White Paper

Broadband Wireless Access

IEEE 802.16* and WiMAX

Broadband Wireless Access for Everyone

Contents

Introduction: the IEEE 802.16 Standard for Broadband Wireless

Many operators and service providers may be unfamiliar with the details of the IEEE 802.16* standard, but this wireless technology is about to revolutionize the broadband wireless access industry. The 802.16 standard, the "Air Interface for Fixed Broadband Wireless Access Systems," is also known as the IEEE WirelessMAN* air interface. This technology is designed from the ground up to provide wireless last-mile broadband access in the Metropolitan Area Network (MAN), delivering performance comparable to traditional cable, DSL, or T1 offerings. The principal advantages of systems based on 802.16 are multi-fold: the ability to quickly provision service, even in areas that are hard for wired infrastructure to reach; the avoidance of steep installation costs; and the ability to overcome the physical limitations of traditional wired infrastructure. Providing a wired broadband connection to a currently underserved area through cable or DSL can be a time-consuming, expensive process, with the result that a surprisingly large number of areas in the US and throughout the world do not have access to broadband connectivity. 802.16 wireless technology provides a flexible, cost-effective, standards-based means of filling existing gaps in broadband coverage, and creating new forms of broadband services not envisioned in a "wired" world.

Drawing on the expertise of hundreds of engineers from the communications industry, the IEEE has established a hierarchy of complementary wireless standards. These include IEEE 802.15 for the Personal Area Network (PAN), IEEE 802.11 for the Local Area Network (LAN), 802.16 for the Metropolitan Area Network, and the proposed IEEE 802.20 for the Wide Area Network (WAN). Each standard represents the optimized technology for a distinct market and usage model and is designed to complement the others. A good example is the proliferation of home and business wireless LANs and commercial hotspots based on the IEEE 802.11 standard. This proliferation of WLANs is driving the demand for broadband connectivity back to the Internet, which 802.16 can fulfill by providing the outdoor, long range connection back to the service provider. For operators and service providers, systems built upon the 802.16 standard represent an easily deployable "third pipe" capable of delivering flexible and affordable last-mile broadband access for millions of subscribers in homes and businesses throughout the world.

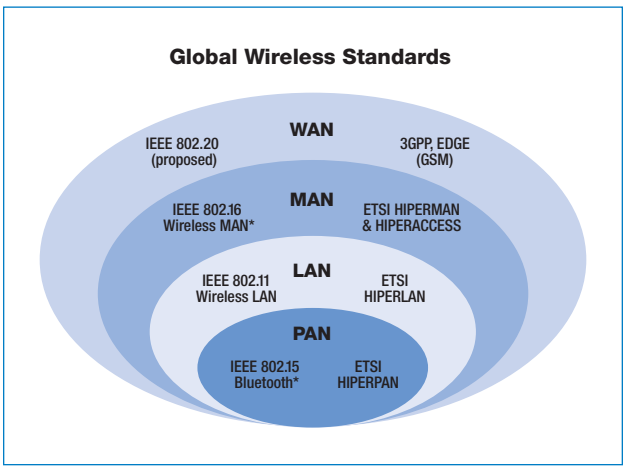

Figure 1 – The IEEE 802.16 standard is one of a number of complementary wireless standards created by the IEEE to help ensure interoperability and reduce the risk of wireless technology deployment.

Designed from the Ground Up for Metropolitan Area Networks

In January 2003, the IEEE approved the 802.16a standard which covers frequency bands between 2 GHz and 11 GHz. This standard is an extension of the IEEE 802.16 standard for 10 – 66 GHz published in April 2002. These sub 11 GHz frequency ranges enable non line-of-sight performance, making the IEEE 802.16a standard the appropriate technology for last-mile applications where obstacles like trees and buildings are often present and where base stations may need to be unobtrusively mounted on the roofs of homes or buildings rather than towers on mountains.

