WiMax Operator's Manual

Building 802.16 Wireless Networks (Second Edition)

Daniel Sweeney

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This book is dedicated to my wife.

Contents at a Glance

About the Author xiii
About the Technical Reviewer xv
Preface xvii
Introduction xix

CHAPTER 1 Wireless Broadband and the Standards Governing It 1
CHAPTER 2 Architecting the Network to Fit the Business Model 13
CHAPTER 3 Strategic Planning of Spectrum and Services 33
CHAPTER 4 Setting Up Physical Infrastructure 63
CHAPTER 5 Strategies for Successful Deployment of Physical Infrastructures 101
CHAPTER 6 Beyond Access 131
CHAPTER 7 Service Deployments over Public Wireless MANs 153
CHAPTER 8 Network Management and OSS 177
CHAPTER 9 Network Security 187

INDEX 195

Contents

About the Author xiii
About the Technical Reviewer xv
Preface xvii
Introduction xix

CHAPTER 1 **Wireless Broadband and the Standards Governing It** 1

Defining Wireless Broadband 1
Introducing the 802.16 Standard 2
Introducing the Media Access Control Layer 3
Introducing the Two Physical Standards 4
Introducing WiMAX 5
Introducing Other Wireless Broadband Standards 5
Deploying Within Urban, Suburban, and Rural Environments 8
Examining the Maturity of the Technology 10

CHAPTER 2 **Architecting the Network to Fit the Business Model** 13

Broadband Fixed Wireless: The Competitive Context 13
Circuit-Based Access Technologies 14
Frame Relay 15
DSL 16
Hybrid Fiber Coax 18
Wireless Broadband 20
Determining When Broadband Wireless Is Cost Effective 23
Total Cost of Ownership 24
How Scalable? 26
Service Delivery and Broadband Wireless 27
Subscriber Density 28
Local Topography and the Type and Distribution of Man-Made Structures 30
Speed of Deployment 31
Independence from Incumbents 31
Making a Final Determination 32

CHAPTER 3 **Strategic Planning of Spectrum and Services** 33

Selecting the Appropriate Spectrum to Meet the Requirements of the Targeted Customers: Propagation Characteristics Across the Radio Spectrum 34
Overview of Commercial Radio Spectrum Suitable for Broadband Data Applications 34
- Beachfront Property: The Lower Microwave Frequencies 35
- Millimeter Microwave: Bandwidth at a Price 36
- Submillimeter Microwave: Tending Toward Light. 39
- Free-Space Optics: Wireless Without the Radio 40
- RF Orphans: The Low ISM Band and Ultrawideband 41

Licensed vs. Unlicensed Spectrum: The Operator’s Dilemma 42
- The Unlicensed Frequencies: A Matter of Peaceful Coexistence . . 42
- Licensed Spectrum. 45

Different Uses for Different Frequencies 47
- Lower Microwave: Primarily a Residential and Small Business Play 47
- Addressing the Bandwidth Problem in the Lower Microwave Regions 48
- Looking at the Range of Services 50
- Higher Microwave: Abundant Throughput Speed but Fewer Applications 58

Looking to the Future: The Importance of a Service Orientation 62

CHAPTER 4 **Setting Up Physical Infrastructure** 63

Looking at the Nuts and Bolts: The Issue of Carrier-Grade Infrastructure Equipment 63
Obtaining Roof Rights, Right of Way, and Access to Appropriate Buildings at Acceptable Cost 65
- Central Office and Main Base Station Facilities. 65
- Additional Base Stations 71
- Backhaul 72

Determining Basic Network Architecture 79
- Point-to-Multipoint 79
- Point-to-Point 80
- Point-to-Consecutive Point 81
- Mesh 81

Performing Site Surveys and Determining Link Budgets 86
Determining Line of Sight and Computing Fresnel Zones 88
RF Analysis 89
Analyzing the Data Stream 91
Establishing the Link Budget. 91
Examining the Equipment Selection Process 92
Generalities 92
Service-Related Specifics 93
Integrating Wireless with Wireline Infrastructure 94
Assembling the Management and Technical Teams 95
Estimating Operating and Capital Budgets 96
Examining Return on Investment for Wireless Broadband Networks. . . . 99
Putting Strategic Planning in Perspective 100

