Mobile VPN: Delivering Advanced Services in Next Generation Wireless Systems

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Wiley Publishing, Inc.
Alex Shneyderman:
To my wife Olga, who has truly become my (better) half, and to our first ten
years together; to my son Mark, who will not need to know about the com-
plexity of the high-tech world around him (unless he chooses daddy’s
path); and to my parents for being there for me.

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To my wife Lina Maria, who helped me throughout this effort with her
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Mobility and security are becoming dominant themes in the Internet of the new millennium. These factors present many challenges and many opportunities for healthy growth of the Internet. Mobility heightens the need for security, just as it brings into sharp focus the need for applying other technologies like service discovery, location management, tunneling, and remote data management. Taken together, these technologies represent a fundamental restructuring of previous approaches for continued growth of the Internet.

Tunneling alone is powerful enough to effect such a restructuring, but network designers rarely create solutions that involve pure tunneling. Instead, the tunnel management is equipped with many and sundry techniques for deciding when to enable, start, and stop the use of the tunnel. All of these techniques amount to an expression of some policies, which are motivated by the problem that the tunneling solution is intended to solve. Two very prominent tunneling policy regimes are Mobile IP and VPNs. The former is intended to create useful routes so that data can be delivered to whatever foreign domain the mobile node should visit. The latter is supposed to create useful routes so that data can be delivered securely to whatever foreign domain at which a portable device may become situated at.

When portable devices become wireless, they (and their users!) become much more mobile. Soon, traditional methods for managing VPNs will be viewed as inadequate. Mobility techniques, perhaps those derived from Mobile IP, or Mobile IP itself, will be adapted to fulfill the needs of devices whose communications are protected by VPNs. This will create the Mobile VPNs described in this book.
I believe this book will help the practitioner understand the many related wireless, mobility management, and security technologies that can be used to create MVPNs. Undoubtedly, there will be many ideas for solutions, depending on the background and goals of the designers. And yet, security is very tricky, so care and study are crucial for success.

Nothing beats experience, and it is important to learn from the experiences of others, understanding why their solutions succeeded or failed. Moreover, vendors for existing products that are related to MVPNs will surely try to take advantage of opportunities for extending their product lifetimes. Thus, we are likely to see many different variations upon the technologies and themes presented in this book.

My own work with Mobile IP has given me the opportunity to meet and work with Alessio Casati and Alex Shneyderman. Alessio and I made an initial effort to make more tunneling tools available to Mobile IP, namely GTP, the tunneling mechanism of choice within GPRS domains. That was after I had grown to enjoy Alessio’s forthright assessments of various developments on the IETF mobile-ip mailing list. That same spirit of forthright assessment and technical presentation will make this book accessible and valuable for the many readers interested in solutions providing mobility and security. I wish them, and this book, the best of luck to find that readership.

Charles E. Perkins
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“Alice came to a fork in the road. ‘Which road do I take?’ she asked. ‘Where do you want to go?’ responded the Cheshire cat. ‘I don’t know,’ Alice answered. ‘Then,’ said the cat, ‘it doesn’t matter.’”

Lewis Carroll, Alice in Wonderland

In June 2002 the worldwide number of wireless subscribers finally reached a long anticipated 1 billion, beating even the most optimistic analyst’s estimates by almost a year. The growth rate of Internet hosts is not far behind, pushing 200 million at the time of this book’s publication. The important conclusions, however, can be drawn from the percentage of total wireless users who are also using the Internet. According to the latest analyst’s research, close to 80 percent of Internet users are also cellular wireless subscribers, and the percentage of business users for both is about 40 percent.