The most common 802.16a configuration consists of a base station mounted on a building or tower that communicates on a point to multi-point basis with subscriber stations located in businesses and homes. 802.16a has up to 30 miles of range with a typical cell radius of 4 – 6 miles. Within the typical cell radius, non-line-of-sight performance and throughputs are optimal. In addition, 802.16a provides an ideal wireless backhaul technology to connect 802.11 wireless LANs and commercial hotspots with the Internet. 802.16a wireless technology enables businesses to flexibly deploy new 802.11 hotspots in locations where traditional wired connections may be unavailable or time consuming to provision and provides service providers around the globe with a flexible new way to stimulate growth of the residential broadband access market segment.

With shared data rates up to 75 Mbps, a single "sector" of an 802.16a base station – where sector is defined as a single transmit/receive radio pair at the base station – provides sufficient bandwidth to simultaneously support more than 60 businesses with T1-level connectivity and hundreds of homes with DSL-rate connectivity, using 20 MHz of channel bandwidth. To support a profitable business model, operators and service providers need to sustain a mix of high-revenue business customers and high-volume residential subscribers. 802.16a helps meet this requirement by supporting differentiated service levels, which can include guaranteed T1-level services for business, or best effort DSL-speed service for home consumers. The 802.16 specification also includes robust security features and the Quality of Service needed to support services that require low latency, such as voice and video. 802.16 voice service can be either traditional Time Division Multiplexed (TDM) voice or Voice over IP (VoIP).

Broadband Wireless Access Applications

The 802.16 standard will help the industry provide solutions across multiple broadband segments:

1. Cellular backhaul. Internet backbone providers in the U.S. are required to lease lines to third-party service providers, an arrangement that has tended to make wired backhaul relatively affordable. The result is that only about 20 percent of cellular towers are backhauled wirelessly in the U.S. In Europe, where it is less common for local exchange carriers to lease their lines to competitive third-parties, service providers need affordable alternatives. Subsequently, wireless backhaul is used in approximately 80 percent of European cellular towers. With the potential removal of the leasing requirement by the FCC, U.S. cellular service providers will also look to wireless backhaul as a more cost-effective alternative. The robust bandwidth of 802.16a technology makes it an excellent choice for backhaul for commercial enterprises such as hotspots as well as point-to-point backhaul applications.

2. Broadband on-demand. Last-mile broadband wireless access can help to accelerate the deployment of 802.11 hotspots and home/small office wireless LANs, especially in those areas not served by cable or DSL or in areas where the local telephone company may have a long lead time for provisioning broadband service. Broadband Internet connectivity is mission critical for many businesses, to the extent that these organizations may actually re-locate to areas where service is available. In today's market, local exchange carriers have been known to take three months or more to provision a T1 line for a business customer, if the service is not already available in the building. Older buildings in metropolitan areas can present a tangle of wires that can make it difficult to deploy broadband connections to selected business tenants. 802.16a wireless technology enables a service provider to provision service with speed comparable to a wired solution in a matter of

days, and at significantly reduced cost. 802.16a technology also enables the service provider to offer instantly configurable "on demand" high-speed connectivity for temporary events including trade shows that can generate hundreds or thousands of users for 802.11 hotspots. In these applications, operators use 802.16a solutions for backhaul to the core network. Wireless technology makes it possible for the service provider to scale-up or scale-down service levels, literally within seconds of a customer request. "On demand" connectivity also benefits businesses, such as construction sites, that have sporadic broadband connectivity requirements. Premium "on demand" last-mile broadband services represent a significant new profit opportunity for operators.

3. Residential broadband: filling the gaps in cable and DSL coverage. Practical limitations prevent cable and DSL technologies from reaching many potential broadband customers. Traditional DSL can only reach about 18,000 feet (3 miles) from the central office switch, and this limitation means that many urban and suburban locations may not be served by DSL connections. Cable also has its limitations. Many older cable networks have not been equipped to provide a return channel, and converting these networks to support high-speed broadband can be expensive. The cost of deploying cable is also a significant deterrent to the extension of wired broadband service in areas with low subscriber density. The current generation of proprietary wireless systems are relatively expensive

