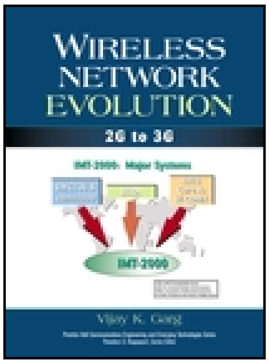
# Wireless Network Evolution: 2G to 3G, 1/e

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## Summary

For upper level undergraduate and graduate level Electrical, Telecommunications, and Computer Engineering courses that cover wireless network technology and its applications. The book is also essential as a reference by practicing telecommunication engineers involved in the design of cellular/PCS systems, as well as by telecommunication managers responsible for 3G systems, from the United States and Europe to developing countries.

The book provides a comprehensive introduction to the basic theory and fundamental technology behind wireless networks as well as the practical applications of that technology in real-world wireless networks.

## Features

- **Fundamental concepts and theoretical background behind code-division-multiple-access (CDMA)**—And the applications of CDMA technology to both cellular and PCS systems.
  - Provides a foundation for understanding the underlying mathematics of spread spectrum, as well as the related 3G wireless standards, while allowing the reader to apply the concepts to practical wireless systems.
- **Evolution of 2G systems to 3G systems.**
  - Introduces students to the wide range of third generation systems, interfaces and the underlying technology, as well as discussing the countries and continents that are employing which wireless systems.
- **Range of essential topics**—Such as wireless data (including CDMA packet data services), wireless local loop (WLL), Wireless Application Protocol (WAP), Wireless Local Area Network (WLAN), and Bluetooth.
  - Introduces students to the topics and technology essential to the design, development, and management of a modern wireless network.
- **Wireless network management, wireless network planning, and RF optimization.**
  - Introduces students to the practical real-world considerations that must be factored into the design, execution, and management of any wireless network.

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## Preface

# Preface

Although wireless data has not yet generated a huge market, it will become a primary force as service providers run out of cost-effective means to compete on price, coverage, and packaging of voice airtime. With the Internet and corporate intranets becoming essential parts to daily business activities, it is becoming increasingly advantageous to have wireless offices that can easily connect mobile users to their enterprises. The potential for technologies that deliver news and other business-related information directly to wireless handsets could also develop entirely new revenue streams for service providers. Since about 40 percent of mobile subscribers already carry cellular phones, these devices are uniquely positioned to integrate the incoming generation of mobile data applications. Integrated voice and data networks are the future for the fixed and wireless network operators. GSM and cdmaOne systems offer operators the opportunity to provide fully integrated networks.

GSM data services were planned from the beginning of the digital wireless communication system and offer many options similar to those offered over Integrated Service of Digital Network (ISDN). GSM data services include circuit-switched and packet-switched data. Circuit-switched data can be sent to an analog modem, an ISDN connection, or fax equipment. Packet-switched data connects to a packet network.

GSM short message service (SMS) allows the exchange of short alphanumeric messages between a mobile and the GSM system or between the cellular system and an external device capable of transmitting and optionally receiving short messages. GSM supports two types of short message services. The first type is the point-to-point service, in which a user sending a short message interacts with a short message entity (SME) in order to enter the message into system. The user can interact with the SME via e-mail, a phone call into an operator console that takes the message and enters it into the system, or by calling into a voice response system that accepts dual-tone multifrequency (DTMF) tones. The second type of service is the SMS call broadcast (SMSCB). In this service, multiple mobile stations are sending the same message via a broadcast message. The purpose of this service is to provide the same information to many mobile stations in the system at the same time. The information could consist of news or sports reports, stock data, and so forth.

Presently, data traffic on most of the GSM networks is modest, at less than 3 percent of total GSM traffic; some operators do not even bother to implement data facilities. However, with new initiatives planned during the course of next two to three years, exponential growth in data traffic is forecasted. Message-based applications may reach a penetration of up to 25 percent in developed markets by 2001, and 70 percent by 2003. GSM data transmission using high-speed circuit-switched data (HSCSD) and general packet radio service (GPRS) may reach a penetration of about 10 percent by 2001 and 25 percent by 2003.

Ushering faster data speeds into the mainstream will be 14.4 kbps and HSCSD protocols that approach wireline access speeds of up to 57.6 kbps using multiple 14.4-kbps time slots. The increase from 9.6 to 14.4 kbps is due to a nominal reduction in the error-correction overhead of GSM radio link protocol (RLP), allowing the freed bandwidth to be used for higher data streams. Implementation of v.42bis compression could double throughput.

Migration to HSCSD will bring data into the mainstream of GSM, and will be enabled in many cases by relatively standard software upgrades in base station and mobile switching center equipment. HSCSD will enable faster Web browsing, file downloads, mobile video conferencing and navigation, vertical applications, telemetry, and bandwidth-secure LAN access. Firmware on most current GSM PC cards will have to be upgraded.