Not surprisingly, there is a growing interest in wireless data for both commercial and residential applications—especially in the context of the next generation systems such as CDMA2000, GPRS, UMTS, EDGE, and WLAN. One of the most prominent recent trends in commercial landline data communications is the use of virtual private networking (VPN) to gain secure connection to remote private networks over public shared infrastructures such as Internet. The obvious next step is to apply the benefits of landline VPN technologies to mobile environments, creating Mobile Virtual Private Networks (MVPNs) that allow secure pervasive private communications over a variety of shared mobile networks offered by wireless operators and wireless Internet service providers (WISPs).
What This Book Is About

We are at the stage in the wireless data communications life cycle when most of its underlying technologies have reached maturity or at least have stabilized in standards. Third-generation wireless systems, which defined new services and provided high-speed data and multimedia support, have been standardized and are being rapidly deployed all over the world (albeit with some expected early-growth problems, unfortunately, perversely associated to financial issues due to unprecedented financial speculation and overexcitement around new technologies at the end of the past millennium). All of these systems include support for packet-switched data communications, as opposed to their predecessors, which relied on circuit-switched technologies. The important aspects of these systems include not only the potentially higher throughput, which is often relatively modest during initial rollouts and under certain circumstances, but also availability, always-on capabilities, higher efficiency, and a strong foundation for the delivery of new services. Packet data (covered in Chapter 4), effectively brought wireless networks one step closer—in functionality, throughput, and resource utilization—to wireline data networks while preserving and enhancing one of its most important features of wireless communications: mobility.

Additionally, advancements in virtual private networking technologies allowed the easy use of public shared wireline infrastructures such as the Internet to securely transmit private data traffic, thus extending the reach of private networks by allowing remote users to connect to remote resources, information, and services. These advancements have mainly occurred in the past 3 years, so we believe now is the best time to come up with a comprehensive guide on the subject that would allow the reader to study it on any desired level of complexity and perhaps help in addressing research and development efforts in the most appropriate direction.

The focus of the book is remote access to private networks in the wireless environment achieved by the use of technology called Mobile Virtual Private Networking. Most of the discussion is centered on the second- and third-generation cellular systems—supporting packet-switched data communications—and Wireless LANs. These systems, including CDMA2000, GPRS, and UMTS, are being deployed at this writing and are expected to proliferate throughout the world during the next few years. With this text we strived to provide a comprehensive guide on the subject complete with background on both wireline data and cellular wireless communications. The book touches on special topics such as support for Mobile VPN over
integrated cellular/WLAN infrastructures and the support of advanced Mobile IP services. In the second part of the book we introduced a new approach to classification of VPN and other private network access methods used in GPRS, UMTS, and CDMA2000 and discussed a variety of other complex issues in the field of wireless data. We supplemented the material with a healthy amount of practical network design scenarios and real-life examples (specifically in Chapters 6, 7, and 9). The book also provides a look at the open issues and future trends in wireless data communications in general and at private network access over untethered medium in particular.

How This Book Is Organized

The book is structured in two main sections. Part One provides necessary background material to prepare you for the discussion on MVPN, such as an overview of related standard bodies, a practical guide to standard documentations, and a discussion of the current state of standardization in the area of wireless data. The second part focuses on the subject at hand—Mobile VPN—and other topics pertinent to providing advanced packet data services in mobile environments.

Chapter 1 introduces the mobile VPN business case and the MVPN market segment, and it gives you an overview of the wireless standardization process and a brief “standard document retrieval manual” template. Here we also provide the explanation of standards organizations’ hierarchy, timelines, and milestones, as well as the organizations’ involvement with particular technologies and systems. Chapter 2 provides a tutorial on relevant topics in data networking and communications, such as MPLS and IP security, while Chapters 3 and 4 discuss radio interface fundamentals and details of various cellular systems of interest, as well as background information on both circuit- and packet-switched wireless data provided within second- and third-generation systems frameworks.

Part Two provides an in-depth discussion of VPN support in the mobile environment, and it contains useful information about how wireless data and specific IP services are supported in current and next-generation cellular wireless systems, such as various flavors of CDMA2000, GPRS, and UMTS. In Chapter 5, we transition from wireless to Mobile VPN (MVPN), while providing a discussion on the VPN taxonomies, underlying technologies, tunneling and security issues, and other VPN building blocks. Chapter 6 focuses on the properties of MVPN provided in GSM and UMTS cellular systems, while Chapter 7 covers MVPN services in the CDMA2000
family of systems. Chapter 8 briefly analyzes main types of the equipment involved in Mobile VPNs. Chapter 9 concludes the book by looking at future trends and forward-looking topics such as cellular/WLAN integration issues, Mobile VPN in converged networking environments, and services provided by Mobile Virtual Network Operators (MVNOs).