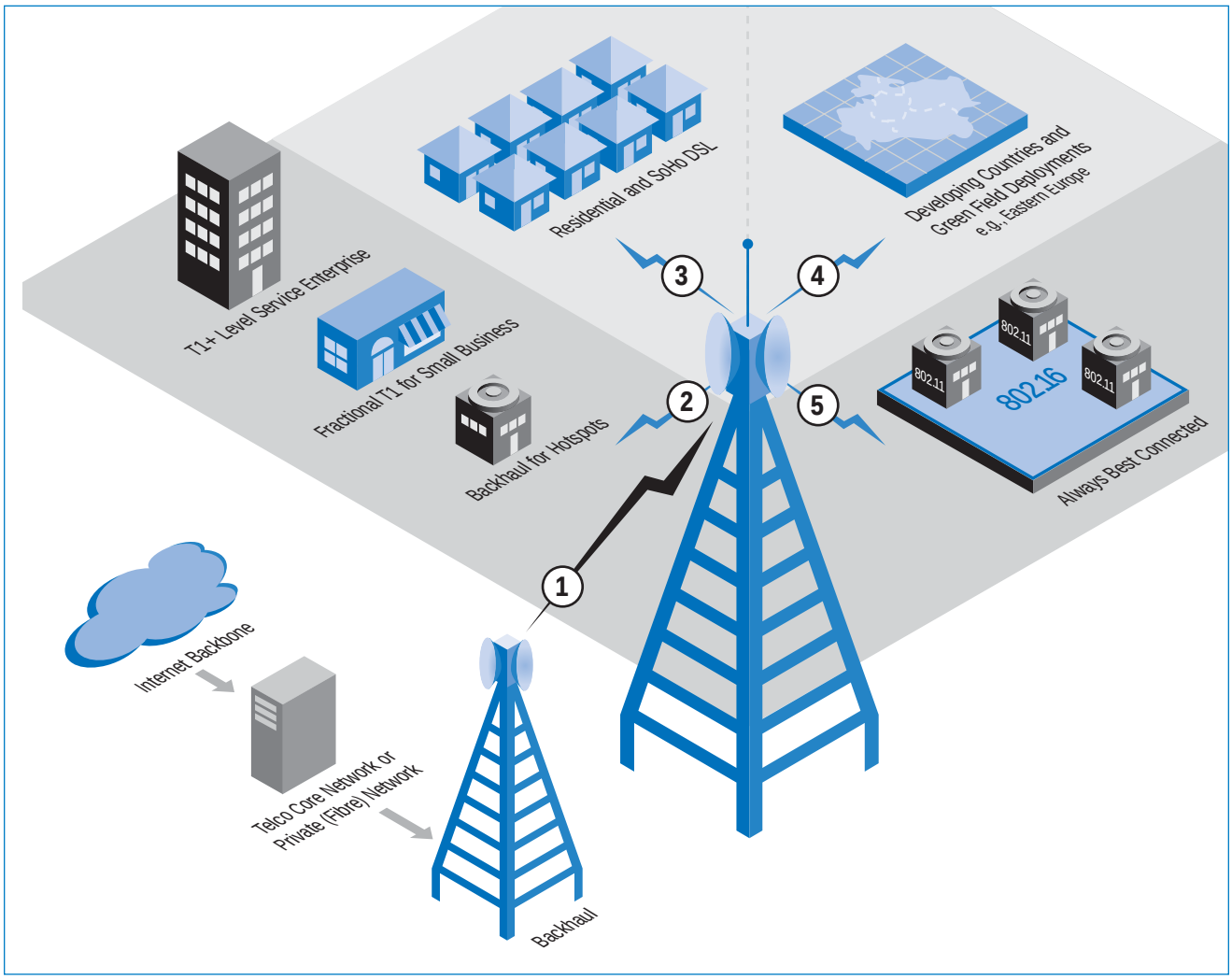

Figure 2 – The IEEE 802.16 standard enables solutions that meet the needs of a variety of broadband access segments.

for mass deployments because, without a standard, few economies of scale are possible. This cost inefficiency will all change with the launch of standards-based systems based on 802.16. In addition, the range of 802.16a solutions, the absence of a line of sight requirement, high bandwidth, and the inherent flexibility and low cost helps to overcome the limitations of traditional wired and proprietary wireless technologies.

