Business White Paper
Broadband Wireless Access

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What WiMAX Forum Certified™ products will bring to Wi-Fi™

While Wi-Fi allows for wireless broadband connectivity within the local area, WiMAX Certified products will extend the broadband wireless experience to the metropolitan area network (MAN). As WiMAX technologies evolve, end users will be able to experience a "best connected" model. In time, WiMAX Forum Certified equipment vendors may develop products that support a combination of Wi-Fi LAN technology and WiMAX MAN technologies. This will enable untethered roaming between business and residential locations as well as broader campus and metropolitan areas. This paper will provide a framework for Wi-Fi and WiMAX network coexistence and technology migration.

Contents

Introduction

Broadband Wireless Access (BWA) has historically had limited success due to the lack of consensus on a common industry standard. This is now changing. The 802.16 standard, developed by the IEEE, in concert with the HIPERMAN standard developed by the European Telecommunications Standards Institute (ETSI), have allowed the BWA industry to develop products to a single global standard. The WiMAX Forum has been developed to promote the use and interoperability of the 802.16/HIPERMAN standard worldwide.

WiMAX products promise to set a new standard in BWA performance. WiMAX Forum Certified products will extend the range of Wi-Fi networks from the local area to the metropolitan area and beyond. These products will be based upon the 802.16 standard and will support distances of up to 50 kilometers (30 miles). These are far longer distances than those supported by Wi-Fi products. WiMAX products are highly efficient, supporting spectral efficiencies of up to 5 bps/Hz in line-of-sight (LOS), obstructed line-of-sight (OLOS) and non-line-of-sight (NLOS) paths. With frequency reuse, base stations can support hundreds of megabits per second (Mbps) of link capacity to service hundreds of business and residential customers.

The BWA industry expects that WiMAX Forum Certified products will be successful for a number of reasons. They provide superior performance over proprietary systems while ensuring multi-vendor interoperability. This is a significant benefit for both the service provider and end user communities. As a result, these products are much better suited to last-mile MAN (metropolitan area network) and WAN (wide area network) use than competing proprietary and Wi-Fi based solutions. For the next 12 to 18 months, however, certain proprietary and Wi-Fi-based solutions will remain attractive to service providers and end users due to cost sensitivity.

Why is Wi-Fi used in the MAN?

It is expected that Wi-Fi technologies will continue to dominate the last 30 meters within the home or office - at least during the 2005 to 2007 timeframe. Wi-Fi has gained considerable success during the past two years, as standardization has caused prices to plummet and allowed for the desired economies of scale.

In homes and offices, Wi-Fi enables untethered connectivity to the network at moderate distances with moderate speeds. While the residential market rapidly embraced Wi-Fi technology, adoption has been slower for enterprise networks.

Wi-Fi has been an overwhelming success because it is interoperable, easy to use and inexpensive. During the past 12 months, the hotspot market has emerged in public locations worldwide. Wi-Fi adapters - whether built-in or external - allow users to roam between the home, business, and public hotspots with a freedom not found with wired connectivity.

When Wi-Fi technologies are used in the MAN, three factors must be kept in mind: range, quality of service (QoS) and security. Since standard Wi-Fi technology is limited to a 100-meter range in a LOS environment, each of these three factors influence the design of the network.

The delivery range is significantly reduced in locations where there are obstacles such as trees or buildings. To overcome this, service providers must build wireless Points of Presence (POPs) with a transport network (backhaul), using either wireline or wireless technologies to deliver the bandwidth to each access point. With the limited range of current standards-based solutions, many wireless ISPs use proprietary outdoor wireless solutions to increase coverage. This however negates the low cost and interoperability benefits of Wi-Fi.

In addition, most Wi-Fi products today are not capable of supporting any degree of QoS. This lack of QoS support impacts a service provider's ability to deliver different grades of service to individual business or residential customers. It also impacts their ability to support latency and bandwidth sensitive applications such as Voice over IP (VoIP), audio and video streaming, or enterprise mission critical traffic such as TN3270 sessions. That being said, IEEE's 802.11e working group is developing a set of recommendations that will add a degree of QoS support. However, this, support is not present on any of the products deployed in the field today.

