



**White Paper
WiMAX Technology and Deployment**

**WiMAX Technology and Deployment
for Last-Mile Wireless Broadband
and Backhaul Applications**

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Contents

<u>Introduction</u>	<u>2</u>
<u>Wide-ranging wireless broadband</u>	<u>3</u>
<u>WiMAX, 802.16 and international interoperability</u>	<u>3</u>
<u>QoS—a powerful WiMAX advantage</u>	<u>5</u>
<u>Base and subscriber stations</u>	<u>6</u>
<u>Standard issues: interoperability and upgrades</u>	<u>9</u>
<u>The deployment outlook</u>	<u>10</u>
<u>For more information</u>	<u>10</u>

Introduction

While wireless connectivity options have expanded rapidly in recent years, wireless network access is available now only in limited physical areas. Internet and intranet users need broadband access that extends over longer distances to more locations. The industry's solution is the Worldwide Interoperability for Microwave Access (WiMAX) standard, developed to create certified standards-based products from a wide range of vendors.

The WiMAX standard enables system vendors to create many different types of WiMAX-based products, including various configurations of base stations and customer premise equipment (CPE). WiMAX supports a variety of wireless broadband connections:

- High-bandwidth metropolitan-area networks (MANs) to home and small-business users, replacing DSL and cable modems;
- Backhaul networks for cellular base stations, bypassing the public switched telephone network;
- Backhaul connections to the Internet for WiFi hotspots.

Where they exist today, these applications use expensive proprietary methods for broadband wireless access. This expense can be dramatically reduced by using interoperability-tested WiMAX silicon solutions based on the IEEE 802.16d standard. Leaders in semiconductor technology, such as Fujitsu Microelectronics America, Inc., will deliver the expanded broadband wireless capability by working in close partnership with infrastructure and equipment manufacturers.

The WiMAX Forum promotes deployment of broadband wireless access networks by using a global standard and certifying interoperability of products and technologies. The

Forum was founded in 2002 and now has more than 150 members, including Fujitsu Microelectronics America, Inc.

Like WiFi (IEEE 802.11) before it, WiMAX promises explosive growth. The key to taking advantage of WiMAX opportunities is to understand the technology’s evolution and anticipated deployment.

Wide-ranging wireless broadband

WiMAX furnishes broadband connectivity over a much wider area than WiFi and does not require a direct line of sight between subscriber terminals and access points. In contrast to WiFi, WiMAX’s range is typically measured in miles rather than feet. This distinction points up the difference between the two standards: WiFi is a local-area networking (LAN) technology, while WiMAX is a MAN technology. The “metropolitan” in “metropolitan-area network” does not restrict WiMAX to urban environments, however. This technology is ideal for providing broadband services in rural areas that may be underserved by DSL or cable.

WiMAX’s channel sizes range from 1.5 to 20MHz, giving a WiMAX network the flexibility to support a variety of data rates such as T1 (1.5Mbps) and higher data rates of over 70Mbps. This flexibility allows WiMAX to adapt to the available spectrum and channel widths in different countries or licensed to different service providers. Equally important, quality-of-service features ensure high performance for voice and video.

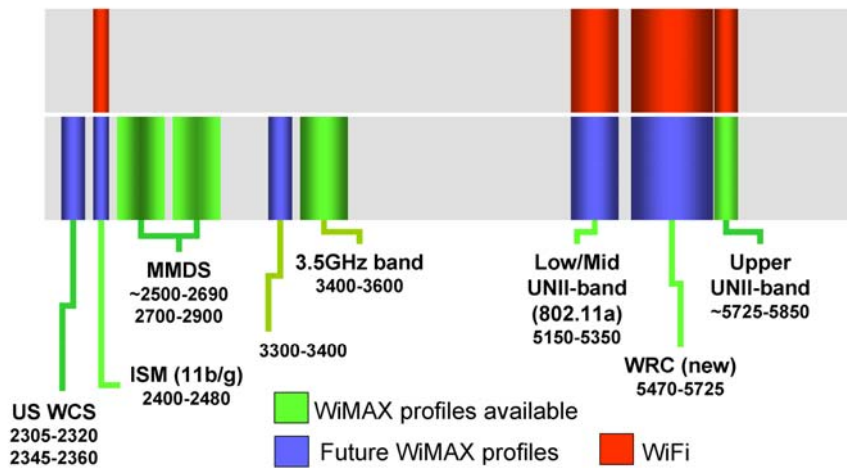


Figure 1–WiMAX RF spectrum choices range from 2 to 11GHz and overlap WiFi bands, as shown here. Within this range, the WiMAX Forum will initially focus on equipment profiles for commonly used frequencies such as 3.5GHz.