CHAPTER 5 Strategies for Successful Deployment of Physical Infrastructures 101

Selecting an Appropriate Network Topology. 101
Deploying Minority Architectures 101
Deeper into Point-to-Multipoint. 102
Principles of Frequency Reuse and the Technologies for Achieving It . . . 108
Use of Repeaters. 108
Sectorization 109
Polarization Diversity 110
Cell Splitting 111
Line of Sight and Non–Line of Sight. 112
Adaptive Modulation and Cell Planning. 122
Frequency-Agile Radios and Network Mapping 122
The Installation Process 123
Frequency Converters, RF Amplifiers, Integrated Radio/Antennas, and Radio Modems 123
Signal Distribution Within the Subscriber Premises 124
Infrastructure for a Purpose 128

CHAPTER 6 Beyond Access 131

The Place of the Central Office in the Business Case 131
The Role of the Central Office 131
Application-Specific Equipment for the Central Office 141
OSS and Network Management 146
Security Devices and Appliances 146

Beyond the Central Office 147
Broadband Wireless Networks in the Larger Context: Connecting to Other Service Providers 148
The Central Office As War Room 152

CHAPTER 7 Service Deployments over Public Wireless MANs 153

Introducing the Pure Packet Services Model 153
The Packet Model and Converged Services 154
Introducing Basic Access and Best-Effort Delivery 155
Moving Beyond Basic Access: VPNs and LAN Extension. 157
Types of VPN and the Role of Network Operator in Administering Them 158
Applications Requiring Quality of Service 162
Marketing QoS Through Service-Level Agreements. 164
Achieving QoS in Broadband Wireless Packet Networks 165
802.16 Provisions for QoS 165
Major Networking Standards for Supporting IP QoS. 166
Other Methods for Supporting QoS. 168
Where QoS Matters Most. 170
Enabling Storage Services. 174
Getting a Services Perspective. 175

CHAPTER 8 Network Management and OSS 177

OSS: A Definition 177
OSS in Perspective. 178
The Anatomy of OSS 179
OSS for the Network Infrastructure 179
OSS for Customer Relations and Transactions 180
OSS Software Integration 183
Protocols for Software Integration 183
OSS Application Interfaces 184
Summation: The Well-Managed Network. 185

CHAPTER 9 Network Security 187

Security Policies. 187
Secure Electrical Systems 188

Cyberwarfare 189
Attacks and Counterattacks. 190
Cybersecurity Technology 191
Safeguarding Network Elements from Hijacking and
Malicious Code: Best Practices 192
Denial-of-Service Attacks: A Special Case 192
CALEA and Other Regulatory Burdens 193
Network Security: Business Overhead or Another Profit Center 194

INDEX 277

About the Author

DANIEL SWEENEY is a technical writer, business reporter, and industry analyst. He has written thousands of articles and several analyst reports. He covers telecommunications, consumer electronics, energy, and the history of technology, with occasional forays into military technology, artificial intelligence, and geology. He has written for leading trade journals in telecommunications and both trade and consumer journals in consumer electronics. In the past he worked as a common laborer, a labor organizer, and a government bureaucrat who compiled mind-numbing statistical reports. He is married and lives in the vicinity of a toxic waste dump (seriously).

About the Technical Reviewer

ROBERT HOSKINS is the publisher and editor of Broadband Wireless Exchange, the leading online publication in the field, and is a former Sprint executive responsible for managing what is still the largest and most successful broadband wireless deployment in the United States.

Preface

The second edition of *WiMax Operator's Manual* includes most of the material from the first edition, plus new discussions of

- The ultra-high-speed mobile telephone standard, HSDPA
- Ultrawideband (UWB)
- Changes to DSL technologies
- Mobile voice
- Mobile entertainment
- New backup systems

The new edition also reflects the changes that have occurred in the industry over the last year and half, including the emergence of prestandards wireless broadband equipment with fully developed mobile capabilities, significant alterations in the competitive landscape, and the opening of valuable new spectrum for broadband wireless operators.

Public broadband wireless data networks represent a truly disruptive technology, one that promises to break the monopolistic and oligopolistic status quo that still represents the norm in high-speed access today. Products that would enable such networks have existed for a number of years and in fact have been deployed in thousands of commercial systems throughout the world, but the lack of standards, the limited production volumes, and the consequent high prices have prevented the full potential of wireless broadband from being realized. Now, with the coming of a widely accepted industry standard, IEEE 802.16, and the introduction of microchips based on that standard by leading semiconductor companies, wireless broadband public networks are becoming mainstream.

Working as a journalist, analyst, and consultant in the field of telecommunications, I have been covering wireless broadband extensively since 1990, before public networks even emerged, and I've witnessed the steady progress of the technology as well as the many false starts of the wireless broadband industry. And for the first time I can report with some confidence that wireless broadband is ready to compete in the marketplace.