It seems that there are weekly announcements on the subject of Wi-Fi security. The Wi-Fi Alliance has reacted to shortcomings in WEP (Wired Equivalency Privacy) by developing WPA (Wi-Fi Protected Access). WPA has yet to become widely deployed, since it requires both the service provider and the end user to upgrade or replace their systems (access points and network adapters). These security shortcomings are key drivers in the use of WiMAX technologies in the MAN and WAN.

OFDM – the basics

BWA suffers the same limitations as cable and DSL (digital subscriber line). Both cable and DSL are only available to portions of the population. WiMAX Forum member companies intend on serving these gaps through OFDM-based 802.16 systems.

OFDM (orthogonal frequency division multiplexing) is a digital encoding and modulation technology. It has been used successfully in wireline access applications, DSL and cable modems. In these cases, throughput is at a premium and channel conditions can severely impair the performance of alternative encoding and modulation schemes. OFDM has also been used in the digital video broadcast industry throughout Europe for many years to address severe multipath disturbances generating from long-range television transmissions.

OFDM achieves its high data rate and efficiency by using multiple overlapping carrier signals versus just one. This parallel carrier ability is called multi-carrier modulation (MCM) or discrete multi-tone (DMT). It is ideal for addressing errors that may arise from the wireless environment. Using multiple carriers to convey the data helps maintain reliable communication should one or more carriers be affected by propagation anomalies. A similar effect on a single carrier on the other hand, can significantly impact or destroy the link. An appropriate analogy would be a multi-lane highway: should one of the lanes experience blockage, the remaining lanes will allow the traffic to continue flowing smoothly.

With this ability, an 802.16 OFDM-based system can squeeze a 72 Mbps uncoded data rate (~100 Mbps coded) out of 20 MHz of channel spectrum. This translates into a spectrum efficiency of 3.6 bps per Hz. Five of these 20 MHz channels are contained within the 5.725 to 5.825 GHz band, giving a total band capacity of 360 Mbps (all channels added together with 1x frequency reuse). With channel reuse, and through sectorization, the total capacity from one base station site could potentially exceed 1 Gbps.

The key advantage of OFDM over single carrier modulation schemes is the ability to deliver higher bandwidth efficiency and therefore higher data throughput. This can be achieved even in the face of challenging deployments - for example, where there is significant degradation in NLOS links due to multipath conditions (i.e. the transmitted signal arrives at the receiver using various paths of different lengths).

To further improve their performance in adverse channel conditions, OFDM systems can be used in conjunction with Convolutional interleaving/Viterbi decoding and Reed-Solomon coding. Such coded-OFDM (COFDM) signal design strategies have been developed and optimized as part of the 802.16 standardization process, where the standard specifies concatenated (or linked) Reed-Solomon/Convolutional coding as a mandatory mode.

802.16/HIPERMAN OFDM PHY

The PHYsical Layer (PHY) defined by 802.16 has three variants: single carrier (optional), 256 carrier OFDM, and 2048 carrier Orthogonal Frequency Division Multiplexing Access (OFDMA) (optional). The WiMAX Forum has elected to focus initial work around the 256 OFDM variant. A practical implementation of a WiMAX-conformant PHY data engine therefore would include a 256-point Fourier Transform (FFT) programmable OFDM processor with associated FFT engines, and incorporate a variable guard interval - also called a cyclic prefix (1/4, 1/8, 1/16, 1/32). In the 802.16 approach, eight pilot carriers are used per OFDM symbol, and Reed-Solomon/Convolutional coding is used as a Forward Error Connection (FEC) technique (see above).

