 4 Protocols and the TCP/IP Suite 69

- 4.1 The Need for a Protocol Architecture 70
- 4.2 The TCP/IP Protocol Architecture 71
- 4.3 The OSI Model 75
- 4.4 Internetworking 77
- 4.5 Recommended Readings and Web Sites 83
- 4.6 Key Terms, Review Questions, and Problems 83
- Appendix 4A Internet Protocol 85
- Appendix 4B Transmission Control Protocol 88
- Appendix 4C User Datagram Protocol 92

## **PART TWO WIRELESS COMMUNICATION TECHNOLOGY 94**

### **Chapter 5 Antennas and Propagation 95**

- 5.1 Antennas 96
- 5.2 Propagation Modes 101
- 5.3 Line-of-Sight Transmission 105
- 5.4 Fading in the Mobile Environment 115
- 5.5 Recommended Readings and Web Sites 122
- 5.6 Key Terms, Review Questions, and Problems 123

### **Chapter 6 Signal Encoding Techniques 127**

- 6.1 Signal Encoding Criteria 129
- 6.2 Digital Data, Analog Signals 131
- 6.3 Analog Data, Analog Signals 142
- 6.4 Analog Data, Digital Signals 148
- 6.5 Recommended Readings 155
- 6.6 Key Terms, Review Questions, and Problems 155

### **Chapter 7 Spread Spectrum 159**

- 7.1 The Concept of Spread Spectrum 160
- 7.2 Frequency Hopping Spread Spectrum 161
- 7.3 Direct Sequence Spread Spectrum 166
- 7.4 Code Division Multiple Access 170
- 7.5 Generation of Spreading Sequences 173
- 7.6 Recommended Readings and Web Sites 186
- 7.7 Key Terms, Review Questions, and Problems 186

### **Chapter 8 Coding and Error Control 192**

- 8.1 Error Detection 193
- 8.2 Block Error Correction Codes 200
- 8.3 Convolutional Codes 216
- 8.4 Automatic Repeat Request 223
- 8.5 Recommended Readings 230
- 8.6 Key Terms, Review Questions, and Problems 231

## **PART THREE WIRELESS NETWORKING 236**

### **Chapter 9 Satellite Communications 237**

- 9.1 Satellite Parameters and Configurations 238
- 9.2 Capacity Allocation—Frequency Division 250
- 9.3 Capacity Allocation—Time Division 256
- 9.4 Recommended Readings and Web Sites 261
- 9.5 Key Terms, Review Questions, and Problems 262

### **Chapter 10 Cellular Wireless Networks 264**

- 10.1 Principles of Cellular Networks 265
- 10.2 First-Generation Analog 282
- 10.3 Second-Generation TDMA 285
- 10.4 Second-Generation CDMA 298
- 10.5 Third-Generation Systems 304

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

## LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

## FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

## E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.