As in the past, wireless will continue to attract entrepreneurs—in many cases, entrepreneurs lacking in experience in either telecommunications or radio frequency electronics. Such individuals will face a "steep learning curve" and will have to acquire working knowledge in both areas in order to stand a chance of succeeding. It is my hope that this book, based on dozens of case histories and my own considerable experience in both fields, will provide such individuals with a wireless broadband survival kit.

Introduction

Broadband wireless has long held the promise of delivering a wide range of data and information services to business and residential customers quickly and cost-effectively. Unfortunately, that promise has been imperfectly met in the past because of both the immaturity of the existing technologies and the relatively high cost of networking equipment. With the publication of a comprehensive industry standard—namely, IEEE 802.16—representing a distillation of the most advanced technology and an industry consensus permitting equipment interoperability, broadband wireless has gained the maturity it lacked and is truly ready for utilization within metropolitan networks.

The first chips adhering in full to the 802.16 standard have begun to be shipped by a number of semiconductor manufacturers. Some time will pass before such chips appear in assembled systems and before they are certified for standards compliance and interoperability, but even now broadband wireless can be said to be approaching the stage of early maturity. Such developments will provide the basis for broadband wireless establishing a real competitive presence in the marketplace, something it has never enjoyed in the past.

This book provides the background in broadband wireless fundamentals, packet data, and overall network operation and management to enable a network operator to set up a network with standards-based equipment and to run it profitably thereafter. It is an operational handbook rather than an engineering text, and it is highly practical rather than theoretical. Technical discussions that occur are always in reference to addressing the real-world problems involved in running a network and serving the customer base. There are no tutorials on radio frequency propagation or digital modulation techniques; rather, the emphasis is on using technology to deliver specific services to specific types of customers.

Broadband wireless as a last-mile access technology is a fairly recent phenomenon, and most of the success stories are recent. Not a lot of standard procedures are extant in the marketplace for operating a network successfully, and not a lot of network executives and managers have a deep knowledge of broadband wireless. And scarcely any texts at all provide compendia of facts and analysis on the subject. This book meets a real need for a concise summary source of information.

Broadband wireless at this point still represents a divergent, even disruptive, technology, and wireline solutions such as fiber optics, hybrid fiber coax, and digital subscriber line (DSL) constitute the mainstream. For this reason, a great many of broadband wireless ventures to date have been highly speculative and entrepreneurial, with many of the pioneers painfully attempting to find their way even as their networks were in the process of being built. This book serves as a guide for present and future entrepreneurs and is intended to assist them in avoiding the experiments and false starts that proved so frustrating for the pioneers.

Since this book is utilitarian rather than highly conceptual, it does not constitute the sum of all information relating to broadband wireless networks. What this text contains is a body of immediately practical knowledge—what to do and how to do it. And perhaps most important, it explains who the appropriate professionals and technicians are to retain when initiating and maintaining a broadband wireless network. The book presents such knowledge from a business perspective with a just consideration of likely costs and payoffs and with the caveat that almost any decision made in regard to the network is provisional and ultimately dependent on the changing nature of the customer base, the regulatory environment, the financial markets, the competitive atmosphere, and of course ongoing advances in technology.

Tremendous strides have been made in digital radio technology over the course of the last decade, culminating in the 802.16 standard, and wireless has emerged as viable broadband access technology where it was marginal at best as recently as four years ago. In many instances, wireless broadband is the preferred access technology, offering the best cost/performance ratio, time to market, and service velocity. Still, it does not always enjoy a competitive advantage, and in many markets a broadband wireless solution may be suboptimal or even ill advised. The physical layer is but one part of the service network, and insisting on wireless for its own sake while ignoring overall network architecture makes little sense. The physical layer, the access layer, and all the intervening layers ultimately support the topmost layer (namely, applications), and the issue that must always be uppermost in the mind of the network operator is how the applications and services wanted by subscribers can be delivered most cost effectively. If the answer includes a wireless physical link, then a complete perusal of the contents of this book is indicated. If the answer is otherwise, then Chapters 1 and 2 will provide all of the information one needs.

Finally, it should be understood that wireless can and often is used in piecemeal fashion to extend wireline infrastructure, and following such a course is not at all illegitimate or even ad hoc. Nothing is particularly admirable about purism in terms of wireless technology, and if wireline technologies serve the same purpose better over some portion of the network footprint, then wise network operators will avail themselves of them.