The standard also defines the use of adaptive modulation (Binary Phase Shift Keying (BPSK), QPSK, 16QAM and 64QAM) using CINR (the ratio of carrier/interference plus noise) measurements as a guide to selecting the highest modulation rate possible while maintaining an acceptable Bit Error Rate (BER) through the use of Automatic Repeat Request (ARQ). In essence, adaptive modulation selects the highest data rate consistent with the lowest error rate, therefore trading off capacity for quality of service. To avoid Transmission Control Protocol (TCP) retransmissions and congestion, the ARQ will “hide” the error from the real TCP stack, and simulate TCP error correction at a lower layer. The PHY will retry a send-receive sequence at a lower modulation level to try to correct the error. The PHY link level error correction occurs much faster, thus maximizing data rate, even in the presence of some errors. The combined use of these two techniques allows systems to achieve real-world BER performance of 10e-9.

The transmit path (Tx Path) of the PHY operates on the complex Quadrature Amplitude Modulation (QAM) systems provided by the interleaver and produces a time domain signal sampled at the FFT rate. The Tx Path also provides the QAM to OFDM symbol mapping functions and performs:

- Pilot modulation and insertion
- Cyclic prefix insertion
- Preamble generation
- Frequency offset pre-correction
- Time domain windowing.

The receive path (Rx Path) of the PHY operates on samples from the Analog Front End (AFE) and produces equalized complex QAM symbols which are then fed to a de-interleaver. The Rx

Path produces quality and ranging information for each connection in a multipoint sector. Further functions provided by this chain include:

- Automatic Gain Control (AGC) setting
- Frequency/frame/symbol synchronization
- Channel estimation
- Equalization
- Receive Signal Strength Indicator (RSSI) and Signal to Noise Ratio (SNR) per sub-carrier estimation
- Frequency offset error correction
- Pilot extraction
- Time and phase correction
- Frequency/ timing tracking loop
- Timing drift correction.

802.16/HIPERMAN MAC

The IEEE 802.16 standard provides for the same Media Access Control (MAC) layer for all PHYs (single carrier, 256 OFDM, 2048 OFDMA). It is important to note that the same MAC is also used for the HIPERMAN OFDM standard. This connection-oriented MAC provides for a Time Division Multiplex (TDM) downlink coupled with a Time Division Multiple Access (TDMA) in the uplink.

The standard as defined supports both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) operation, as well as provides for a Half Duplex FDD (HD-FDD) mode. TDD is a technique in which the system transmits and receives within the same channel, assigning time slices for transmit and receive modes. FDD requires two separate spectrum allocations generally separated by 50 to 100 MHz within the operating band. TDD provides an advantage where spectrum is allocated by a regulator in an adjacent block. This is the case with the Industrial Scientific and Medical Equipment (ISM) and Unlicensed National Information Infrastructure (UNII) bands in Canada and the United States. With TDD there is no need for band separation. Thus the entire spectrum allocation is used efficiently both upstream and downstream and where traffic patterns are variable or asymmetrical.

The MAC contains a queuing and traffic-shaping engine (QE) that is ultimately responsible for the reception and transmission of 802.16a packets according to the enforced QoS parameters. These parameters can be different from service flow to service flow. The QE is also responsible for command dispatching to the Multi-Dwelling Unit (MDU) and all modem blocks, and supports efficient availability of the modem with minimal dependence on software timing and availability. Other QE functions include interfacing modem units status values, where the queuing manager in general depends on the sequence or speed status resulting from previous activities.

The MAC is also responsible for managing the process of OFDM symbol data padding (all 1's) and Co-Channel (CC) return-to-zero bits. Other functions within the MAC include:

- Parsing
- TDD frame building
- CRC calculation and success/failure detection
- DES encryption/decryption
- Key handling
- Data/header separation and concatenation or fragmentation between MPDU
- Message management
- Rx and Tx data FIFOs management
- Packet header operation in the Rx chain.

What do service providers want from 802.16?

WiMAX products were built from the ground up to meet the requirements of both large and small service providers. Over the next 12 to 24 months, the BWA industry can expect that WiMAX will become the dominant delivery technology for the MAN. Wi-Fi technologies will revert to being used predominantly for in-home, office or public hotspot LANs.