WiMAX, 802.16 and international interoperability

The IEEE 802.16 standard originally specified an operating frequency band from 10 to 66 GHz. The 802.16d amendment supports fixed broadband wireless access for both licensed and unlicensed spectra in the 2-to-11-GHz range (Figure 1). This amendment was ratified in June 2004, and the specification is available now. However, the 802.16e amendment is under development to address mobile broadband wireless access.

In addition to supporting the 2-to-11-GHz frequency range, the 802.16d standard supports three physical layers (PHYs). The mandatory PHY mode is 256-point FFT Orthogonal Frequency Division Multiplexing (OFDM). The other two PHY modes are Single Carrier (SC) and 2048 Orthogonal Frequency Division Multiple Access (OFDMA) modes. The corresponding European standard—the ETSI HiperMAN standard—defines a single PHY mode identical to the 256 OFDM mode in the 802.16d standard.

Because WiMAX's goal is to promote the interoperability of equipment based on either the 802.16d or HiperMAN standards, the forum has chosen to support the 256 OFDM mode exclusively. To ensure worldwide interoperability, the WiMAX Forum will only certify equipment supporting that particular PHY mode.

WiFi 802.11a and 802.11g also use OFDM and have established an excellent performance record for robust wireless networking. However, WiFi uses 64 OFDM. The number before "OFDM" refers to the number of carriers that can be used in the overall modulation scheme. The much greater number of carriers for WiMAX helps achieve greater range because a receiver using 256 OFDM can tolerate delay spreads up to 10 times greater than systems using 64 OFDM. Also, 256 OFDM provides good non-line-of-sight capability.

For security, the 802.16d standard specifies the Data Encryption Standard (DES) as the mandatory encryption mechanism for data and Triple DES for key encryption. The allowed cryptographic suites are:

- CBC-Mode 56-bit DES, no data authentication & 3-DES, 128
- CBC-Mode 56-bit DES, no data authentication & RSA, 1024
- CCM-mode AES, no data authentication & AES, 128

The WiMAX Forum is currently evaluating these long-standing choices in light of recent advances in encryption technology. Specifically, the Forum is considering whether to specify the Advanced Encryption System (AES) from the US National Institute of Standards as an alternate encryption method; AES could become the preferred choice for service providers.

QoS—a powerful WiMAX advantage

Several features of the WiMAX protocol ensure robust quality-of-service (QoS) protection for services such as streaming audio and video. As with any other type of network, users have to share the data capacity of a WiMAX network, but WiMAX's QoS features allow service providers to manage the traffic based on each subscriber's service agreements on a link-by-link basis. Service providers can therefore charge a premium for guaranteed audio/video QoS, beyond the average data rate of a subscriber's link.

One aspect of WiMAX QoS provisioning is a grant-request mechanism for letting users into the network. This mechanism's operation and value become apparent from a comparison of WiMAX with the CSMA/CD or CSMA/CA mechanisms used in LAN technologies such as 802.11. When a CSMA/CA-based wireless LAN has fewer than 10 users per access point, the network experiences little contention for use of airtime. Occasional packet collisions occur, and they require back-off and retransmissions, but the resulting overhead does not waste a significant amount of bandwidth.

If the number of CSMA/CA access-point users goes up to dozens or hundreds of users, many more users tend to collide, back-off and retransmit data. In such an environment, average network loading factors can easily rise past 20 to 30 percent, and users notice delays—especially in streaming-media services.

WiMAX avoids such issues by using a grant-request mechanism that allocates a small portion of each transmitted frame as a contention slot. With this contention slot, a subscriber station can enter the network by asking the base station to allocate an uplink (UL) slot. The base station evaluates the subscriber station's request in the context of the subscriber's service-level agreement and allocates a slot in which the subscriber station can transmit (send UL packets).

The WiMAX grant-request mechanism establishes a fixed overhead for airtime contentions and prevents large numbers of subscribers from interfering with one another. Overall, the mechanism allows for much higher utilization of available channel resources. Even when a base station has thousands of users and a high load factor, the network does not bog down with packet collisions and retransmissions. As more users join a WiMAX network, the base station schedules the subscribers using dynamic scheduling algorithms that the service provider can define and modify to achieve the promised level of service to each subscriber.

Another aspect of WiMAX QoS provisioning is link-by-link data-rate manageability. The signal strength between base and subscriber stations affects a wireless link's data rate and ability to use various modulation schemes within the 256 OFDM framework. Signal strength depends mainly on the distance between the two stations. If the network were restricted to a single modulation scheme per carrier, subscribers that are farther away from the base station would limit the network's ability to use the most efficient scheme.