Unfortunately, no department of broadband wireless administration exists in any university of which I am aware. Such knowledge as I have obtained has been from various scattered engineering texts and from those individuals who have developed the products and procedures and have overseen the implementation of the first successful networks. Their names are legion, and I cannot thank all of them, but I will mention the following individuals who have taught me much: Bill Frezza of Adams Venture Capital, Craig Matthias of the FarPoint Group, Doug Lockie of Endwave Corporation, and Keith Reid of Cisco Systems. Any inaccuracies in this text must be laid to my account and not to any of them.

CHAPTER 1

Wireless Broadband and the Standards Governing It

This book focuses on standards-based public broadband wireless networks operated on a per-profit basis. In the past many broadband wireless networks utilizing equipment not based on standards or utilizing equipment based on wireless local area network (WLAN) standards have been launched only to fail within a short period. The emergence of standards-based equipment stemming from the specific needs of the public service provider marks a momentous change in the broadband marketplace and will enable wireless networks to take their place beside successful wireline services such as optical fiber networks, digital subscriber line (DSL), and cable. The appearance of such equipment will also enable the network operator to generate consistent revenues and to attract and retain valued customers, provided, that is, that the operator understands both the strengths and the limitations of the technology and comprehends how to run a network in a businesslike manner.

Defining Wireless Broadband

The term *wireless broadband* generally refers to high-speed (minimally, several hundred kilobits per second) data transmissions occurring within an infrastructure of more or less fixed points, including both stationary subscriber terminals and service provider base stations (which themselves constitute the hubs of the network). This is distinct from mobile data transmissions where the subscriber can expect to access the network while in transit and where only the network operator's base stations occupy fixed locations. You can expect that this distinction will become somewhat blurred in the future inasmuch as several manufacturers are developing very high-speed wireless networking equipment that will support mobility or stationary usage almost equally well, but the emphasis of high-speed wireless service providers serving stationary subscribers will remain. Broadband wireless, as it is today, is properly a competitor to optical fiber, hybrid fiber coax (the physical infrastructure of most cable television plants), DSL, and, to a much lesser extent, broadband satellite.

Third-generation (3G) and 2.5G cellular telephone networks, which have special provisions for delivering medium-speed packet data services, have not, in most instances, been directly competitive with broadband wireless services. They share a radio frequency airlink and, in some cases, core technologies, but they have traditionally served a different type of customer and have presented different types of service offerings.

This may be changing. Recently, a new mobile standard known as High-Speed Downlink Packet Access (HSDPA) has emerged, and the first networks utilizing it are already in operation in Asia. HSDPA, which is an extension of Global System for Mobile Communications (GSM), the most widely used standard for digital cellular telephony, supports throughputs exceeding 10 megabits per second (Mbps) while affording full mobility to the user. An HSDPA capability, which may easily and inexpensively be added to an existing GSM network, provides the network operator with a true broadband service offering capable of competing with cable or DSL data services. GSM networks, for the most part, still face the challenge imposed by bandwidth allocations that are marginal for provisioning large numbers of broadband customers, but HSDPA definitely undercuts many of the assumptions in the marketplace on the limitations of mobile services and appears to pose a real alternative.

Whether that alternative will be sufficient to retard the acceptance of 802.16 in the broadband marketplace remains to be determined. HSDPA will be utilized almost exclusively by existing mobile license holders, in most cases large incumbents with multiple local networks extending over a national footprint. 802.16, on the other hand, is likely to be the province of independents or of non-telco wireline operators such as cable networks that are seeking a wireless and, in many cases, a mobile offering. Because of the differences in service orientation that characterize the two camps, the service bundles actually offered to the public are likely to be different and the outcome of the contest between HSDPA and 802.16 will probably depend as much on market positioning as on the capacities of either technology. At the same time, the fact that the mobile operators possess built-out physical infrastructure and can leverage it effectively to deploy HSDPA either rapidly or incrementally, depending on their strategies, means that challengers operating 802.16 networks will face formidable opposition in the markets where HSDPA gains a foothold.

Introducing the 802.16 Standard

A number of industry standards govern the design and performance of wireless broadband equipment. The standards that chiefly concern wireless broadband are 802.16 and its derivative 802.16a, both of which were developed by the Institute of Electrical and Electronic Engineers (IEEE), a major industry standards body headquartered in the United States.

The complete standards are available as book-length documents on the IEEE Web site at `http://www.ieee.org`. This chapter focuses on only the most salient points in respect to network operators.