This book also includes appendixes with specific information about Mobile IP extensions and RADIUS attributes and a Bibliography that lists books and standard documents containing additional material on a variety of related subjects. We believe the resulting structure should provide a sufficient foundation to follow the discussion in the second half of the book, even for the readers with limited background in wireless and data communications.

**Who Should Read This Book**

While this book provides an ample tutorial of wireline data and wireless communications, we did not want to write yet another book on data communications or the basics of cellular wireless systems. *Mobile VPN: Delivering Advanced Services in Next-Generation Wireless Systems* covers only relevant topics and disciplines comprising Mobile VPN and other advanced wireless data service. Consequently, this book requires a reader to have basic education in computer science and electrical engineering. We also assume you have some exposure to the basics of data communications and cellular wireless concepts, as well as an understanding of OSI model and TCP/IP, and link layer technologies such as PPP, ATM, and Frame Relay.

Reading this book does not require a previous understanding of IP tunneling, wireless data communications, Wireless LAN fundamentals (although knowledge of regular LAN technology is still required), VPN concepts, data networking security, or next-generation cellular systems and services taxonomies. Those readers with a good understanding of these and other related technologies will find in-depth discussions on these and other related subjects especially useful. Sometimes even familiar and well-studied and documented subjects are presented in a new light of application to wireless and mobile VPN.

We tried to make this book useful for a wide audience of professionals and students in wireline and wireless data communications and networking, as well as representatives from other professions, such as investors and financial analysts wishing to gain proficiency in this subject. In particular: Chapters 6, 7, discussing the implementation of Mobile VPNs within
particular wireless systems, and Chapter 9, discussing the future directions of wireless data services, offer comprehensive case studies and real-life examples of virtual private network deployments and address practical network design issues such as IP addressing strategies, VPN optimization methods, and practical wireless IP security. This makes this book especially useful to both wireless and wireline data network architects, IT managers, network administrators, and even corporate security officers involved in implementing of real-life systems.

Engineers and product managers involved into implementation and definition of products supporting MVPN functionalities will benefit from our in-depth descriptions of the functionalities of various elements required in next-generation cellular and WLAN systems to offer MVPN services. The analysis of business issues and future trends of MVPN field provided in the first and last chapters should be of special interest to product managers and other professional involved in the product feature decision making and market forecasting.

**From Here**

We believe that wireless data services and Mobile VPN in particular have a great potential to not only improve business productivity and give services providers new revenue opportunities, but also offers significant improvements in our everyday lives. The successful deployment of complex third-generation wireless data systems and services like Mobile VPNs will entirely rest on the shoulders of thousand of professionals in the fields of wireless and data communications, as well as the next generation of engineers and managers completing their studies. With their help, new and exciting products will be rolled out by equipment manufacturers and new services will be offered by operators. We hope this book will help this group in both understanding of the technology and its application and practical deployment to bring the progress in wireless communication to a new level and continue the remarkable run it has enjoyed for the last two decades.

After all, unlike Alice and the Cheshire cat, we believe that it does matter which way you choose. There are many forks on the road of wireless communications and we hope that this book will not only help the readers to decide where they want to go, but also guide them through many difficult turns.
PART One

Wireless Data Fundamentals
Contracting margins and revenues per user, cost-based competition, and focus on customer retention rather than acquisitions are all signs that mobile telephony is not likely to show significant revenue growth—comparable to that enjoyed over the past decade—over the next several years. Service providers are therefore forced to look for innovative ways to invest in new technologies, which can potentially become the next growth enablers. For instance, in recent years much attention has been paid to “mobile Internet” services, which are believed to pose a significant revenue-generation potential for service providers.

This belief was in part responsible for the massive investment in spectrum for next-generation radio access technologies, with the potential to support higher data rates for mobile Internet services, commonly known as third generation (3G). More recently, service providers have recognized that Internet access per se may not justify the significant investments they made. As a result, the search is back on for innovative ways to generate revenues by using the new service capabilities offered by the deployment of packet-data-based systems such as General Packet Radio Service (GPRS), Universal Mobile Telecommunication System (UMTS), or CDMA2000 (CDMA stands for Code Division Multiple Access). So far, it is
Chapter 1

apparent that the most promising kind of services mix traditional mobile voice capabilities and new location-based and messaging services. Such systems must provide users personalized and predictable access to private networks where they can belong to communities of interest for both business and leisure, such as corporate networks or instant messaging groups.