WiMAX enables optimization of each subscriber's data rate by allowing the base station to set modulation schemes on a link-by-link basis. A subscriber station close to the base station could use 64QAM modulation, while the weaker signal from a more remote subscriber might only permit the use of 16QAM or QPSK. The 802.16 MAC can even use a different modulation method for each subscriber's downlink and uplink bursts. As shown in Figure 2, the minimum granularity of a DL or UL burst is one OFDM symbol.

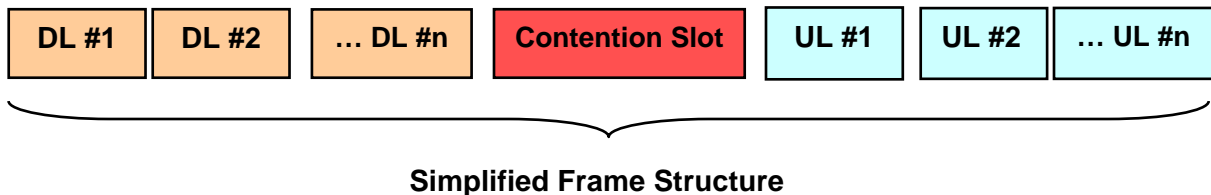


Figure 2—The frame structure for WiMAX (simplified in this example) allows use of different modulation schemes for each symbol of the overall Orthogonal Frequency Division Multiplexing (OFDM) modulation system. For example, downlink (DL) #1 can use 64QAM modulation, while DL #2 can use 16QAM or QPSK modulation. Similar choices can be made in the uplink (UL) direction. The contention slot shown in this frame structure is the sole time allotted to requests from subscriber stations that want to join the network, thus eliminating contention at other times.

Optimizing overall bandwidth usage and maximizing each subscriber's data rate establishes a solid foundation for high quality of service. In addition to these general-purpose QoS features, WiMAX provides specific QoS support for voice and video. To enable toll-quality voice traffic, for example, voice packets can be tagged as such. The base-station's scheduler then manages the passage of these packets through the air interface to provide deterministic latency.

Base and subscriber stations

WiMAX base stations can range from units that support only a few subscriber stations to elaborate equipment that supports thousands of subscriber stations and provides many carrier-class features. Whatever number of subscriber stations a base station supports, the latter must manage a variety of functions that are not required in subscriber equipment. Some base stations must support sophisticated antenna capabilities, for example, and implement efficient frequency reuse.

As a result, WiMAX base stations will have many different configurations. They will likely range from simple stand-alone units that support a few users to redundant, rack-mounted systems and server blades that operate alongside wireline networking equipment. On the hardware side, this equipment will typically use off-the-shelf microprocessors and discrete radio-frequency (RF) components. Required software includes an 802.16 Media Access Control (MAC), scheduler and many other software applications such as network management services and protocol stacks. A typical presentation of WiMAX system components is given in Figure 3 with emphasis on different levels of interface.

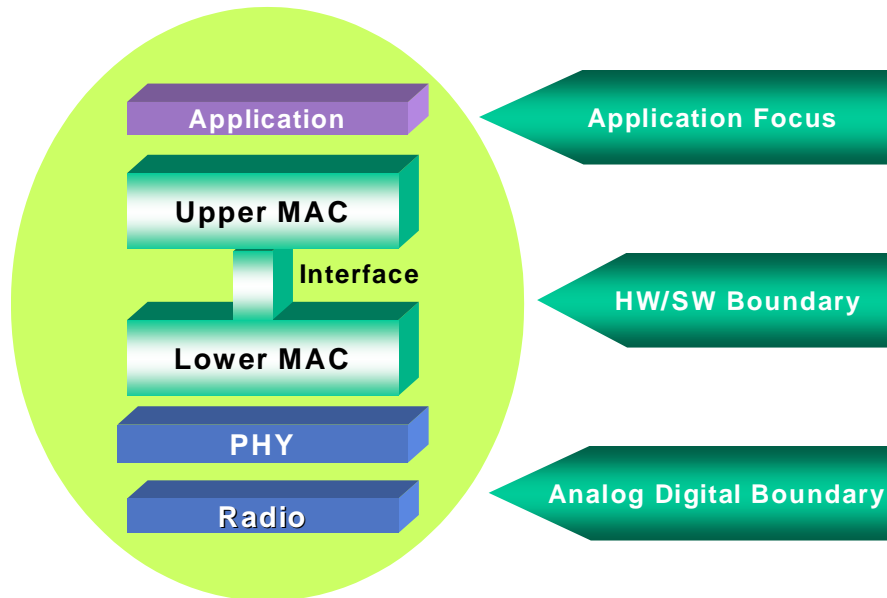


Figure 3—WiMAX system components include dedicated hardware such as the PHY and “lower” MAC in addition to MAC-related software functions. The radio and PHY are distinguished here according to analog and digital functionality, respectively.