Both standards have as their goal the standardization of acceptable performance levels and the achievement of full interoperability among the products of standards-compliant manufacturers. The latter will allow the network operators to mix base stations and subscriber premises equipment from different manufacturers so as not to be dependent on single sourcing and, perhaps more important, to encourage the mass production of standards-based chipsets by competing manufacturers. This in turn will lead to a drop in equipment prices because of economies of scale and market pressures.

In the past, the high prices of carrier-grade wireless base stations and subscriber terminals have saddled network operators with unacceptable equipment costs, and such costs, coupled with the disappointing performance of first-generation products, severely hindered wireless network operators attempting to compete with wireline operators. The present availability of substantially better-performing and less-expensive infrastructure equipment should finally enable network operators to utilize wireless access technologies advantageously and compete effectively with wireline broadband services.

The 802.16 and 802.16a standards share the same media access control (MAC) layer specifications but posit different physical layers because of the different areas of spectrum covered by the respective standards. The 802.16 standard covers what has come to be known as the *millimeter microwave spectrum* and extends from 10 gigahertz (GHz) up to 66GHz, and 802.16a covers 2GHz to 11GHz; the two standards thus overlap. In fact, most of the activity involving 802.16a-based equipment is likely to occur at frequencies below 6GHz because lower-microwave equipment is both less expensive and more versatile.

Unlike the standards governing WLANs (namely, 802.11 and its derivatives—802.11b, 802.11a, 802.11g, 802.11e, 802.11n, 802.11p, and 802.11s), the 802.16 standards do not state fixed throughput rates for the individual user but state only a maximum of 124Mbps for a channel for 802.16 and 70Mbps for a 20 megahertz (MHz) channel bandwidth in the 802.16a standard. In fact, the lack of stated rates is entirely appropriate to a standard intended for a public service provider because the operator needs to have the flexibility of assigning spectrum selectively and preferentially and of giving customers willing to pay for such services high continuous bit rates at the expense of lower-tier users—and conversely throttling bandwidth to such lower-tier users in the event of network congestion. In a public network, the operator and not the standard should set bit rates such that the bit rates are based on business decisions rather than artificial limits imposed by the protocol.

Introducing the Media Access Control Layer

The *media access control layer* refers to the network layer immediately above the physical layer, which is the actual physical medium for conveying data. The access layer, as the name suggests, determines the way in which subscribers access the network and how network resources are assigned to them.

The media access control layer described in the 802.16 standard is designed primarily to support point-to-multipoint (PTMP) network architectures, though it also supports the point-to-point (PTP) and point-to-consecutive point (PTCP) architectures. The lower-frequency bands also support mesh topologies, although the mesh standard adopted by the 802.11 committee does not reflect the latest research into mesh networking. Chapter 3 fully explains these terms.

The 802.16 standard has been optimized for Internet Protocol (IP) traffic, and IP-based services represent the best approach for most operators; however, standards-based equipment will also support legacy circuit-based services such as T1/E1 and asynchronous transfer mode (ATM). In general, the older circuit-based services represent inefficient use of bandwidth, an important consideration with wireless where bandwidth is usually at a premium. Moreover, they put the wireless broadband operator in the position of having to compete directly with the incumbent wireline telephone operator. Wireless insurgents attempting to vie for circuit traffic with strong, entrenched incumbents have been almost uniformly unsuccessful for reasons Chapter 6 will fully explore.

A few words about the circuit and quasi-circuit protocols: A *circuit transmission* is one in which a prescribed amount of bandwidth is reserved and made available to a single user exclusively for the duration of the transmission; in other words, the user occupies an individual channel. In a *packet transmission*, a channel is shared among a number of users, with each user transmitting bursts of data as traffic permits.

The T1/E1 terms mentioned previously refer to two closely related standard circuit-based service offerings delivered over aggregations of ordinary copper telephone wires. A T1, the American standard, consists of 24 copper pairs, each capable of a throughput speed of 64 kilobits per second (Kbps). E1 consists of 30 pairs and is commensurately faster. E1 is the standard offering in most countries outside the United States. A T1 is delivered over a synchronous optical network (SONET), which is covered in the following chapters. An E1 is delivered over a synchronous digital hierarchy (SDH) network, the European equivalent of SONET. Both services go through ordinary telephone switches to reach the subscriber.

