WiMAX Tutorial

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1. Introduction

WiMAX is defined as Worldwide Interoperability for Microwave Access by the WiMAX Forum, formed in June 2001 to promote conformance and interoperability of the IEEE 802.16 standard, officially known as Wireless MAN. The Forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL".

2. Technical overview

The definition: "WiMAX is not a technology, but rather a certification mark, or 'stamp of approval' given to equipment that meets certain conformity and interoperability tests for the IEEE 802.16 family of standards. A similar confusion surrounds the term Wi-Fi (Wireless Fidelity), which like WiMAX, is a certification mark for equipment based on a different set of IEEE standards from the 802.11 working group for wireless local area networks (WLAN). Neither WiMAX, nor Wi-Fi is a technology but their names have been adopted in popular usage to denote the technologies behind them. This is likely due to the difficulty of using terms like 'IEEE 802.16' in common speech and writing."
WiMAX is a term coined to describe standard, interoperable implementations of IEEE 802.16 wireless networks, in a rather similar way to Wi-Fi being interoperable implementations of the IEEE 802.11 Wireless LAN standard. However, WiMAX is very different from Wi-Fi in the way it works.
In Wi-Fi the media access controller (MAC) uses contention access — all subscriber stations that wish to pass data through a wireless access point (AP) are competing for the AP's attention on a random interrupt basis. This can cause subscriber stations distant from the AP to be repeatedly interrupted by closer stations, greatly reducing their throughput. This makes services such as Voice over IP (VoIP) or IPTV, which depend on an essentially constant Quality of Service (QoS) depending on data rate and interupptibility, difficult to maintain for more than a few simultaneous users. In contrast, the 802.16 MAC uses a scheduling algorithm for which the subscriber station need compete once (for initial entry into the network). After that it is allocated an access slot by the base station. The time slot can enlarge and contract, but remains assigned to the subscriber station which means that other subscribers cannot use it. The 802.16 scheduling algorithm is stable under overload and over-subscription (unlike 802.11). It can also be more bandwidth efficient. The scheduling algorithm also allows the base station to control QoS parameters by balancing the time-slot assignments among the application needs of the subscriber stations. The original WiMAX standard (IEEE 802.16) specified WiMAX for the 10 to 66 GHz range. 802.16a, updated in 2004 to

802.16-2004 (also known as 802.16d), added specification for the 2 to 11 GHz range. 802.16d (also known as "fixed WiMAX") was updated to 802.16e in 2005 (known as "mobile WiMAX"). and uses scalable orthogonal frequency-division multiplexing (OFDM) as opposed to the OFDM version with 256 sub-carriers used in 802.16d. This brings potential benefits in terms of coverage, self installation, power consumption, frequency re-use and bandwidth efficiency. 802.16e also adds a capability for full mobility support. The WiMAX certification allows vendors with 802.16d products to sell their equipment as WiMAX certified, thus ensuring a level of interoperability with other certified products, as long as they fit the same profile. Most interest will probably be in the 802.16d and .16e standards, since the lower frequencies suffer less from inherent signal attenuation and therefore give improved range and in-building penetration. Already today, a number of networks throughout the World are in commercial operation using certified WiMAX equipment compliant with the 802.16d standard.

The WiMAX specification improves upon many of the limitations of the Wi-Fi standard by providing increased bandwidth and range and stronger encryption. It provides connectivity between network endpoints without need for direct line of sight in favorable circumstances. The non-line-of-sight propagation (NLOS) performance requires the .16d or .16e revisions, since the lower frequencies are needed. It relies upon multi-path signals, somewhat in the manner of 802.11n.

3. Uses for WiMAX

A commonly held misconception is that WiMAX will deliver 70 Mbit/s, over 70 miles (112.6 kilometers). Each of these are true individually, given ideal circumstances, but they are not simultaneously true. WiMAX has some similarities to DSL in this respect, where one can either have high bandwidth or long reach, but not both simultaneously. The other feature to consider with WiMAX is that available bandwidth is shared between users in a given radio sector, so if there are many active users in a single sector, each will get reduced bandwidth. The bandwidth and reach of WiMAX make it suitable for the following potential applications:

