Business White Paper
Broadband Wireless Access

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

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. As WiMAX technologies move out over time, end-users will be able to experience a "best connected" model. WiMAX Forum Certified™ equipment vendors may develop products that support a combination of Wi-Fi™ LAN technology and WiMAX MAN technologies to enable untethered roaming between the business location and residence and the broader campus and metropolitan area. This paper will develop a framework for Wi-Fi and WiMAX network coexistence and technology migration.

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Introduction

Broadband Wireless Access (BWA) has had limited success to date since it was lacking a common standard around which an industry could coalesce. 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 to a single global standard. The WiMAX Forum™ has been developed in order to promote the use and interoperability of the 802.16/HIPERMAN standard world-wide.

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 – far longer distances than supported by Wi-Fi™ products. WiMAX products set a new standard in BWA performance. The products are highly spectrally efficient supporting spectral efficiencies of up to 5 bps / Hertz in Line of Sight (LOS), Obstructed Line of Sight (OLOS) and Non Line of Sight (NLOS) paths. With frequency reuse, base stations will be able to support hundreds of megabits per second (Mbps) of link capacity supporting hundreds of business or residential customers.

The BWA industry expects that WiMAX Forum Certified products will be successful since they provide superior performance to proprietary systems with the assurance of multi-vendor interoperability much desired by the service provider and end user communities. In short, these products are much better suited to last-mile MAN and WAN use than competing proprietary and Wi-Fi™ based solutions. For the next 12 – 18 months, certain proprietary and Wi-Fi™-based solutions will remain attractive to service providers and end users where there is a degree of cost sensitivity.

Why is Wi-Fi used in the MAN?

It is expected however that Wi-Fi™ technologies will continue to dominate the last 30 meters within the home or office during the 2005 – 2007 timeframe. Wi-Fi™ has been very successful during the past twenty-four months, as prices have plummeted due to the economies of scale brought about by standardization.

In homes and offices, Wi-Fi™ allows untethered connectivity to the network at moderate distances with moderate speeds. While the residential market rapidly embraced the use of Wi Fi™ technology, it has been slower to move into enterprise networks. During the part twelve months, the hotspot market has emerged in public locations world-wide. Wi-Fi™ adapters whether built-in or external allow users to roam between the home, business, and public hotspots

with a freedom not allowed by wired connectivity. In short, Wi-Fi™ has been an overwhelming success because it is interoperable, easy to use, and cheap.

When Wi-Fi™ technologies are used in the MAN, three factors must be kept in mind: range, Quality of Service (QoS) and Security. Each of these factors influence the design of the network, standard Wi-Fi™ technology is limited to a 100m range in a LOS environment.

The range delivered is significantly reduced if there are significant numbers of obstacles such as trees or building. To overcome this when building an urban canopy coverage model, service providers need to build a significant number of wireless Points of Presence (POPs) with a transport network (backhaul) using either wireline or wireless technologies delivering the bandwidth to each access point. Because of limited range with standards-based solutions many wireless ISPs use proprietary outdoor wireless solutions that allow for a greater coverage losing the desirable benefit of Wi-Fi™'s low cost and interoperability.

Today, most Wi-Fi™ clients are not capable of supporting any degree of QoS. IEEE's 802.11e working group is working on 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. This lack of QoS support impacts a service providers ability to deliver different grades of service to individual business or residential customers and also impacts their ability to support latency and bandwidth sensitive applications such as Voice over IP (VoIP), streaming audio and video or enterprise user mission critical traffic such as TN3270 sessions.

It seems that there are weekly announcements of various exploits of Wi-Fi™'s 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 and requires that both the service provider and the end user upgrade their system (Access Point and Network Adapter) to the latest revision if allowed by the hardware in use. This relative lack of security is one key driver towards the use of WiMAX technologies in the MAN and WAN.

OFDM – The Basics

BWA faces the same limits as cable and DSL – both cable and DSL are great technologies that only portions of the population can access. WiMAX Forum member companies intend on serving these "pockets of opportunity" by filling the gaps using OFDM-based 802.16 systems.

