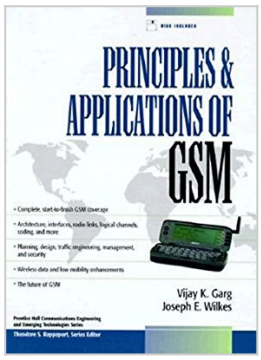

Principles & Applications of GSM with 3.5 Disk (Prentice Hall Communications Engineering and Emerging Technologies)

By Vijay Kumar Garg, J. E. Wilkes, Joseph E. Wilkes

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Editorial Review

From the Inside Flap

Preface During the last several decades, the world has seen phenomenal changes in the telecommunications industry. Communications that were formerly provided by wires are now provided by radio (wireless) means. Thus, wireless communication, which uncouples the telephone from its wires to the local telephone exchange, has exploded. During the early 1980s, six incompatible analog mobile systems were operational in Western Europe, which precluded interoperability between systems; thus, roaming between countries of Europe was not possible. With the growth of the European Common Market, roaming between these countries became important. In 1985 the main governing body of the European Postal Telephone and Telegraph (PTTs)--Conference Europeenne des Postes et Telecommunications (CEPT)--set up a committee known as Groupe Special Mobile, later changed to Global System for Mobile Communications (GSM), under the auspices of its Committee on Harmonization to define a mobile system that could be introduced across Europe in the 1990s. This initiative gave the European mobile communications industry a home market of about 300 million subscribers, while at the same time providing it with a significant technical challenge. The early years of the GSM were devoted mainly to the selection of the radio techniques for the air interface. In 1986 field trials of different candidate systems proposed for the GSM air interface were conducted in Paris. A set of criteria ranked in order of importance was established to assess these candidate systems. Some of the criteria to be met by the candidate system included Spectral efficiency Subjective voice quality Cost of mobile Hand portable feasibility Cost of base station Ability to support the new services Coexistence with existing systems The performance of a cellular radio system depends primarily upon cochannel interference, and a given quality of voice can be achieved at much higher levels of cochannel interference when digital transmission instead of analog transmission is used for the system. After a considerable debate over the most suitable transmission mode (Frequency-Division Multiple Access FDMA, Time-Division Multiple Access TDMA, or Code-Division Multiple Access CDMA), the final decision in 1987 was to adopt TDMA for GSM. In 1989 the responsibility for generating specifications for GSM was passed from the CEPT to the newly formed European Telecommunications Standards Institute (ETSI). The specifications for GSM Phase 1 were completed by 1990 and are divided into 12 sets of recommendations covering different aspects of the GSM system. GSM Phase 1 is a self-contained version of the standard that supports only a subset of the services that were originally thought to be in GSM. Based on these original specifications, GSM systems have been installed and mobile communications services have been offered in most continents of the world. GSM Phase 2 is a full-fledged version of the standard. It differs from Phase 1 primarily in a number of added supplementary services. However, upon a close examination one finds that the signaling protocol Mobile Application Part (MAP) and the protocol between mobile station and the infrastructure have been modified in many areas. The GSM Phase 2+ activities are organized as a set of independent tasks so that each of them could be introduced with little or no impact on the others. So far, more than 80 tasks are identified in the Special Mobile Group (SMG). They cover aspects from radio transmission to call management. The challenge of GSM Phase 2+ is to gradually introduce important changes while maintaining upward compatibility. Interfaces, protocols, and protocol stacks in GSM are aligned with the Open System Interconnect (OSI) principles. GSM is an open architecture that provides maximum independence between network elements (such as the Base Station Controller BSC, Home Location Register HLR, and so on). This approach simplifies design, testing, and implementation of the system. It also favors an evolutionary growth path, since network element independence implies that modification to one network element can be made with minimum or no impact on the others. Also, a system operator has a choice of using network elements from different manufacturers. GSM 900 has been adopted in