Implementing subscriber stations with this same type of customized hardware and software would be prohibitively expensive—exactly the limitation of earlier-generation proprietary wireless systems. One of the benefits of complying with an industry standard such as WiMAX is that merchant semiconductor firms will support the standard with high-volume, cost-effective silicon solutions. A typical implementation of system components is shown in Figure 4. Fujitsu Microelectronics is developing a highly integrated solution as a single chip, which includes most of the necessary components aside from the radio (Figure 5).

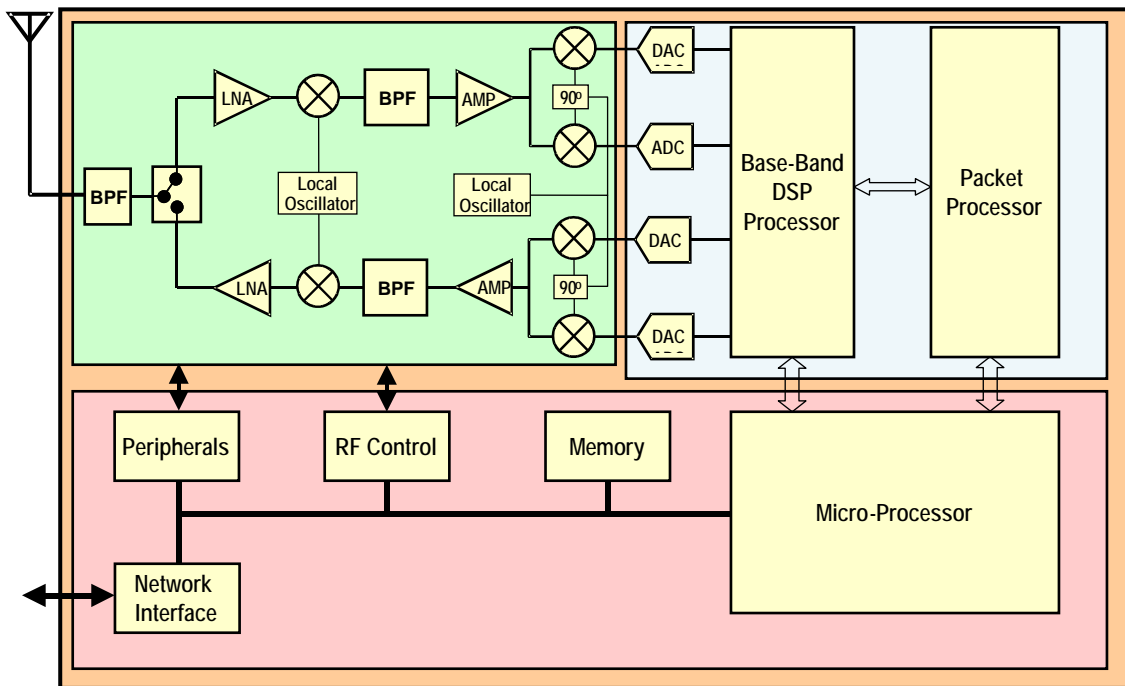


Figure 4—A typical implementation of a WiMAX subscriber station shows the analog radio functionality at upper left and digital PHY/MAC functionality in the other blocks.

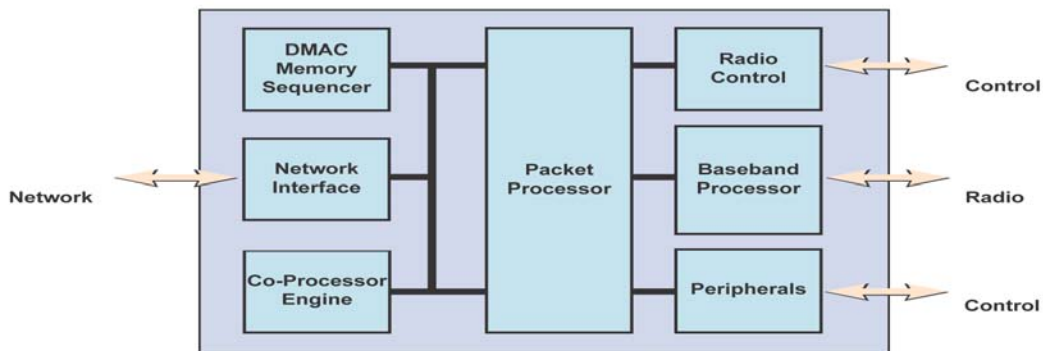


Figure 5—Integrated silicon solutions will make WiMAX subscriber stations highly cost-effective and help drive wide adoption of WiMAX networks.