The next phase in the high-speed roadmap will be the evolution of current SMS, such as smart messaging and unstructured supplementary service data (USSD), toward the new GPRS. The GPRS is a new radio service that uses TCP/IP or X.25 to offer data rates of up to 115 kbps. The GPRS extends the packet capabilities of GSM to higher data rates and longer messages. The service supports sending point-to-point and point-to-multipoint messages. The key factors in making GPRS a success are

- Cost-effective network deployment

- Billing and service support
- Application support
- User-friendly terminals

Two new nodes have been added to the GSM network to support GPRS. The serving GPRS support node (SGSN) communicates with mobile stations within its service area. The gateway GPRS support node (GGSN) communicates with packet networks that are external to the GSM network. Call setup via GPRS will be instantaneous and users will be charged only for actual packet data transmitted rather than for online time. GPRS will make it practical to transmit bursty e-mail and demanding multimedia applications over the GSM network through its very efficient use of the available radio spectrum and channels. GPRS terminals linked to laptops via a cable or Bluetooth device registered with a GSM network can simultaneously send and receive data packets, such as e-mail, and make and receive voice calls. This is because even during the busy hours, GSM time slots are free between the ongoing calls, which means that short GPRS packets will be able to get through when normal circuit-switched traffic would be blocked.

Although, GPRS can produce 115 kbps by using up to 8 GSM 14.4-kbps time slots, most phones will probably provide up to 56 kbps. The GPRS standard also defines a mechanism by which a mobile can request the amount of bandwidth it desires at the time of establishing a data session. The direct IP nature of the GPRS will in large measure also make wireless middleware unnecessary, as users contact directly into the IP of a carrier.

The next generation of data heading toward the third-generation (3G) and personal multimedia environments is known as Enhanced Data Rate for GSM Evolution (EDGE) or GSM++. It builds on GPRS and will allow GSM operators to use existing GSM radio bands to offer wireless multimedia IP-based services and applications at theoretical maximum speeds of 384 kbps, with a bit rate of 48 kbps per time slot, and up to 69.2 kbps per time slot with good radio conditions. EDGE will be relatively painless to implement and will require relatively small changes to network hardware and software since it uses the same time division multiple access (TDMA) frame structure, logical channel, and 200-kHz carrier bandwidth as GSM networks. As EDGE progresses towards coexistence with 3G W-CDMA, data rates of up to 2 Mbps could be available.

Although cdmaOne (15-95-based technology) started offering SMS and asynchronous data later than GSM networks, the two technologies are on the same timeline when it comes to high-speed data and packet data development. The faster speed is crucial to luring data users. From a marketing perspective of operators, high-speed data is important to customers. Although cdmaOne networks were not the first to offer data access, they are uniquely designed to accommodate data. To start with, cdmaOne networks handle data and voice transmission in much the same way. The cdmaOne's variable-rate transmission capability allows data rate determination to accommodate the amount of information being sent, so system resources are used only as needed. Since cdmaOne systems employ a packetized backbone for voice, packet data capabilities are already inherent in the hardware. Circuit-switched data capability up to 14.4 kbps was the first data communication technology available over cdmaOne, but considerable work has been done to offer packet data capability at over 14.4 kbps. The cdmaOne packet data uses a TCP/IP-compliant cellular digital packet data (CDPD) protocol stack to provide seamless connectivity with enterprise networks and expedite third-party application development. Data to cdmaOne networks allows an operator to continue using its existing radios, backhaul facilities, infrastructure, and handsets while merely implementing a software upgrade with interworking functionality.

The recent IS-95B upgrade allows for code or channel aggregation to provide data rates of 64-115 kbps, as well as offering improvements in soft handoffs and interfrequency hard handoffs. To achieve speeds of 115 kbps, up to eight CDMA traffic channels offering 14.4 kbps need to be aggregated. It is expected that operators will initially support data rates between 28.8 kbps and 57.6 kbps on the forward link to mobiles, and 14.4 kbps on the reverse link since mobile users generally receive more data than they send over the air. Looking further ahead, IS-95 (cdma2000 lX) may double the capacity of IS-95A, as well as provide a basic data rate of 24.4 kbps. IS-95C will provide ultrafast data of more than 1 Mbps using a dedicated data channel and separate base stations. This step will be close to 3G data speed. cdmaOne equipment manufactures have announced IS-707 packet data, circuit-switched data, and digital fax capabilities on their cdmaOne infrastructure equipment. Some equipment manufactures are also adding mobile IP, the proposed Internet standard for mobility, as an enhancement to basic packet data services. Mobile IP allows users to maintain a continuous data connection and retain a single IP address while traveling between base stations or roaming on other CDMA networks.

The International Telecommunications Union (ITU) began studies on globalization of personal communications in 1986 and identified the long-term spectrum requirements for future 3G mobile wireless telecommunications systems. In 1992, the ITU identified 230 MHz of spectrum in the 2-GHz band needed in order to implement the International Mobile Telecommunications 2000 (IMT-2000) system on a worldwide basis for satellite and terrestrial components. IMT-2000 capabilities include a wide range of voice, data, and multimedia services with quality equivalent or better than the fixed telecommunications networks in different radio environments. The aim of IMT-2000 is to provide a universal coverage that enables terminals to have seamless roaming across multiple networks. The ITU accepted the overall standardization responsibility of IMT-2000 with the aim to define a family of radio interfaces applied in different radio environments including indoor, outdoor, terrestrial, and satellite.