ATM is a predominantly layer-2 (the switching layer) protocol developed in large part by Bellcore, the research arm of the Bell Operating Companies in the United States. Intended to provide a common platform for voice, data, and multimedia that would surpass the efficiency of traditional circuit networks while providing bandwidth reservation and quality-of-service (QoS) mechanisms that emulate circuit predictability, ATM has found its place at the core of long-haul networks where its traffic-shaping capabilities have proven particularly useful. In metropolitan area networks it is chiefly used for the transportation of frame-relay fast-packet business services and for the aggregation of DSL traffic. The 802.16 standard obviates the need for ATM, however, by providing comparable mechanisms of its own for bandwidth reservation and service-level stratification. Because ATM switches are extremely expensive and represent legacy technology, I do not recommend using ATM as a basis for the service network, unless, of course, the wireless network is an extension of an existing wired network anchored with ATM switches.

The 802.16 standard can accommodate both continuous and bursty traffic, but it uses what is essentially a connection-oriented protocol somewhat akin to those of ATM and frame relay. Modulation and coding schemes may be adjusted individually for each subscriber and may be dynamically adjusted during the course of a transmission to cope with the changing radio frequency (RF) environment. In the higher frequencies, 16 quadrature amplitude modulation (QUAM) and 64 QUAM are automatically invoked by the protocol to match signal characteristics with network conditions, with 64 QUAM providing greater information density and 16 QUAM providing greater robustness. The orthogonal frequency division multiplexing (OFDM) modulation scheme is specified for the lower band with a single carrier option being provided as well. Chapter 4 discusses these terms.

The 802.16 protocols are highly adaptive, and they enable subscriber terminals to signal their needs while at the same time allowing the base station to adjust operating parameters and power levels to meet subscriber needs. Polling on the part of the subscriber station is generally utilized to initiate a session, avoiding the simple contention-based network access schemes utilized for WLANs, but the network operator also has the option of assigning permanent virtual circuits to subscribers—essentially reservations of bandwidth. Provisions for privacy, security, and authentication of subscribers also exist. Advanced network management capabilities extending to layer 2 and above are not included in the standard.

Introducing the Two Physical Standards

The 802.16 standard requires two separate physical-layer standards because the propagation characteristics of radio waves are so different in the lower- and upper-microwave regions.

Lower-frequency signals can penetrate walls and can travel over considerable distances—more than 30 miles with highly directional antennas. Higher-frequency transmissions, on the other hand, must meet strict line-of-sight requirements and are usually restricted to distances of a few kilometers. The lower-frequency ranges also lend themselves to complex modulation techniques such as OFDM and wideband Code-Division Multiple Access (CDMA). These conduce to high levels of robustness and higher spectral efficiencies—that is, more users per a given allocation of bandwidth.

The singular advantage enjoyed by users of higher-frequency bands is an abundance of bandwidth. Most spectral assignments above 20GHz provide for several hundred megahertz minimally, and the 57GHz to 64GHz unlicensed band available in the United States can support several gigabits per second at one bit per hertz for fiberlike speeds.

Introducing WiMAX

Standards are of relatively little value unless there is some way of enforcing compliance to the standard. Promoters of 802.16 were well aware of this, and some of them elected to form an organization to test and certify products for interoperability and standards compliance. That organization is known as the Worldwide Interoperability for Microwave Access (WiMAX).

WiMAX also promotes the 802.16 standard and the development of what it calls *systems profiles*. These are specific implementations, selections of options within the standard, to suit particular ensembles of service offerings and subscriber populations.

At the time of this writing, the WiMAX has not certified any equipment designed according to the 802.16 standards, although the first 802.16 chips have reached the market and some have been submitted to the organization for evaluation and testing. WiMAX itself expects that some products will be certified by the end of 2005, but this is only an estimate. For this reason, the 802.16 network equipment that the operator intends on using today cannot be assumed to provide total interoperability.

Currently 802.16 chips are being shipped or have been announced by Intel, Fujitsu, Wavesat, Sequans, TeleCIS, Beceem Communications, Adaptix, and picoChip. WiMAX certification of at least some of these products will follow in 2006. Most industry observers believe that incorporation of first-generation chips in products will take place on a fairly small scale and that radio manufacturers are awaiting the finalization of the 802.16e mobility standard before committing to volume production.

Introducing Other Wireless Broadband Standards

An earlier IEEE standard, 802.11, and its derivatives (802.11b, 802.11a, 802.11g, and soon 802.11e) have seen wide deployment in commercial, governmental, and residential LAN settings and some application in public service networks, primarily localized *hotspots* where coverage is provided within a picocell not exceeding a couple of hundred yards in radius. I anticipate that low-priced 802.11 solutions will continue to be attempted within pervasive metropolitan networks better served by 802.16-based equipment. Table 1-1 compares the two standards in detail.