- Connecting Wi-Fi hotspots with each other and to other parts of the Internet
- Providing a wireless alternative to cable and DSL for last mile (last km) broadband access.
- Providing high-speed mobile data and telecommunications services (4G)

4. Broadband Access

Many cable, wireless, and traditional telephone companies are closely examining it, in active trials or small scale deployments, for "last mile" connectivity at high data rates. This could result in lower pricing for both home and business customers as competition lowers prices. In areas without pre-existing physical cable or telephone networks,

WiMAX will, it appears, be a viable alternative for broadband access that has been economically unavailable. Prior to WiMax, many operators have been using proprietary fixed wireless technologies for broadband services. WiMAX subscriber units

are available in both indoor and outdoor versions from several manufacturers. Self install indoor units are convenient, but the subscriber must be significantly closer to the WiMax base station than with professionally installed units. As such, indoor installed units require a much higher infrastructure investment as well as operational cost (site lease, backhaul, maintenance) due to the high number of base stations required to cover a given area. Indoor units are comparable in size to a cable modem or DSL modem. Outdoor units allow for the subscriber to be much further away from the WiMax base station, but usually require professional installation. Outdoor units are roughly the size of a textbook, and their installation is comparable to a residential satellite dish.

5. Mobile applications

There is potential for using WiMAX with legacy cellular networks. WiMAX antenna equipment can "share" a cell tower without compromising the function of cellular arrays already installed. Some cellular companies are evaluating WiMAX as a means of increasing bandwidth for a variety of data-intensive applications; indeed, Sprint Nextel has announced in mid-2006 that it will be investing about US$ 3 billion in a WiMAX technology build out over the next few years. Mobile WiMAX network equipment and terminals is expected to become available in the next few years. In line with these possible applications is the technology's ability to serve as a high bandwidth "backhaul" for Internet or cellular phone traffic from remote areas back to an internet backbone. Although the cost-effectiveness of WiMAX in a remote application will be higher, it is not limited to such applications, and may be an answer to reducing the cost of T1/E1 backhaul as well. Given the limited wired infrastructure in some developing countries, the costs to install a WiMAX station in conjunction with an existing cellular tower or even as a solitary hub are likely to be small in comparison to developing a wired solution. Areas of low population density and flat terrain are particularly suited to WiMAX and its range. For countries that have skipped wired infrastructure as a result of inhibitive costs and unsympathetic geography, WiMAX can enhance wireless infrastructure in an inexpensive, decentralized, deployment-friendly and effective manner.

6. Spectrum Allocations for WiMAX

The 802.16 specification applies across a wide swath of the RF spectrum. However, specification is not the same as permission to use. There is no uniform global licensed spectrum for WiMAX. In the US, the biggest segment available is around 2.5 GHz, and is already assigned, primarily to Sprint Nextel and Clearwire. Elsewhere in the world, the most likely bands used will be around 3.5 GHz, 2.3/2.5 GHz, or 5 GHz, with 2.3/2.5 GHz probably being most important in Asia. In addition, several companies have announced plans to utilize the WiMAX standard in the 1.7/2.1 GHz spectrum band recently auctioned by the FCC, for deployment of "Advanced Wireless Services"(AWS). There is some prospect in the U. S. that some of a 700 MHz band might be made available for WiMAX use, but it is currently assigned to analog TV and awaits the complete rollout of digital TV before it can become available, likely by 2009. In

any case, there will be other uses suggested for that spectrum if and when it actually becomes open.
It seems likely that there will be several variants of 802.16, depending on local regulatory conditions and thus on which spectrum is used, even if everything but the underlying radio frequencies is the same. WiMAX equipment will not, therefore, be as portable as it might have been - perhaps even less so than WiFi, whose assigned channels in unlicensed spectrum varies little from jurisdiction to jurisdiction.
The actual radio bandwidth of spectrum allocations is also likely to vary. Typical allocations are likely to provide channels of 5 MHz or 7 MHz. In principle the larger the bandwidth allocation of the spectrum, the higher the bandwidth that WiMAX can support for user traffic.

7. Standards

The current 802.16 standard is IEEE Std 802.16e-2005[1], approved in December 2005. It followed on from IEEE Std 802.16-2004[2], which replaced IEEE Standards 802.16-2001, 802.16c-2002, and 802.16a-2003. IEEE Std 802.16-2004 (802.16d) addresses only fixed systems. 802.16e adds mobility components to the standard.