OFDM is a digital encoding and modulation technology. It has been used successfully in wire-line access applications, such as Digital Subscriber Line (DSL) modems and cable modems, where throughput is at a premium and channel conditions 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 harsh multi-path disturbances arising from long-range television transmissions.

OFDM achieves its high data rate and efficiency by using multiple overlapping carrier signals instead of just one. This parallel carrier ability is called multi-carrier modulation (MCM) or Discrete Multi-Tone (DMT), and is ideal for addressing errors that may arise from the wireless environment. By using multiple carriers to convey the data, reliable communication is still maintained should one or more carriers be affected by propagation anomalies, unlike single carrier, where a similar effect significantly impacts or destroys the link. An analogy can be drawn with a multi-lane highway – should one of the lanes experience blockage, the remaining lanes will allow the traffic to continue flowing smoothly.

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 – 5.825 GHz band giving the band a total capacity of 360 Mbps. (All channels added together with 1x frequency reuse). With channel reuse, through sectorization, at the base station, 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 even in the face of challenging deployment scenarios such as NLOS links suffering from significant degradation due to multipath (i.e. the transmitted signal arrives at the receiver using various paths of different lengths) conditions.

OFDM systems can be used in conjunction with Convolutional interleaving/Viterbi decoding and Reed-Solomon coding to further improve their performance in adverse channel conditions. 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 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 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 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 8 pilot carriers are used per OFDM symbol and Reed-Solomon / Convolutional coding is used as a FEC technique as indicated above.

The standard also defines the use of adaptive modulation (BPSK, QPSK, 16QAM and 64QAM) using CINR measurements as a guide to selecting the highest modulation rate possible while maintaining an acceptable BER through the use of ARQ (Automatic Repeat Request). 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 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 Bit Error Rate (BER) performance of 10e-9.

The transmit path (Tx Path) of the PHY operates on the complex QAM systems being 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 and 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 deinterleaver. 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; estimation of RSSI and SNR per sub-carrier; frequency offset error correction; pilot extraction; time and phase correction; frequency/ timing tracking loop; and 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 HiperMAN OFDM standard. This MAC is connection oriented and provides for a Time Division Multiplex (TDM) downlink coupled with a Time Division Multiple Access (TDMA) access in the uplink.

The standard as defined supports both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) operation and 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 mode. FDD requires two separate spectrum allocations generally separated by 50 – 100 MHz within the operating band. TDD provides an advantage where spectrum is allocated by a regulator in a contiguous block, such as is the case with the ISM and 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. QoS parameters can be different from service flow to service flow. The QE is also responsible for command dispatching to the 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; the queuing manager in general depends on the status resulting from previous activities both in sequence or speed.

The MAC is also responsible for managing the process of OFDM symbol data padding (all 1's) and 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; management messages; management of the Rx and Tx data FIFOs; and 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 twelve to twenty-four months the BWA industry can expect that WiMAX will become the dominant delivery technology for the MAN and Wi-Fi™ technologies will revert to being used predominately in the LAN be it within the home, office or public hotspot location.

A service provider who elects to deploy 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 in that the technology can be redeployed quickly and essential capital is not stranded in the ground. Second generation BWA technologies based upon 802.16/HIPERMAN bring new tools into the hands of service provider engineering and marketing teams.

Public and private network operators world-wide seem 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 useable data
NLOS Operations	➢ 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 QPSK mode
Large Channel Bandwidth	➢ 802.16 systems offer between 1.5 and 20 MHz channel plans matching with worldwide regulatory regimes.
Low Latency	➢ System 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 IETF L3 - L7 protocols

Figure 1: Operator Requirements for BWA Systems

Key to the operator is a system design that is focused on minimizing the cost of installation. This can be achieved through high system gain; smart antenna technology; MIMO techniques etc. but the objective 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 many if not most 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 MPLS as required by the operator.