4. Underserved areas. Wireless Internet technology based on IEEE 802.16 is also a natural choice for underserved rural and outlying areas with low population density. In such areas, local utilities and governments work together with a local Wireless Internet Service Provider (WISP) to deliver service. Recent statistics show that there are more than 2,500 WISPs who take advantage of license-exempt spectrum to serve over 6,000 markets in the U.S. [Source: ISP-Market 2002]. On an international basis, most deployments are in licensed spectrum and are deployed by local exchange carriers who require voice services in addition to high-speed data. This is because in these areas the wired infrastructure either does not exist or does not offer the quality to support reliable voice, let alone high-speed data. The term, "Wireless Local Loop" is often used to describe such applications, since it is used as a substitute for traditional copper phone wire in the local loop.

5. Best-connected wireless service. As the number of IEEE 802.11 hotspots proliferates, users will naturally want to be wirelessly connected, even when they are outside the range of the nearest hotspot. The IEEE 802.16e extension to 802.16a introduces nomadic capabilities which will allow users to connect to a WISP even when they roam outside their home or business, or go to another city that also has a WISP.

Throughput, Scalability, QoS, and Security

Throughput. By using a robust modulation scheme, IEEE 802.16 delivers high throughput at long ranges with a high level of spectral efficiency that is also tolerant of signal reflections. Dynamic adaptive modulation allows the base station to tradeoff throughput for range. For example, if the base station cannot establish a robust link to a distant subscriber using the highest order modulation scheme, 64 QAM (Quadrature Amplitude Modulation), the modulation order is reduced to 16 QAM or QPSK (Quadrature Phase Shift Keying), which reduces throughput and increases effective range.