A service provider deploying WiMAX Forum Certified systems has a formidable advantage. By deploying 802.16 BWA technologies, a next generation carrier can develop and deploy a very nimble architecture that leverages many of the core value added features of wireless systems. By their very nature, 802.16 systems are flexible. The technology can be redeployed quickly without jeopardizing existing capital investment. Second generation BWA technologies based upon 802.16/HIPERMAN will bring new tools into the hands of service provider engineering and marketing teams.

Public and private network operators worldwide appear to have converged on a set of requirements that must be met by successful equipment manufacturers hoping to win their business. These requirements are outlined in Figure 1 below.

General Operator Requirements	802.16 addresses by….
True Broadband Speeds	➢ 802.16 delivers > 1 Mbps per user: 69 Mbps (coded) in a 14 MHz channel – 52 Mbps (uncoded) of usable data.
NLOS	➢ OFDM-based 802.16 systems offer better multipath protection (due to Intersymbol Interference) than CDMA based 802.11x systems.
High Link Budget	➢ 802.16 systems will typically deliver > 150 dB of link budget.
High number of Simultaneous Sessions	➢ 802.16 systems will generally offer > 100 simultaneous sessions per carrier.
High Spectral Efficiency	➢ 802.16 offers > 5 bps/Hz in 64QAM mode and cell radii >30 km in Quadrature Phase Shift Keying (QPSK) mode.
Large Channel Bandwidth	➢ 802.16 systems offer between 1.5 and 20 MHz channel plans matching with worldwide regulatory regimes.
Low Latency	➢ Systems latencies will meet operator requirements for voice, video and data applications.
IP Quality of Service	➢ Depending upon the system provider, full Class, Service, Protocol and Application based differentiation can be provided for (Internet Engineering Task Force (IETF) L3 – L7 protocols.

Figure 1: Operator requirements for BWA systems

A key element for the operator is a system design focused on minimizing the cost of installation. This can be achieved through high system gain; smart antenna technology; and/or Multiple Input Multiple Output (MIMO) techniques, and other measures. The objective of all this is clear: eliminate or minimize the cost of “truck rolls” to the operator.

Another critical system level requirement is a robust scheduler to address “carrier-class” deployments, where thousands of subscriber stations may be deployed within the catchment area of a single base station.

In order to provide the breadth of advanced data services desired by operators, it is important that a fully functioned L2 – L7 classifier be included within the MAC on the selected BWA system. The system should also fully support 802.1p/Q tagging and evolve to support Multi Protocal Label Switching (MPLS) as required by the operator.

Many operators are electing to use wireless to support all of their services. Therefore, they are looking for base station and subscriber station hardware that provides support for both structured and unstructured T1/E1 traffic.

Finally, the system should have an associated element management system that enables full Fault Configuration Accounting Performance Security (FCAPS) support. This should include a provisioning methodology that meets the varying business models of public and private network operators.

Ultimately, WiMAX products will be successful if the equipment vendor community delivers products that meet the abovementioned operator requirements. The key will be delivering high performance levels at a reasonable cost in a timely fashion. Service providers, for their part, will focus on three key deliverables: range, CPE (customer premise equipment) cost/form factor, and the overall ease of use of the system.

Applications where Wi-Fi and WiMAX can complement each other

Generally, it is accepted that WiMAX will be used to deliver bandwidth to Wi-Fi. Because it delivers greater bandwidth over distance, it will likely be used as the transport solution for several key service models.

In Europe and less developed countries, the majority of the population lives in MDUs. This is a natural service model for WiMAX and Wi-Fi to coexist. A service provider can use WiMAX products in either a point-to-multipoint (PMP) or point-to-point (PTP) mode to deliver multiple megabits of traffic to a building. Wi-Fi can then be used to distribute Internet service to suites within the building, as well as public spaces such as lobbies and special function rooms. This same service architecture can be used with multi-tenant units (MTUs) to deliver voice, video and data services to small/medium enterprises (SMEs).

