WiMAX: Moving Broadband a Giant Step Forward

By Aditya Agrawal and George Wu

WiMAX is poised to tackle the challenge of worldwide broadband interoperability. It is poised to be a significant player in metropolitan area networking and as a wireless alternative for cable, DSL and T1, last mile broadband access, as well as providing backhaul for WiFi hotspots.

Like many other technologies in their early stages, broadband wireless has stalled due to the lack of a universal standard. The World Interoperability for Microwave Access standard (WiMAX) will meet that need. WiMAX is designed to achieve standards conformance, interoperability, quality of service assurances, independent testability, and compliance, which in turn will ensure open interoperability and technological efficiency. It's optimized for fixed applications and, over the longer term, mobile, in the wide area network. Aside from its role in metropolitan area networking, it will enable a wireless alternative for cable, DSL and T1 level services for last mile broadband access, as well as providing backhaul for WiFi hotspots.

WiMAX creates a competitive broadband wireless access market by specifying minimum air-interface performance between and among vendors' products and certifying products that meet the performance benchmarks. The original 802.16 standard for 10 to 66 GHz operation was ratified in January 2001, and the 802.16a amendment to the standard to support lower frequency operation in the 2 to 11 GHz range was approved in January 2003 by the IEEE.

The WiMAX Forum is an industry forum, similar to the WiFi Alliance, with a goal of

promoting the deployment of broadband wireless access networks by using a global standard and certifying interoperability of products and technologies. One of WiMAX's current objectives is to certify equipment that conforms to the mandatory modes of the IEEE 802.16a and the corresponding European standard, ETSI HiperMAN.

The first WiMAX Certified&#153 equipment is likely to be available towards the end of 2004.

Some key attributes of the 802.16a standard are a protocol that supports low latency applications such as voice and video, provides broadband connectivity without requiring a direct line of sight between subscriber terminals and the base station (BTS) and will support hundreds if not thousands of subscribers from a single BTS. The standard will help accelerate the introduction of wireless broadband equipment, speeding up last-mile broadband deployment worldwide by enabling service providers to increase system performance and reliability while reducing their equipment costs and investment risks.

There are three physical layers (PHYs) defined in the IEEE 802.16a standard. The mandatory PHY mode is 256 OFDM (Orthogonal Frequency Division Multiplexing). There are two other PHY modes in the standard, namely Single Carrier (SC) mode and 2048 Orthogonal Frequency Division Multiple Access (OFDMA) mode.

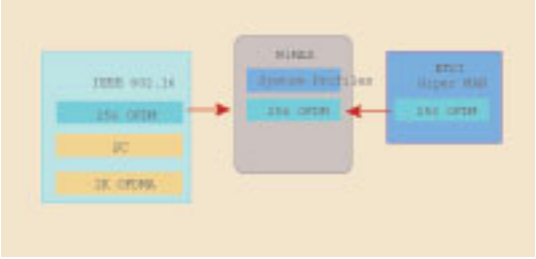

Figure 1. WiMax's objective is to certify both IEEE 802.16 and ETSI HiperMan equipment..

In contrast, the ETSI HiperMAN standard defines a single PHY mode that is identical to the 256 OFDM mode in the 802.16a standard. In keeping with WiMAX's charter to promote interoperability for equipment built on either the 802.16 standard or the HiperMAN standard, WiMAX has made the choice to support the 256 OFDM mode as the single PHY mode for which it will certify equipment. In effect, WiMAX-certified equipment will need to operate in 256 OFDM.

The use of 256 OFDM provides very good non-line of sight capability. Just as a reference, 802.11a and 802.11g each use 64 OFDM. Utilizing this larger OFDM provides for greater range because a receiver that use 256 OFDM can tolerate delay spreads of up to 10 times greater than systems that use 64 OFDM.

Figure 1. Up and downlink packets with contention slot.

This greater range is just one of many critical factors that make WiMAX systems attractive for a service provider interested in deploying such equipment. Some of the other factors that make WiMAX-certified equipment attractive to service providers include the following: Quality of Service (QoS) provisioning: The 802.16 MAC (Media Access Control) layer uses a grant-request based mechanism for letting users into the network. In contrast with CSMA/CD or CSMA/CA mechanisms used in local area networking technologies like 802.11, grant-request based mechanisms allow much higher utilization of available channel resources. For example, when a CSMA/CA based shared LAN environment like 802.11 has less than 10 or so typical users per access point, contention for use of &quotairtime&quot is low. There may be occasional packet collisions and consequent 'backoff' and retransmissions, but overhead caused by the collisions and retransmissions do not waste significant airtime resources. However, if the number of users moves to tens or hundreds of users per access point, there is likely to be a much greater number of users that collide and constantly need to backoff and retransmit data. In such a CSMA/CA environment, reaching average network loading factors of greater than 20 to 30 percent begins to result in an unacceptable number of collision-caused retransmissions.