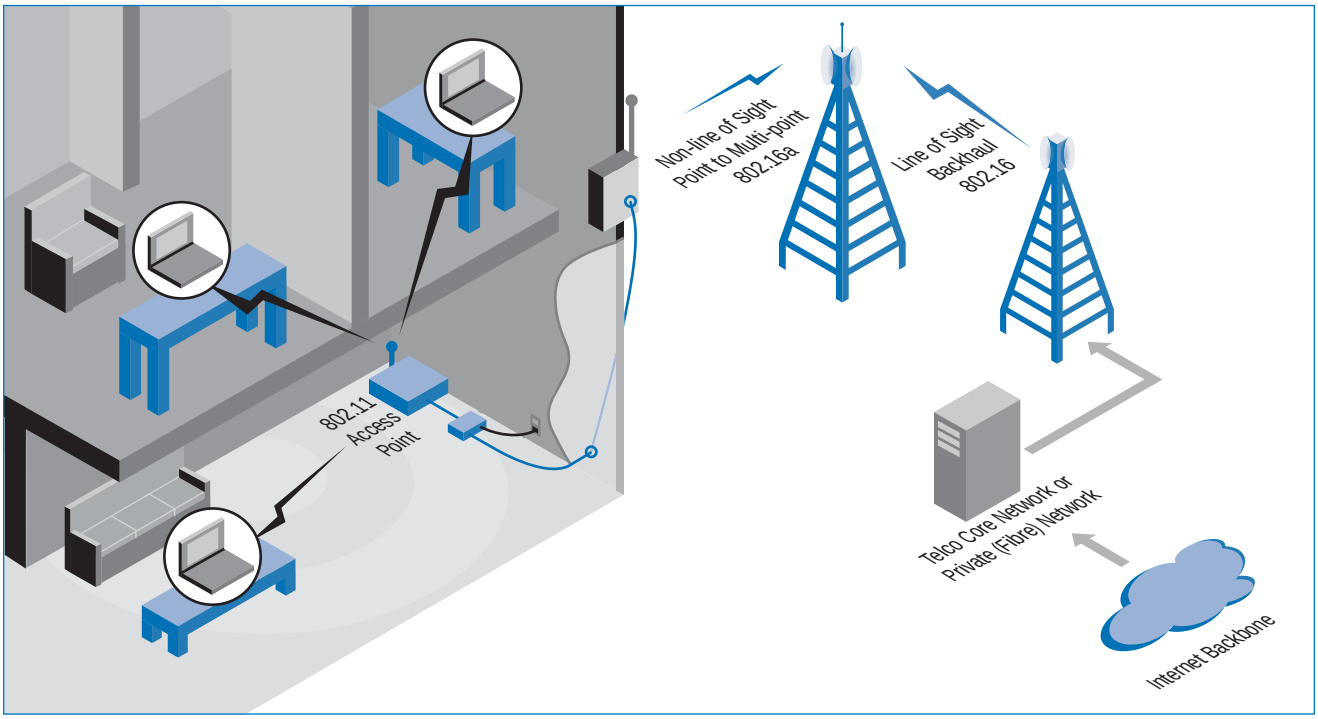

Figure 3 – The IEEE 802.16 standard enables non line-of-sight wireless point to multipoint connections and line-of-sight backhaul applications.

Scalability. To accommodate easy cell planning in both licensed and license-exempt spectrum worldwide, 802.16 supports flexible channel bandwidths. For example, if an operator is assigned 20 MHz of spectrum, that operator could divide it into two sectors of 10 MHz each, or 4 sectors of 5 MHz each. By focusing power on increasingly narrow sectors, the operator can increase the number of users while maintaining good range and throughput. To scale coverage even further, the operator can re-use the same spectrum in two or more sectors by creating proper isolation between base station antennas.

Coverage. In addition to supporting a robust and dynamic modulation scheme, the IEEE 802.16 standard also supports technologies that increase coverage, including mesh topology and "smart antenna" techniques. As radio technology improves and costs drop, the ability to increase coverage and throughput by using multiple antennas to create "transmit" and/or "receive diversity" will greatly enhance coverage in extreme environments.

Quality of Service. Voice capability is extremely important, especially in underserved international markets. For this reason the IEEE 802.16a standard includes Quality of Service features that enable services including voice and video that require a low-latency network. The grant/request characteristics of the 802.16 Media Access Controller (MAC) enables an operator to simultaneously provide premium guaranteed levels of service to businesses, such as T1-level service, and high-volume "best-effort" service to homes, similar to cable-level service, all within the same base station service area cell.

Security. Privacy and encryption features are included in the 802.16 standard to support secure transmissions and provide authentication and data encryption.

Benefits of Standards

Standards are important for the wireless industry because they enable economies of scale that can bring down the cost of equipment, ensure interoperability, and reduce investment risk for operators. Without industry-wide standards, equipment manufacturers must provide all the hardware and software building blocks and platforms for themselves, including the fundamental silicon, the sub-