many countries, including a major part of Europe, North Africa, Middle East, many East Asian countries, and Australia. In most of these cases, roaming agreements exist to make it possible for subscribers to travel in different parts of the world and enjoy continuity of their telecommunications services with a single number and a single bill. DCS 1800 is also being deployed in East Asia and some South American countries. PCS 1900, a derivative of GSM for North America, is planned to cover a substantial area of the United States. All these systems will also enjoy a form of roaming, referred to as Subscriber Identity Module (SIM) roaming, between them and with all other GSM-based systems. A subscriber from any of these systems could access telecommunication services by using the SIM card in a handset suitable to the network from which coverage is provided. If the subscriber has a multiband phone, then one phone could be used worldwide. This globalization is making GSM and its derivatives the leading contenders to offer digital cellular and Personal Communications Services (PCS) worldwide. This book describes the emerging digital cellular communications and Personal Communications Networks (PCNs) being envisioned. It discusses the recent history of GSM technology that is being used to synthesize one version of PCN and delineates the alternative approaches being considered. The primary focus of this book is to discuss the past, present, and future evolution of the technical aspects of the GSM 900 system and its derivatives such as DCS 1800 and PCS 1900. The book describes GSM Phase 1 and Phase 2 and identifies major future trends. The book is divided in three parts. The first part covers the technical aspects of cellular communications that are used for GSM 900 and its derivatives. The second part describes the GSM system in detail. The third part of the book describes adjuncts to the GSM system and compares GSM with other cellular systems that use TDMA. Finally we examine the future trends of wireless systems and GSM. This book can be used by telecommunication managers engaged in managing GSM cellular/PCS networks with little or no technical background in GSM technologies; by practicing communication engineers involved in the design of the GSM cellular/PCS systems; and by senior/graduate students in electrical, telecommunication, or computer engineering planning to pursue a career as a telecommunication engineer. Since the deployment of GSM in Europe in the early 1990s, about a dozen books have been written to describe the GSM technology. Unfortunately, none of these books provide a total picture of the GSM technology and GSM networks. Some of these books focus on the radio aspects of the GSM, whereas others provide a simple high-level view of GSM networks but ignore important parameters of them. Also, most of these books are written with the assumption that a reader has been exposed to the telecommunications field and possesses adequate knowledge of fundamental disciplines such as traffic engineering and Signaling System 7 (SS7) upon which GSM is built. We use a different approach in this book by presenting a comprehensive treatment of the subject. We start from ground zero and first introduce basic principles essential to understanding any wireless technology. Next we discuss the GSM technology in depth and provide GSM architecture; radio link operations; logical channel structure and framing; speech coding; the physical, data link, and network layers; and the message flows between network elements. Since there is a worldwide explosion in wireless data communications, we present material on the GSM solution for wireless data. Security is an important feature in digital systems; therefore we cover the security methods used in GSM without revealing details that would compromise the system. We then cover modulation and radio propagation and use the knowledge to show how a GSM system is planned. We then describe the network aspects of the GSM network and provide a step-by-step procedure to size GSM network elements. We also discuss management of the GSM network based on the Telecommunications Management Network (TMN) approach. Finally we introduce the reader to traffic engineering and SS7. To make the book fully self-sufficient, we include the comparison of various wireless systems based on TDMA technology, and the low-mobility systems adjunct to GSM called Digital Enhanced Cordless Telephone (DECT). Finally, we conclude the book by providing a chapter on the future of wireless technology with a focus on GSM. We have written the book to satisfy the needs of the large technical community ranging from college students to practicing designers/engineers and managers. To satisfy the needs of students, we provide several numerical examples to illustrate the applications of formulas. On the other hand, we limit the use of advanced mathematical principles to make the book readable for practicing engineers and managers. For a GSM designer, we include enough design examples so