The value of such networks to the customers appears to be strictly related to:

- Ensuring secure network access with predictable performance
- Making sure that access to such networks is exclusive to members with appropriate permissions.

These service requirements are compelling service providers to use Mobile Virtual Private Networking (MVPN), which we define as the emulation of private secure mobile data networks over generally insecure shared mobile and wireless facilities. This definition is based on a number of assumptions:

- Data user mobility is defined as uninterrupted connectivity or the ability to stay connected and communicate to a possibly remote data network while changing the network access medium or points of attachment.
- Despite MVPN service is usually provided over wireless media, and in fact, this book is written about VPN implementation over various wireless access systems. We make clear distinction between “mobile” and “wireless,” since these terms have different meanings and we believe that for our purposes “mobile” is more accurate and inclusive (see Chapter 5 for more discussion on wireless versus mobile).
- The term “wireless facilities” refers to current and future generations of cellular systems of interest such as Global System for Mobile Communications (GSM), CDMA2000, Time Division Multiple Access (TDMA), and UMTS, wireless networks such as Wireless LANs (WLANs), and overlay wireless packet data systems such as GPRS.

A simple visualization of MVPN can be found in Figure 1.1, which shows secure tunnels connecting a mobile device with a variety of private networks over multiple shared public networks, such as the Internet and an arbitrary cellular wireless system or WLAN network.
In this chapter we concentrate on business and standardization issues as an introduction to topics addressed in the rest of the book. The first half of this chapter discusses the MVPN business case and marketplace, explaining what benefits this technology can bring to service providers and their customers. We start with the discussion of pervasive mobility and its consequences, moving on to MVPN history and business case. The section ends with an overview of MVPN market segments and stakeholders. The second half of the chapter examines the current wireless data standardization status and trends and provides the reader with a reference to the standard documents usage and retrieval from various standard body repositories. The reader will become familiar with standards organizations such as 3GPP, 3GPP2, and the Internet Engineering Task Force (IETF), along with their standardization processes. An understanding of what a given standard body does within the landscape of mobile networking will be helpful to the reader for the remainder of the book.

**The Era of Pervasive Mobility**

We are fortunate to be witnessing the beginning of an era of pervasive mobility, when access to information resources will not be determined by the availability or type of network access technology but rather by factors such as the desire, necessity, and eligibility to obtain information or services. Information and services will be requested and accessed not only by individuals but also by virtual and physical entities such as automated
manufacturing processes, “smart” vending machines, information-collecting devices such as utility meters, intelligent cash registers, highway toll stations, security systems, and medical equipment. (See Chapter 9 for some anticipated next-generation services scenarios.) Remote network access service characteristics will not be dependent on geographical location, but rather on the existence of proper roaming and service agreements between home and visited data networks, allowing for home service profile retrieval into foreign networks. When proper agreements are in place, mobile entities or individuals will be able to receive services identical to those available in their “home” networking environments while roaming foreign networks.

Pervasive Mobility Drivers

So what drives the need for pervasive mobility, or permanently available uninterrupted on-demand connectivity? The most important drivers are productivity gains via advancing IT technology, the rise of the Internet, the ever-increasing speed of evolution of mobile devices, cellular and noncellular network coverage, and plummeting costs of cellular wireless service.

Increase in Productivity

The changing role of information technology in corporations and institutions throughout the world was responsible for major productivity gains in the workplace during the last decade of the twentieth century. That was, of course, accompanied by the rise of the Internet, which brought together masses of information and united disparate communities of interest all over the world. However, massive computerization also brought total dependence on computing and information resources often available only at a limited number of select locations, such as corporate headquarters or data centers. The newly available services, so indispensable to users in their offices, are more and more often requested from remote locations such as satellite or home offices, customer sites, and from the road. These needs in turn drive demand for global network roaming and ubiquitous remote network access. The uncertainty of the location where the user will require access imposes the need for mobile (dynamic) private connectivity to the home network to be available throughout a wide area (also referred to as ubiquitous access).