Table 1-1. *Standards: 802.11 vs. 802.16*

Feature	802.11	802.11b	802.11a	802.11g	802.16	802.16a
Assigned spectrum	2.46GHz	2.4GHz	5.8GHz	2.4GHz	10GHz–66GHz	2GHz–11GHz
Maximum throughput	2Mbps	11Mbps	54Mbps	54Mbps		70Mbps
Propagation distance	200 yards	200 yards	200 yards	200 yards	More than a mile	Several miles
Network architecture supported	Point to multipoint PTMP	PTMP	PTMP	PTMP	PTP, PTCM	PTMP, PTCM, mesh
Transport protocols supported	Ethernet	Ethernet	Ethernet	Ethernet	TCP, ATM	TCP/IP, ATM
Modulation system	Frequency hopping, direct sequence	Frequency hopping, direct sequence	OFDM	OFDM	QUAM, phase shift keying (PSK)	OFDM
Adaptive modulation?	No	No	No	No	Yes	Yes
Support for full mobility?	No	No	No	No	No	Upcoming
QoS?	No	No	No	No	Yes	Yes

I will not devote much attention in this book to the specifics of the 802.11 standard. Optimized for indoor and campus environments, 802.11 was intended to serve the needs of Ethernet LAN users and is quite limited in terms of range and the number of users that can be accommodated simultaneously. In fact, transmission speed and signal integrity drop off precipitately at distances beyond about 500 feet from an access point.

So why, given the intentional limitations inherent in the standard, would anyone contemplate employing 802.11 equipment in a public setting? In a word, price. Specifically, 802.11 gear has become a commodity; also, network interface cards for subscriber terminals are available at the time of this writing for less than $100, and access points are available for less than $200. Simply put, a network constructed of 802.11 network elements will cost a fraction of the amount of money required to purchase 802.16 equipment.

If the network consists of nothing but short cell radius hotspots, 802.11 will suffice and indeed may be preferable, but for a metropolitan network most 802.11 equipment represents a severe compromise. A few manufacturers (such as Tropos, Vivato, and Airgo) are attempting to manufacture adaptive-array antenna systems or mesh-networked base stations for 802.11-compliant equipment, expedients that will presumably emulate some of the characteristics of 802.16 in respect to distance and reuse of spectrum within a cell, but such equipment is much more expensive than conventional 802.11 products and still lacks the full complement of protocols for supporting QoS and advanced network management. Possibly in some situations, such “hotrodded” 802.11 gear will be adequate and will represent the most cost-effective equipment choice, but to regard it as a general substitute for 802.16 infrastructure is misguided. When a service provider is attempting to serve a number of small businesses in a single building where the subscribers lack networking capabilities of their own, enhanced performance 802.11 may be adequate, provided that the base station assigned to the building does not have to serve a larger area. No one should be tempted to believe that an entire metropolitan market can be served with 802.11 equipment.

At the same time, 802.11 in its various iterations definitely bears watching. The standard has been subject to continuous revision ever since it was introduced in 1998, and it has definitely not solidified as yet. Further revisions of the standard are in preparation, and some of these could render further generations of 802.11 equipment more competitive with 802.16 in the context of the metropolitan area network (MAN).

Of particular interest is the proposed 802.11e revision, which is currently in committee. The standard endows 802.11 networks with QoS capabilities. The standard calls for prioritization of different traffic types and also allows for contention-free transmissions to take place over short durations of time, a provision that would significantly reduce latency. But because 802.11 remains Ethernet rather than IP based, as is the case with 802.16, a comparable range of ancillary QoS protocols is not available. 802.11e may be entirely sufficient for transmitting time-sensitive traffic such as voice or video within a LAN environment, but its ability to maintain QoS across the metro may be questioned. Rumor has it that the IEEE will ratify 802.11e some time in 2006. Its appearance in silicon would probably take place a year or so later.