that the book can be used as a reference during the early design and planning phases of GSM networks. If this book is used as a textbook for teaching a two-semester course in wireless and GSM technology, we recommend covering chapters 1 through 8 during the first semester and chapters 9 to 15, and 20 during the second semester. For engineering managers, we recommend chapters 1-3, 5-7, 11, and 20, and for the practicing engineers/designers we suggest chapters 1-11, 14, 15, and 20. For those readers who are not exposed to the SS7 and teletraffic engineering, we recommend reading chapters 17 and 18. Throughout the book, we present material on GSM and on other radio systems that have evolved in parallel with GSM. By comparing the various systems, the reader can understand the advantages and disadvantages of GSM compared to other systems. In chapter 1 we describe first-generation analog cellular systems, second-generation digital cellular systems, emerging digital cellular communications, and PCNs being envisioned. Also discussed is the recent history of GSM technology. In chapter 2 we present standards for wireless communications. We discuss the European cordless systems--CT2, DECT, and others--and discuss the GSM standard developed by ETSI. We describe Universal Personal Telecommunication (UPT) based on the use of a Personal Telecommunication Number (PTN) and concentrate on IMT-2000 and Universal Mobile Telecommunications System (UMTS) standards. We also discuss the North American standards IS-54 and IS-95 and include the Japanese standards. Next we discuss, in chapter 3, the narrowband channelized and wideband nonchannelized systems for wireless communications. Our focus is on access technologies including FDMA, TDMA, and CDMA. We also present the concepts of the Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In chapter 4 the fundamentals of cellular communications are presented. The concept of cochannel interference for both omnidirectional and sectorized cell sites is studied. The cell splitting procedures used in cellular communications is also discussed. In chapter 5 we present an overview of GSM as described in the ETSI's recommendations. We describe the architecture and network interfaces of a GSM system. In chapter 6 we first describe radio link measurements in GSM and present the details of Adaptive Power Control (APC), Discontinuous Transmission (DTX), and Slow Frequency Hopping (SFH). The chapter also discusses future techniques (e.g., channel borrowing and smart antenna) that may be used in GSM to reduce interference and improve system performance. GSM has a rich set of logical channels that are used on the radio link. We devote chapter 7 to the discussion of these logical channels. They are used to carry user information and control signaling data. In chapter 8 we first discuss speech coding methods and attributes of speech codec. These are then followed by a brief discussion of the Linear-Prediction-based Analysis-by Synthesis (LPAS) and the ITU-T standards providing comparison of different codecs. In chapter 9 we discuss messages that are passed on the open interfaces in a GSM network. These interfaces are: mobile station to base station, base station to MSC and MSC to HLR and Visitor Location Register (VLR). Using these messages, we construct some typical call flows used on the GSM network. Chapter 10 describes the methods used to support data services in a GSM system. We examine the issues of interoperability with wireline data services. We then describe circuit-switched data services in GSM. Next we examine the Short Message Service (SMS) used to provide two-way paging capabilities in GSM. Finally, we examine the GSM Packet Radio Service (GPRS). In chapter 11 we concentrate on the security in GSM. We discuss the primary mechanisms used in the GSM system to achieve security--cryptographic security algorithms, SIM cards, and authentication procedures. In chapter 12 we study three modulation methods--Minimum Shift Keying (MSK), Gaussian Minimum Shift Keying (GMSK), and p/4 Differential Quadrature Phase Shift Keying (p/4-DQPSK). These modulation methods are used in GSM, DECT, and PWT. Many of the figures in chapter 12 were generated using Matlab 5, and useful information about the modulators can be obtained by studying the Matlab programs. Therefore we include Matlab source files used to generate the figures on the attached disk. A student version of Matlab is available from Prentice-Hall. In chapter 13 we discuss propagation and multipath characteristics of a radio wave. The concepts of delay spread, which causes channel dispersion and intersymbol interference, are also presented. In chapter 14 we first present the teletraffic models required in cellular/PCS network planning and design. We then provide an overview of the methods used for subscriber location management in the GSM system. We include a design example of the GSM system to illustrate a systematic procedure for determining