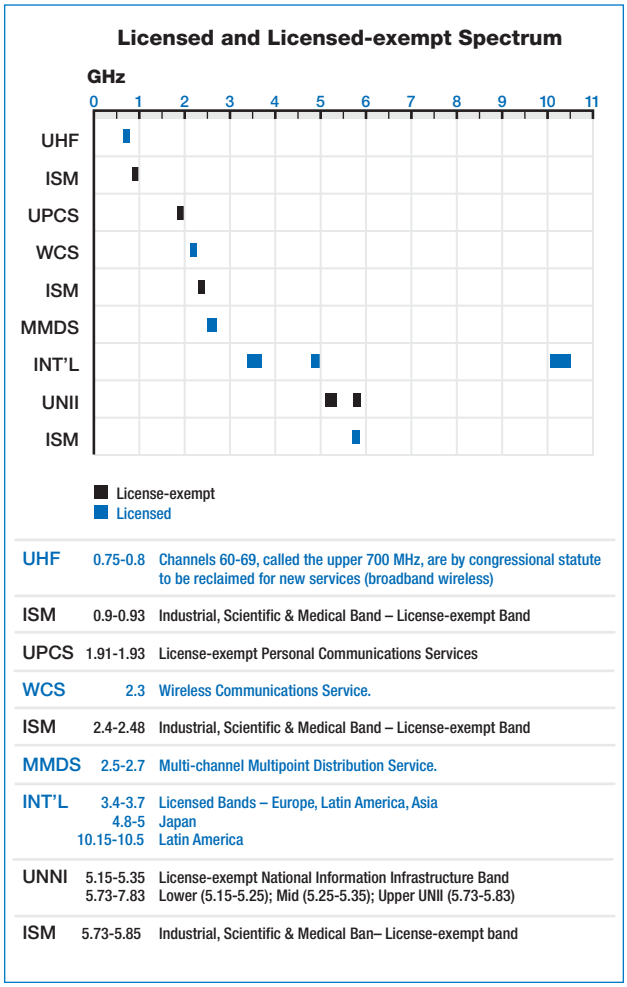

Figure 4 – The IEEE 802.16 standard is designed for licensed and license-exempt spectrum to accommodate easier cell planning throughout the world.

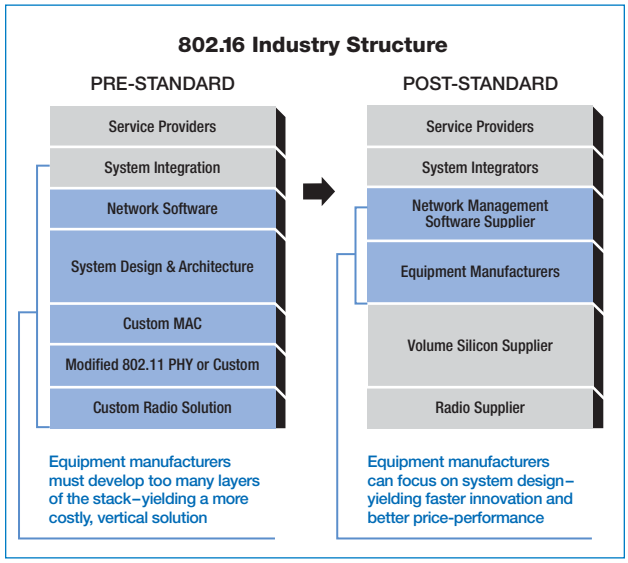

Figure 5 – With the IEEE 802.16 standard equipment manufacturers can focus their resources on innovative system design for improved price/performance.

scriber station, the base station, and the network management software that is used to provision services and remotely manage the subscriber station. With the 802.16 standard in place, suppliers can amortize their research and development costs over much higher product volume. For example, a volume silicon supplier can supply the same standard component to many equipment makers at a far lower cost than would be possible if the device manufacturers were required to develop proprietary silicon for use only by their equipment.

Standards also specify minimum performance criteria for equipment, enabling a common broadband wireless access baseline platform that equipment manufacturers can use as the foundation for ongoing innovations and faster time-to-market. With its broad industry support, the 802.16 standard lets device manufacturers and solutions vendors do what they do best, achieving overall price/performance improvements and opening mass-market opportunities that cannot be equaled by proprietary approaches.

WiMAX Focuses on Interoperability

WiMAX (the Worldwide Interoperability for Microwave Access Forum) is a non-profit corporation formed by equipment and component suppliers, including Intel Corporation, to promote the adoption of IEEE 802.16 compliant equipment by operators of broadband wireless access systems. The organization is working to facilitate the deployment of broadband wireless networks based on the IEEE 802.16 standard by helping to ensure the compatibility and interoperability of broadband wireless access equipment. In this regard, the philosophy of WiMAX for the wireless MAN is comparable to that of the Wi-Fi* Alliance in promoting the IEEE 802.11 standard for wireless LANs.