At the same time, the challenge of a standards-based product is to differentiate it from competing products. With WiMAX, vendors may target different frequency bands using various RF solutions. Moreover, if the integrated silicon at the heart of the subscriber station permits vendors to use some of their own software (MAC software, for instance), vendors may be able to distinguish subscriber stations with a variety of unique features.

Standard issues: interoperability and upgrades

The WiMAX Forum is emphasizing interoperability between equipment from different system vendors at an early stage in the standard's development. As shown by the WiFi Alliance's efforts with the 802.11 standard, a focus on certifying product interoperability helps drive wide adoption of the standard in the marketplace.

On the other hand, the WiFi interoperability program began relatively late in the development cycle, which may have delayed acceptance. The WiMAX Forum has noted this lesson and determined to begin interoperability testing as soon as possible. Table 1 shows the timeline for interoperability testing and certification.

WiMAX Milestones	Completion Date
System Profiles	5/05/03
PICS (Protocol Implementation)	8/20/04
Test Suite Structure Set	10/15/04
Test Cases with Executable Test Scripts	12/10/04
Abstract Test Suites	12/10/04
Plugfest Lab Ready	March 2005
1 st WiMAX Plugfest	May-June 2005
WiMAX Certification	July 2005
2 nd WiMAX Plugfest	Sep-Oct 2005

Source: WiMAX Forum
(July 2004)

Table 1

As the IEEE 802.16 standard continues to evolve, the WiMAX Forum will follow the latest version of the standard for interoperability testing. At the same time, the Forum seeks to maintain backward compatibility with deployed WiMAX Certified equipment.

Ongoing work on the 802.16 standard is adding significant new capabilities to the technology. For example, the 802.16e standard will define mechanisms for portability and nomadic mobility to enable ubiquitous connectivity.

To further support ubiquitous connectivity, the IEEE is defining a handoff mechanism between 802.11 and 802.16 equipment. Using this mechanism, a laptop could transition from using a WiFi hotspot or enterprise WiFi WLAN to a WiMAX network furnished by a local service provider. This handoff will take place seamlessly and without user intervention while maintaining network connectivity.

The deployment outlook

The first form of the WiMAX standard primarily supports fixed wireless access, so the initial deployment will most likely be in non-cellular data-networking applications. Companies that have been marketing proprietary OFDM systems have a market foothold from which to deploy WiMAX-certified base stations in small towns or cities. Service providers in metropolitan areas may use WiMAX as their technology of choice over DSL and cable modems. Rural service providers in both developed and developing countries may need to deploy the WiMAX base stations, introduce an attractive sign-up package and then provide the CPEs to subscribers via the mail or in-store pick-up.

Other WiMAX players will include WiFi product vendors, pure-play CPE companies and traditional networking equipment manufacturers. The WiFi product vendors can leverage their existing sales channels by incorporating WiMAX into their products as a way to backhaul hotspot traffic to the public WAN.

Because WiMAX deployment requires the push of service providers, the WiFi product vendors must work with these providers for product launch. The pure-play CPE companies will most likely either partner with base station companies that have service provider ties or solicit the service providers to evaluate their products.

Understanding the enormous potentials of the fixed wireless networking market, networking equipment makers have shown great interests in WiMAX. Like the WiFi product vendors, the networking equipment makers will have to work with the service providers for deployment.

As the 802.16d standard evolves, a variety of wireless products such as WiMAX-enabled internet access cards may appear. Similarly, as 802.16e becomes the mobile standard for the wireless MAN, products such as laptops, PDAs and cell phones will be the revenue drivers.

In the early days of deployment, trial networks will be scattered around the globe. Once users understand WiMAX's benefits, the adoption rate could spread like wildfire—a possible scenario for 2006 and beyond. Toward that goal, the companies participating in WiMAX product development are establishing a foundation of high-performance, affordable silicon and systems that customers will find irresistible.

For more information

More information on the IEEE802.16 standard for broadband wireless access and the WiMAX Forum is available at www.wimaxforum.org and www.ieee802.org/16. For more information on Fujitsu's broadband wireless SoC, please address e-mail to inquiry.bwa@fma.fujitsu.com.