Many operators are electing to use wireless to support all of their services and therefore 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 FCAPS support including a provisioning methodology that meets the varying business models of public & private network operators.

Ultimately, WiMAX products will be successful if the equipment vendor community manages to deliver products that meet the operator requirements detailed above. The key will be delivering the performance promised at reasonable cost in a timely fashion. Service providers will focus on three key deliverables: the range delivered; CPE cost and form factor; and finally 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™. It has the capability to deliver greater bandwidth at distance so therefore will likely be used as the transport solution for several key service models.

In Europe, and most less developed countries the majority of the population lives in Multi-Dwelling Units (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) mode or in Point to Point (PTP) mode to deliver multiple megabits of traffic to a building. Wi-Fi™ can then be used to distribute the internet service to the suites within the building and 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 for the residence with a 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 metro edge network with license exempt Wi-Fi™ technology used within the residence to deliver bandwidth and applications to computers and internet enabled devices throughout the home. This service model could be used with indoor CPE where the link budget allows or with a split architecture 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 a natural backhaul media for Wi-Fi™ public hotspots. Since backhaul is the greatest contributor to operations cost in the hot spot service providers business model. The use of licensed or license exempt WiMAX products to connect the public hotspot site with the POP of the Hot Spot Service Provider is a key driver for WiMAX/Wi-Fi™ coexistence.

WiMAX products will deliver high bandwidth with a one time capital expense to the hotspot service provider.

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 will support their desired business models. It has been seen that in the wireless industry the use of standards based technologies can drive down costs rapidly through high volumes incenting silicon manufacturers to develop ever more integrated devices continuing the downward spiral of product costs. This virtuous cycle has been seen in Ethernet products, DSL products and Wi-Fi™ products; the more traction a standard gains – the lower the eventual cost of the CPE and associated common equipment.

When a service provider or end user selects a WiMAX Forum Certified product they are allowing themselves the option of building a multi-vendor network. This can allow them to adopt the standard earlier by being assured that if their primary vendor cannot deliver a product with the desired features at the desired price point another vendor will be able to meet their needs. This multi-vendor approach will also allow service providers to develop business relationships with a broad base of WiMAX vendors that may result in industry-wide collaborative efforts such as field trials that create awareness about WiMAX in their region and driving 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. They must attend a WiMAX Forum PlugFest to prove interoperability with another WiMAX member company and then they must prove conformance by having their product tested by a WiMAX Forum approved certification body. Equipment manufacturers who successfully complete this two-step process ensuring that their product is interoperable with another WiMAX Forum Certified™ product and have ensured that their products is conformant with the system profiles adopted by and promoted by the WiMAX Forum will be allowed to place the WiMAX Forum Certified seal of approval on their products.

What is 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 that will enable the certification process to be kicked off during the first half of 2005 at certification 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 with WiMAX in the metropolitan and wide area.

Attributing Company: **Redline Communications**

Redline Communications is a leading provider of standards based broadband fixed wireless equipment, helping companies reduce costs, extend and enhance networks and increase customer satisfaction. Redline is a leader in using OFDM technology to provide robust high-speed wireless connectivity. Redline's AN-30 and AN-50 are recognized for their unique capabilities in providing backhaul links and high-speed access links to urban and rural service providers. Redline has also introduced the AN-100, the world's first IEEE 802.16a standards based solution. Redline has more than 5,000 systems installed by customers in over 40 countries in industries as diverse as carriers, school boards, manufacturing, Internet providers, transportation, government, and health care facilities. Redline is a principal member of the WiMAX Forum(tm), and is committed to developing WiMAX Forum Certified(tm) products. www.redlinecommunications.com

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Mr. Suitor has held many senior level positions in several organizations most recently within CopperCom's Business Development Group. Earlier, Mr. Suitor 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. He brings to Redline extensive market and technology knowledge relating to North American service providers and equipment manufacturers. Mr. Suitor has written numerous contributed articles in several industry publications and is a regular speaker on topics such as ATM, Gigabit Ethernet, Virtual Private Networks and Voice Services.

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