equipment needs in the system. In chapter 15 we present the traditional approaches to network management (NM). We then briefly introduce TMN concepts. We provide management requirements for wireless networks and focus on the platform-centered NM approaches by presenting two widely used network management approaches. Companions to cellular systems are wireless local loop phones and extended cordless phones. Chapter 16 describes DECT (and its U.S. equivalent PWT) that is used to provide voice and data services for wireless local loop and cordless phones as adjuncts to GSM systems. In chapter 17 we provide a brief overview of SS7 for the benefits of those of you who are not familiar with SS7. In chapter 18 we provide definitions of the terms often used in teletraffic engineering. Several numerical examples are provided to illustrate applications for calculating MSC traffic. We present the results of Erlang B traffic engineering for 1-100 servers in appendix A. We also provide a Windows 95 and Windows NT-4 program for calculating the offered load for any number of servers from 1-130 with an arbitrary selected blocking probability. In chapter 19 we focus on the three TDMA-based PCS/cellular systems (DAMPS-1900, DCS-1900/GSM 1900, and PDC) that have been deployed or are being deployed in North America and Japan. We compare these systems. In chapter 20 we examine the future of wireless communications and focus on the activities under way in ETSI for the next generation of wireless systems under the banner of IMT-2000. We would like to thank the many people who helped us prepare the material in this book. Bernard Goodwin provided his encouragement in motivating us to write the book. Professor Theodore Rappaport of Virginia Tech took us under the banner of his new series and also reviewed the manuscript. Our coworkers at Bellcore and Lucent have answered our many questions on GSM. Reed Fisher provided us with his insight on the future of wideband CDMA; Don Zelmer helped in obtaining information on the latest ETSI activities and reviewed the manuscript. Mike Loushine and Zygmond Turski provided reviews of the manuscript. Lois Wilkes read parts of the manuscript and improved our writing. We especially want to thank Peter Wilkes for preparing the list of abbreviations, and editing some of the files. We also thank Peter for his excellent work in writing the traffic engineering program for the supplied disk and the data in appendix A. We have included a disk of software with our book. While appendix A has a set of traffic tables, you may want to determine the number of servers for an arbitrary blocking probability and offered load. The Microsoft Windows-based program WErlangB provides that capability. A setup program can be found on the disk under the traffic directory. Double-click on Setup and the program will be installed on your hard disk with an icon established on the Start menu. The program runs under Windows NT-4 and Window 95. The chapter_12 directory on the included floppy disk contains the Matlab files for generating the signal and spectrum plots in chapter 12. The programs were generated in Matlab 5 on a Windows platform. If we need to update our m-files, we will use The Mathworks, Inc., web page. For additional information about Matlab please contact The MathWorks, Inc.
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August 1998

From the Back Cover

The first complete guide to designing GSM wireless systems!

GSM and its derivatives have become the world's #1 wireless technology, enabling users to roam across most of Europe, the Middle East, North Africa, East Asia, and even much of the U.S. -- all with one number and one bill. Principles & Applications of GSM is the first complete technical guide to this remarkable technology. Best-selling wireless experts Vijay K. Garg and J.E. Wilkes begin by introducing basic

principles that apply to any wireless technology. Next, they present GSM in depth, covering everything you need to know to design and implement a GSM system, including:

* GSM architecture.
* Radio link operations: APC, DTX, SFH, channel borrowing, and smart antennae.
* Logical channel structure and framing.
* Speech coding and Linear-Prediction based Analysis-by-Synthesis (LPAS).
* Physical, data link, and network layers.
* Message flows among mobile stations, base stations, MSCs, HLRs and VLRs.

Garg and Wilkes systematically address planning and sizing GSM wireless systems, managing GSM networks via TMN, and working with SS7 -- key issues often ignored in GSM texts. You'll find detailed coverage of modulation, along with valuable Matlab source files on diskette. The book's practical traffic engineering coverage is supplemented by powerful WErlangB Windows software for analyzing loads and blocking. There are detailed chapters on implementing wireless data and low-mobility adjuncts in a GSM network. You'll also learn how GSM achieves security via cryptographic algorithms, SIM cards and authentication. The authors present differences between GSM and other TDMA-based wireless technologies and close with a preview of next-generation wireless systems made possible by the UMT-2000 standards effort.

Whether you're a wireless communications engineer, faculty member or student, you won't find a more thorough, insightful guide to GSM wireless technology.

About the Author

VIJAY K. GARG is a Distinguished Member of Technical Staff at Lucent Technologies (formerly AT&T Bell Laboratories). His responsibilities include design of GSM-based systems, evaluation of the performance and capacity of mobile switching centers, and specification of operations system requirements for wireless networks.

J.E. WILKES was on the team that designed the world's first cellular system, and is principal author of the original EIA compatibility specification for cellular telephones. He is currently a Senior Research Scientist at Bellcore.

Users Review

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