7.1. IEEE 802.16e

IEEE 802.16-2005 (formerly named, but still best known as, 802.16e or Mobile WiMAX) provides an improvement on the modulation schemes stipulated in the original (fixed) WiMAX standard. It allows for fixed wireless and mobile Non Line of Sight (NLOS) applications primarily by enhancing the OFDMA (Orthogonal Frequency Division Multiple Access).
SOFDMA (Scalable OFDMA) improves upon OFDM256 for NLOS applications by:
* Improving NLOS coverage by utilizing advanced antenna diversity schemes, and hybrid-Automatic Retransmission Request (hARQ)
* Increasing system gain by use of denser sub-channelization, thereby improving indoor penetration
* Introducing high-performance coding techniques such as Turbo Coding and Low-Density Parity Check (LDPC), enhancing security and NLOS performance
* Introducing downlink sub-canalization, allowing administrators to trade coverage for capacity or vice versa
* Improving coverage by introducing Adaptive Antenna Systems (AAS) and Multiple Input Multiple Output (MIMO) technology
* Eliminating channel bandwidth dependencies on sub-carrier spacing, allowing for equal performance under any RF channel spacing (1.25-14 MHz)
* Enhanced Fast Fourier transform (FFT) algorithm can tolerate larger delay spreads, increasing resistance to multipath interference
On the other hand, 802.16-2004 (fixed WiMAX) offers the benefit of available commercial products and implementations optimized for fixed access. Fixed WiMAX is a popular standard among alternative service providers and operators in developing areas due to its low cost of deployment and advanced performance in a fixed environment. Fixed WiMax is also seen as a potential standard for backhaul of wireless

base stations such as cellular, WiFi of even mobile WiMAX. SOFDMA and OFDMA256 are not compatible so most equipment will have to be replaced. However, some manufacturers are planning to provide a migration path for older equipment to SOFDMA compatibility which would ease the transition
for those networks which have already made the OFDMA256 investment.

7.2. HIPERMAN

The equivalent of 802.16 in Europe is HIPERMAN. The WiMAX Forum is working to ensure that 802.16 and HIPERMAN inter-operate seamlessly.

7.3. WiBro

Korea's electronics and telecommunication industry spearheaded by Samsung Electronics and ETRI has developed its own standard, WiBro. In late 2004, Intel and LG Electronics have agreed on interoperability between WiBro and WiMAX. WiBro has South Korean government support with the requirement for each carrier to spend over US$1 billion for deployments. The Koreans sought to develop WiBro as a regional and potentially international alternative to 3.5G or 4G cellular systems. But given the lack of momentum as a standard, WiBro has joined WiMAX and agreed to harmonize with the similar OFDMA 802.16e version of the standard. What makes WiBro roll-outs, which will start in April 2006, a good 'test case' for the overall WiMAX effort is that it is mobile, well thought out for delivery of wireless broadband services, and the fact that the deployment is taking place in a highly sophisticated, broadband-saturated market.
WiBro will go up against 3G and very high bandwidth wire-line services rather than as gap-filler or rural under-served market deployments as is often exampled as the 'best fit' markets for WiMAX.

8. Associations

8.1. WiMAX Forum

The WiMAX Forum is "the exclusive organization dedicated to certifying the interoperability of BWA products, the WiMAX Forum defines and conducts conformance and interoperability testing to ensure that different vendor systems work seamlessly with one another." Those that pass conformance and interoperability testing achieve the "WiMAX Forum Certified" designation and display this mark on their products and marketing materials. Vendors claiming their equipment is "WiMAX-ready", "WiMAX-compliant", or "pre-WiMAX" are not WiMAX Forum Certified, according to the Forum. [2]

8.2. WiMAX Spectrum Owners Alliance

WiSOA is the first global organisation composed exclusively of owners of WiMAX spectrum. WiSOA is focussed on the regulation, commercialisation, and deployment of WiMAX spectrum in the 2.3–2.5 GHz and the 3.4–3.5 GHz ranges. WiSOA are dedicated to educating and informing its members, industry representatives and government regulators of the importance of WiMAX spectrum, its use, and the potential for WiMAX to revolutionise broadband.[3]