The 3G mobile telecommunications systems are expected to provide worldwide access and global roaming for a wide range of services. Standards bodies in Europe, Japan, and North America are trying to achieve harmonization on key and interrelated issues. These include radio interfaces, system evolution and backward compatibility, user's migration and global roaming, and phased introduction of mobile services and capabilities to support terminal mobility. The European Telecommunications Standards Institute's (ETSI) Universal Mobile Telecommunications System (UMTS) studies were carried out in parallel with IMT-2000 to harmonize its efforts with the ITU. In Japan and North America, the ARIB and TIA committee TR45 are carrying forward standardization efforts for 3G, respectively. Two partnership projects-3GPP and 3GPP2-are underway to achieve harmonization between various 3G regional standards.

In Europe, 3G systems will support a substantially wider and enhanced range of services as compared with 2G (GSM) systems. This enhancement will include high-speed data and multimedia services. These will be achieved through an evolutionary path using the GPRS and EDGE to capitalize on the investments for GSM systems in Europe.

In North America, the 3G wireless telecommunications system, cdma2000, has been proposed to the ITU. It meets most of the IMT-2000 requirements in indoor office, indoor-to-outdoor/pedestrian, and vehicular environments. In addition, the cdma2000 also satisfies the requirements for 3G evolution of 2G cdmaOne (TIA/EIA 95 family of standards).

In Japan, evolution of the GSM platform is planned for the IMT-2000 (3G) core network due to its flexibility and widespread use around the world. Smooth migration from GSM to IMT-2000 is planned. The service area of the 3G system will overlay with the existing 2G (PDC) system. The 3G system will connect and interwork with 2G systems through interworking functionality (IWF). IMT-2000 PDC dual-mode terminals as well as IMT-2000 single-mode terminals will be deployed.

Mobile telephony services and their tariff structures are likely to change substantially over next few years. Mobile tariffs will decline to the point where they are priced only slightly above fixed wireline services, and mobile communications will be the norm. The conventional view is that mobile operators will not be able to increase revenue per customer for simple voice services. However, additional spending for new applications will counterbalance the decline in average monthly bills. These new applications will include data communications and other related services to divert spending from fixed-network services.

Today's mobile use relates almost exclusively to voice telephony. Nonvoice communications will increase substantially and account for an ever-increasing share of total traffic. An increasing number of wireless smart telephones and other wireless data connections will facilitate this condition. The UMTS Forum predicts that by 2005 nonvoice usage will exceed voice usage over mobile communications devices in Europe. Analysis by Nokia shows that a GSM operator pursuing an aggressive strategy on wireless data would be able to generate about 20 to 30 percent of its revenue from new services by 2001. High-speed circuit-switched data over cellular telephony will play a significant role; packet-oriented transport may be far more important, meaning that pricing will have to incorporate aspects of bandwidth and quality of service (QoS). Other components will be usage related to the volume of data and QoS. Bundled-up tariffs with a low marginal per-minute cost are closer to this concept than traditional mobile tariffs.

Since the deployment of wireless communications in early 1990s, about three dozen books have been written to describe wireless technologies. Unfortunately, none of these books address wireless data technologies in great detail. Some of these books provide a high-level view of wireless data. Moreover, these books assume that the reader is exposed to the data communications field and possesses adequate knowledge of fundamental disciplines such as the open system interconnect (OSI) model, channel capacity, data link, and other higher level protocols.

Soon, wireless data communications will see a worldwide explosion with the introduction of 3G systems. The motivation for writing this book is to present a comprehensive treatment of the subject. Starting at ground zero, the reader is first introduced to basic principles that are essential to an understanding of the 2G wireless systems. Mobile data communication services that have been used for TDMA/CDMA-based air interfaces are then discussed. Details of network architecture; logical channel structure; framing; channel coding; radio link operations; physical, data link, and network layers; and messages flow between the various layers are also provided. Management of a wireless network and highlights of the 3G data services for the UTRA/W-CDMA, cdma2000, GPRS, and EDGE networks are also discussed. I also focus on the network aspects and present evolutionary paths for 2G networks to 3G.

This book has been divided into three parts. Part I addresses the basics of 2G wireless technologies (particularly cdma0ne). Part II focuses on 3G air interfaces (UTRA/W-CDMA, cdma2000) and provides details for the evolution of TDMA-based GSM and IS-136 networks. Part III concentrates on the network aspects of wireless networking, including network management, network planning, and network optimization. This book can be used by practicing telecommunications engineers involved in the design of 3G networks, as well as by senior or graduate students in electrical engineering, telecommunication engineering, computer engineering, and computer science curricula.

This book can be adapted for two courses in the CDMA and 3G technologies. For the first semester course in the CDMA technology, I recommend using Chapters 1-10, 18, and 19. The second semester course in the 3G technologies should include Chapters 11-17 and 20.