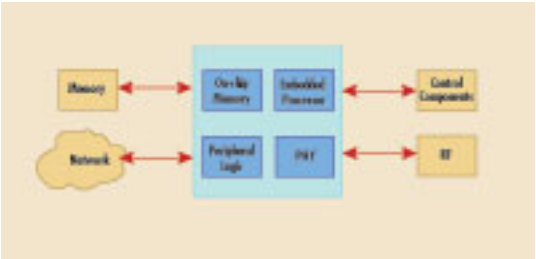

Figure 2. System-on-a-chip concept.

However, using the grant-request mechanism that 802.16 does removes the issue. A small portion of the duration of a frame is designated as a &quotcontention slot&quot in which new users can enter the network and ask the base station to allocate it an uplink (UL) slot. The base station considers the request of the subscriber station in the context of the service level agreement that governs the particular user, and allocates the subscriber station a slot in which it can talk, i.e., send uplink packets.

As more users join the network, the base station schedules the subscribers using dynamic scheduling algorithms, which the service provider can define and modify. Even if there are thousands of users per base station and the load factor of the network is very high, the network does not get bogged down by collisions and retransmissions of packets.

Of course, total network capacity has to be divided between the users attached to the base station, a challenge not unique to WiMAX systems or to wireless technologies. Rather, this is an attribute of any communications technology that uses shared media, like shared 802.3 Ethernet, cable modems or cellular networks. What the 802.16 standard allows service providers to do is to manage the traffic based on their service level agreements with the individual subscribers on a link-by-link basis. Managing the traffic based on SLAs on the link-link basis aligns the price of service with the quality of service fairly and evenly.

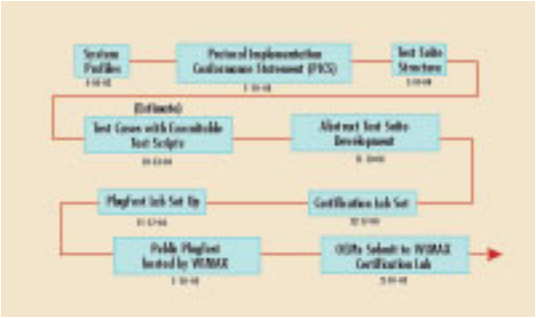

Figure 3. The roadmap for WiMax Interoperability certification. (Source: WiMax Forum)

Link-by- Link Manageability (LLM): Different subscribers on the network can be at very different distances from the base station. To optimally serve these subscribers with the best possible data rate they can receive, each subscriber's link is individually managed by the base station. A subscriber station that is closer to the base station will have greater signal strength and is capable of using 64QAM modulation. In contrast, a subscriber located further away may only be able to get connected using 16QAM or QPSK. The 802.16 MAC allows each subscriber's link to be managed individually and the modulation method for each subscribers downlink and uplink bursts can be different.

For example, as shown in the figure above, DL #1 might be using 64QAM while DL #2 may use 16QAM or QPSK modulation, and similarly in the uplink direction. The minimum granularity of either the DL burst of the UL burst is one OFDM symbol consisting of 192 symbols.

Support for Voice and Video: QoS provisioning and Link-by-Link Manageability enable support for services like high quality voice and video. To manage and control the latency of voice packets through the air interface part of the network, voice packets can be tagged as such and the base-stations' scheduler can provide deterministic latency to these packets to allow for toll quality voice traffic.

Flexible Channel Sizes: Different countries have different regulations for spectrum allocations for both licensed and license-exempt bands. Moreover, different service providers will have different chunks of licensed spectrum available for use.

To allow for these variations, the standard allows for use of different channel bandwidths ranging from channel sizes as low as 1.5 MHz to as high as 20 MHz. Some popular channel bandwidths are likely to be 5 MHz, 7 MHz and 10 MHz.

Advanced Security: The 802.6 standard defines DES and Triple DES as the mandatory encryption mechanisms for data and key, respectively. This was defined in the standard some years ago and is since in the process of being revisited by WiMAX to incorporate advances made in this arena in the past few years. Accordingly, WiMAX profiles now define AES as an alternate means of encryption that may end up being the preferred choice for service providers at least in many of the industrialized nations of the world where WiMAX equipment gets deployed.