In an effort to bring interoperability to Broadband Wireless Access, WiMAX is focusing its efforts on establishing a unique subset of baseline features grouped in what is referred to as “System Profiles” that all compliant equipment must satisfy. These profiles will establish a baseline protocol that allows equipment from multiple vendors to interoperate, and that also provides system integrators and service providers with the ability to purchase equipment from more than one supplier. System Profiles can address the regulatory spectrum constraints faced by operators in different geographies. For example, a service provider in Europe[1] operating in the 3.5 GHz band who has been allocated 14 MHz of spectrum is likely to want equipment that supports 3.5 and/or 7 MHz channel bandwidths and TDD (time-division duplex) or FDD (frequency-division duplex) operation. Similarly, a WISP in the U.S. using license-exempt spectrum in the 5.8 GHz UNII band may desire equipment that supports TDD and a 10 MHz bandwidth. WiMAX will establish a structured compliance procedure based upon the proven test methodology specified by ISO/IEC 9646[2].

The process starts with standardized Test Purposes written in English, which are then translated into Standardized Abstract Test Suites in a language called TTCN[3]. In parallel, the Test Purposes are also used as input to generate test tables referred to as the PICS (Protocol Implementation Conformance Statement) pro forma. The end result is a complete set of test tools that WiMAX will make available to equipment developers so they can design in conformance and interoperability during the earliest possible phase of product development. Typically, this activity will begin when the first integrated prototype becomes available.

Ultimately, the WiMAX suite of conformance tests, in conjunction with interoperability events, will enable service providers to choose from multiple vendors of broadband wireless access equipment that conforms to the IEEE 802.16a standard and that is optimized for their unique operating environment. Internationally, WiMAX will work with ETSI, the European Telecommunications Standards Institute, to develop similar test suites for the ETSI HIPERMAN standard for European broadband wireless metropolitan area access.

1. European radio standards are developed through ETSI (European Telecommunications Standards Institute).
2. IEC is the International Electrotechnical Commission, a leading global organization that publishes international standards for all electrical, electronic, and related technologies.
3. TTCN: Tree and Tabular Combined Notation.

WiMAX has key benefits for operators. By choosing interoperable, standards-based equipment, the operator reduces the risk of deploying broadband wireless access systems.

- Economies of scale enabled by the standard help reduce monetary risk.
- Operators are not locked in to a single vendor because base stations will interoperate with subscriber stations from different manufacturers.
- Ultimately, operators will benefit from lower-cost and higher-performance equipment, as equipment manufacturers rapidly create product innovations based on a common, standards-based platform.

Intel Corporation and the IEEE 802.16 Standard

To help accelerate the deployment of wireless broadband access Intel Corporation is taking a leading role in industry-enabling programs and working to build the ecosystem for IEEE 802.16. Intel's involvement includes:

- Board member and officer of WiMAX
- Board member of the Wireless Communications Association International (WCA), including chair of the Rural Broadband Task Force and chair of the License Exempt Alliance
- A lead role in accelerating the completion of conformance test specifications (802.16d) and mobility specifications (802.16e) and chair of the IEEE 802 Handoff Study Group.

Conclusion

The cost and complexity associated with traditional wired cable and telephone infrastructure have resulted in significant broadband coverage gaps in the U.S. and international geographies. Early attempts to use wireless technology to fill these coverage gaps have involved a number of proprietary solutions for wireless broadband access that have fragmented the market without providing significant economies of scale.

High-speed wireless broadband technology based on the IEEE 802.16 standard promises to open new, economically viable market opportunities for operators, wireless Internet service providers, and equipment manufacturers. The flexibility of wireless technology, combined with the high throughput, scalability, long range and Quality of Service features of the IEEE 802.16 standard will help fill the broadband coverage gaps and reach millions of new residential and business customers worldwide. The WiMAX Forum is an industry group focused on creating system profiles and conformance programs to help ensure interoperability among devices from different manufacturers. Intel is actively participating in these industry efforts to help reduce investment risks for operators and service providers while enabling them to more cost effectively take advantage of the tremendous market potential of wireless broadband access.

For More Information

More information on the IEEE 802.16 standard for broadband wireless and information on the WiMAX Forum, is available at www.wimaxforum.org and www.ieee802.org/16

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