Also of considerable interest is 802.11n, the high-speed standard. Projected speeds are in excess of 100Mbps. Two variants are currently in contention: the World-Wide Spectrum Efficiency (WWiSe) specification backed by Broadcom and TGn Sync, supported by Intel and Philips, among others. Intel, it should be noted, has not previously been a player in the wireless fidelity (WiFi) space, and by devising a new 802.11 standard it would be redressing past deficiencies. The new standard will definitely make use of multiple input, multiple output (MIMO) technology, where arrays of antennas are required for both base stations and subscriber terminals. Ratification is expected to take place in late 2006. Incidentally, many manufacturers are discussing a standard beyond 802.11n that has yet to gain a number designation and is simply known as Gigabit 802.11. Achieving such throughputs over any unlicensed band currently accessible to 802.11 radios would be a major challenge with existing technology, and I think gigabit throughputs are still years away.

Finally, a mesh standard named 802.11s is in preparation. What effect this will have on the positioning of 802.11 vis-à-vis 802.16 is difficult to determine at present.

The 802.15 standard is another IEEE fixed-point wireless broadband standard, but it is one of even less relevance to public networks. The 802.15 standard incorporates an older standard promoted and largely developed by Ericsson and Nokia known as Bluetooth (named after Harald Bluetooth, a tenth-century Viking monarch). Bluetooth has been used in a few hotspot public networks, but the range is so short—no more than 50 yards or so—that it is utterly inapplicable in pervasive MANs. Also, work is under way on the formulation of a substandard within 802.15 to include ultrawideband (UWB) radio, a revolutionary RF technology that uses extremely low-power, wideband pulses intended to coexist with channelized radio communications. UWB may well represent the far future of broadband wireless, but current power restrictions confine it to very short ranges, just as with Bluetooth, and it is not suitable for overarching MANs as it is currently configured.

Finally, I should briefly mention High-Performance Radio Metropolitan Area Network (HIPERMAN), a standard that is somewhat analogous to 802.16 but that emanates from a different standards body, namely the European Telecommunications Standards Institute

(ETSI). HIPERMAN is an outgrowth of an earlier stillborn standard called HIPERLAN2. HIPERLAN2 appears to have been positioned to play in two distinct markets, one encompassing large, campuswide corporate LANs and one for commercial MANs. In some respects HIPERLAN2 is reminiscent of IEEE 802.11a, and in others it is closer to IEEE 802.16a. HIPERLAN2—which, as the name suggests, proceeded from HIPERLAN, an abortive standard that saw embodiment in only a few products made by Proxim—appears to have found even less market success than its predecessor, which is to say precisely none to date. The marketplace has already decisively rejected HIPERLAN in all its forms, but HIPERMAN is still being actively promoted by ETSI. Currently discussions are under way between the IEEE and ETSI toward merging HIPERMAN with 802.16. As it stands, no equipment embodying the HIPERMAN standard is in the marketplace.

Deploying Within Urban, Suburban, and Rural Environments

The IEEE 802.16 standards represent the institutionalization of several of the best-performing technologies in wireless communications and the aggregation of a number of advances made by various manufacturers that are unavailable in a single platform up to this time. As such, the new standards-based equipment enables broadband wireless networks to perform at a level that was unattainable previously and extends the capabilities of wireless access technologies to permit the penetration of markets where previously wireless broadband was marginal or simply ineffective.

Broadband wireless is still not the best access technology for all geographical markets or all market segments within a given geography, but many more customers are potentially accessible than in the past. It is scarcely an exaggeration to say that the new standards provide an effective solution to the most severe geographical limitations of traditional broadband wireless products, though the reach of any given wireless network is still constrained by its location, and its attractiveness is affected by the presence or absence of competing broadband technologies.

The most difficult geographical markets for wireless broadband remain large cities, especially where high-rises predominate in the downtown business district. In the developed world the largest cities are already fairly well served by fiber for the most part, and fiber, where it is present, is a formidable competitor. The largest business buildings housing the most desirable customers will usually have fiber drops of high-speed fiber rings encircling the city core, and individual subscribers can purchase OC-3 (144Mbps), OC-12 (622Mbps), or, in some cases, wavelength services (variously 1Gbps or 10Gbps). Generally, such customers are lost to wireless service providers because the availability (the percentage of time that a link is available to the user) of the radio airlink will always be less than for fiber, and availability is critically important to most purchasers of high-bandwidth data services.

Also, you cannot discount the generally unfavorable topography represented by most large modern metropolises. Millimeter microwave transmissions demand a clear path to the subscriber terminal, and unless the base station resides on a tower that is considerably higher than any other structure in the vicinity, many promising buildings are apt to remain out of reach within the cell radius swept by the base station. Lower-frequency microwave base stations using non-line-of-sight (NLOS) technology can reach subscribers blocked by a single structure, but there are clear limits in the ability of even the most intelligent adaptive antenna