WiMAX System Implementation Considerations

A WiMAX based system deployment at its simplest consists of a Base Station (BS) and a Subscriber Station (SS). Base Stations can range from basic units that can support only a few users to more elaborate units that support thousands of users and provide a host of carrier class features. Since the BS actively manages many Subscriber Stations and each SS just follows instructions that the BS issues, the BS implementation and SS implementations can differ substantially. In the early phases of the deployment lifecycle, the hardware for a BS will be implemented largely by using FPGAs, standard product microprocessors, discrete RF components, and customized software for the 802.16 MAC, scheduler and other software components.

Pre-WiMAX Subscriber Station units for broadband wireless access have until now been implemented using either FPGAs and discrete RF components or custom ASICs and semi-integrated RFIC components. With the advent of WiMAX, it is now attractive for silicon vendors like Fujitsu Microelectronics and Intel to develop integrated silicon solutions.

A integrated WMAN System-on-a-chip (see Figure 2) is an example of the integrated silicon planned for availability in the second half of the year. It integrates PHY and MAC functionality on one chip using an embedded processor to run the 802.16 MAC in software.

With availability of such integrated solutions, the selling price to the end consumer of WiMAX Subscriber Stations will likely be in the $300 to $350 range, and will drop further as volume drives prices lower.

One of the challenges for silicon and equipment vendors alike in any standards based market is one of differentiating themselves versus their competition. Fortunately, and unlike some other standards based markets, there are many areas over and above the standards with which silicon and equipment vendors can differentiate themselves.

Base Station: WiMAX Base-stations are expected to come in many different, shapes, and sizes. They could range from basic Base-stations that support a few users to redundant, rack mounted base-stations, to server blades designed to sit alongside wireline networking equipment. Software requirements and capabilities for different classes of base-stations will also be different. Antenna capabilities and the ability of base stations to handle frequency reuse also will differ between different vendors.

Subscriber Station: Whether an equipment vendor is able to provide one of more differentiating capabilities could be tightly linked to the capabilities of the integrated silicon being used to implement the subscriber station. For example, if a silicon vendor's solution is flexible enough to allow an equipment vendor to use their own MAC software or other software on the subscriber station, it could be of immense value to equipment vendors whose main differentiation may lie in the subscriber station software domain. Similarly, different equipment vendors may choose to focus on different frequency bands since each band poses its own set of

system level challenges and requires a different RF solution.

Certification and Interoperability

Providing a means to ensure interoperability between equipment from different system vendors is a key role that the WiMAX Forum is playing. This is much like the role played by the WiFi Alliance with respect to the 802.11 standard. Just as interoperability between different vendors equipment was a key factor in helping drive the large volumes in the WiFi market, interoperability will be a key determinant in whether WiMAX equipment will see mass deployment. In the case of the WiFi Alliance, or WECA as it was then called, interoperability efforts were started long after the 802.11 standard was first ratified in 1997. WiMAX has learned from this experience and to accelerate adoption of the technology, has started its work to ensure equipment interoperability much sooner.

The Technical Working Group (TWG) within WiMAX is chartered with driving interoperability efforts. Figure 3 below illustrates the process that is being followed that will lead to WiMAX Certified interoperable vendor equipment.

The IEEE 802.16 standard, like most other standards, is a constantly improving standard, with ongoing discussions in the IEEE standards group about amendments to the 802.16a standard &#151 called 802.16d &#151 designed to improve the performance capabilities. WiMAX Forum constantly follows these improvements and as a result of these improvements more system profiles will be added by WiMAX to address the increasing capabilities defined by the base standards. At the same time, WiMAX's charter is to maintain backwards compatibility with already deployed WiMAX equipment. Following 802.16d, there is work being done in the IEEE group on 802.16e standard that will enable portability and nomadic mobility to enable ubiquitous connectivity anywhere. In addition, another set of efforts is in place to review the handoff between 802.11 and 802.16, which will further support the vision of ubiquitous broadband wireless connectivity. As an example: a user's laptop could transition from using a WiFi hotspot or enterprise WiFi WLAN to a WiMAX network provided by a local service provider seamlessly and without user intervention while maintaining network connectivity.

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Glossary Of Acronyms

WiMAX - World Interoperability for Microwave Access Standard
WiFi - Wireless High Fidelity
PHY - Physical Layer

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