Some WiMAX Forum member companies will develop CPE that will enable the use of WiMAX as an access technology to the residence, combined with Wi-Fi distribution within the home. These dual PHY/RF systems will likely use a licensed band as the WiMAX downlink/uplink connection to the service provider's edge network. License-exempt Wi-Fi technology will be used within the residence to deliver bandwidth for applications within the home. Alternatively, a split architecture could be used where there is an outdoor antenna/radio and an indoor residential gateway device providing the power to the outdoor unit and the Wi-Fi distribution.

Finally, WiMAX products are natural backhaul media for Wi-Fi public hotspots. Backhaul is the greatest contributor to operations cost in the hotspot service provider's business model. WiMAX products will deliver high bandwidth with a one time capital expense to the hotspot service provider. The ability to use licensed or license-exempt WiMAX products to connect the public hotspot site with the service provider's POP is a major driver for WiMAX/Wi-Fi coexistence.

What are the benefits of using a standards-based solution?

Service providers who engage with WiMAX member companies today can help drive the development of standards-based products that support their desired business models. It has been seen in the wireless industry that the use of standards-based technologies can quickly drive down costs through high volumes. This has prompted silicon manufacturers to develop ever more integrated devices, which contributes to the downward product cost spiral. This cycle has already been witnessed in Ethernet, DSL and Wi-Fi products. The more traction a standard gains, the lower the eventual cost of the CPE and associated common equipment.

Selecting a WiMAX Forum Certified product allows service providers and end users the option of building a multi-vendor network. They can adopt the standard earlier and be assured that if their primary vendor cannot meet their needs, another vendor will. This multi-vendor approach will also allow service providers to develop business relationships with a broad base of WiMAX vendors. This in turn will result in industry-wide collaborative efforts to create WiMAX awareness in the region and drive the demand for wireless broadband services.

How does a product obtain WiMAX Forum Certified status?

In order to mark a product as WiMAX Forum Certified, a WiMAX Forum member company must follow a two-step process. A representative must attend a WiMAX Forum PlugFest to prove product interoperability with another WiMAX member company. The product must be tested by a WiMAX Forum approved certification body to validate conformance. Equipment manufacturers who successfully complete this two-step process can validate that their product is interoperable with another WiMAX Forum Certified product. It is also proven that these products are conform with the system profiles adopted by and promoted by the WiMAX Forum. Once proven, a WiMAX Forum Certified seal of approval can be placed on the product.

What are the current timelines for certification?

During the first half of 2004, the WiMAX Forum Technical and Certification Working Groups have been developing a series of systems profiles and interoperability tests. The certification process is expected to launch during the first half of 2005. The process will be conducted at designated facilities to be announced shortly. The development of these profiles is a key milestone in the WiMAX Forum's efforts to emulate the success of Wi-Fi in the local area market, with WiMAX in the metropolitan and wide area.

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Mr. Suitor is Vice President, Business Development at Redline Communications. Hebrings to Redline extensive market and technology knowledge of North American service providers and equipment manufacturers. Before joining Redline, Mr. Suitor held various senior level positions in several organizations, most recently with CopperCom's Business Development Group. Earlier, he built a solid track record at the executive level in a variety of roles with organizations such as CTI Datacom, Tekelec, DCI Digital Communication Inc. and Wandel & Goltermann. Mr. Suitor has written numerous contributed articles in a variety industry publications and is a regular speaker on topics such as WiMAX, ATM, Gigabit Ethernet, Virtual Private Networks and Voice Services.

Attributing company: Redline Communications Inc.

Redline Communications is a technology leader in the development of standards-based broadband wireless access solutions. Its groundbreaking and award winning products feature longer range, more robust performance, and higher capacity than competing products. Redline is a principal member of the WiMAX Forum™, and was first in the world to market an 802.16 compliant product.

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