9. Competing technologies

WiMAX is a framework for wireless development based on a forward-looking core set of technologies. More recently 3GPP cellular's 4G, 802.22 Cognitive Radio RAN (Rural Area Network), and 802.20, the High Speed Mobile Broadband Wireless Access (MBWA) Working Group, have shifted toward use of similar constructs of multi-channel scalable OFDM, HARQ, FEC, MIMO-AAS and other complementary technologies as are part of WiMAX. UMTS.For some applications, UMTS could be a direct competitor to WiMAX. UMTS has been deployed in Europe and elsewhere mostly by Mobile Telephone operators. The HSDPA technology enables down-link with data transmission up to 14.4 Mbit/s (see above for comparison). UMTS also provides a circuit channel optimized for voice and video traffic. In July
2005 EU frequency allocation for WiMAX was blocked by France and Finland, where manufacturers have invested heavily in UMTS technology. On the other side of the world, frequency bidding in Malaysia was stopped and any allocation of WiMAX has been suspended indefinitely in September 2006.
While ordinary UMTS service is being provided largely as an upgrade to existing cellular telephone systems, a variant of UMTS, UMTS-TDD, exists which is being deployed primarily as a mobile broadband Internet provisioning system, and as such could be seen as a more direct competitor to WiMAX. A number of ISPs around the world have deployed the system already.[4]. UMTS-TDD uses a Time Division Duplexed air interface (so both the downlink and uplink can share the same frequency, making it more dynamic in terms of being able to allocate spectrum as traffic patterns change compared to traditional UMTS. UMTS-TDD provides lower bandwidth and less range than WiMAX at both standard's theoretical maximums, but is more consistent in terms of its capabilities within the range it does allow.

9.1. LTE

The most recent 3GPP standardization activities are development of advanced systems based on OFDM rather than CDMA. The 3G Long Term Evolution (LTE) platform will be based on MIMO-OFDM similar to WiMAX/802.16e-2005. This is a major shift from CDMA/WCDMA system evolution or the prior road map for over-laying OFDM onto the WCDMA system architecture such as MC-CDMA and TD-SCDMA to frequency interference mitigation via orthogonal canalization methods. Some suggest that WiMAX is disruptive while LTE is an evolution of the cellular road map. Both WiMAX and

LTE use a different core technology than 3G and prior cellular systems and neither can provide shared use of current cellular spectrums. A major reason for the shift from the CDMA platform to OFDM is the ability of OFDM to make better use of MIMO and AAS multi-antenna and signal path technologies. Debates about core spectral efficiencies are dwarfed by improvements already achievable via the use of MIMO and, so far, limited AAS. The evolution of wireless calls for greater gains from the synergistic combination of these technologies in the future. While both systems use OFDM/OFDMA, LTE is optimized more for wide area mobile voice communications. LTE will use OFDMA for the down-link and SC-OFDM (Single Carrier OFDM) for the uplink while WiMAX/802.16e-2005 uses OFDMA for both the up and down links. SC-OFDM can maintain connections at longer distance but has lower bandwidth than OFDMA. However, WiMAX advocates perceive evolution of WBB as also shifting the 'architectural evolution' of wireless networks to more symmetrical, higher bandwidth in which multi-mode CDMA and other technologies can fulfill long range and low bandwidth persistent requirements.

9.2. EV-DO

Evolution-Data Optimized is a wireless radio broadband data standard adopted by many CDMA mobile phone service providers around the globe. It is standardized by 3GPP2, as part of the CDMA family of standards.

9.3. Wi-Fi

Wi-Fi is a Wireless Local Area Network (LAN) technology that works in unlicensed spectrum, using the 2.4GHz and 5 GHz bands. Wi-Fi is a cheap and easy way of providing local connectivity at high speed. WiMAX uses licenced spectrum and has strong authentication mechanisms built in. It has considerably greater range than Wi-Fi. Taken together, this means that WiMAX and Wi-Fi are generally complementary rather than competing.

9.4. Mobile Broadband Wireless Access

MBWA is a technology under development by IEEE 802.20. It is a future technology for true wireless broadband or 4G. However The IEEE recently (June 2006) said it would pause the 802.20 working group that has the backing of Qualcomm, the US cellular communications giant that acquired 802.20 developer Flarion Technologies in Janua