WiMAX: Opportunity or Hype?

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Abstract

The newest generation of connectivity, currently in research and testing phases, is Worldwide Interoperability for Microwave Access (WiMAX), a new wireless standard for large coverage areas. This paper describes the purpose of WiMAX, its forms, the status of its standardization, and the impact it will have on wireless broadband capabilities. Although it is still too early to tell just how successful WiMAX will be, we conclude that it will play an important part in the future of Internet access. Once the technology hits wide-scale production it should create a low cost connectivity solution that will bee able to provide Internet access to locations where it currently is neither feasible nor affordable.

Introduction

A decade after most Americans started using the Internet, questions continue to arise about how to provide adequate access to it. Thus far, there are only two broadband “pipes”—cable and DSL—and cable and phone companies have provided reasonably low-cost cable and DSL connections in most areas. However, in addition to general technical limitations related to data rates, cable and DSL require a physical network connection, thus tying the user to a single physical location. In recent years, a set of wireless local area network (LAN) standards, commonly known as Wi-Fi, has become widely used, but Wi-Fi has nontrivial limitations of overall size of the wireless network because of its small nodes.

The newest generation of Internet connectivity, currently in research and testing phases, is Worldwide Interoperability for Microwave Access, commonly referred to as “WiMAX,” a certification mark for products that pass conformity and interoperability tests for the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard. WiMAX is an exciting new wireless standard intended for large coverage areas on the order of several kilometers (instead of a few hundred meters, as is the case with current Wi-Fi standards). WiMAX is the subject of considerable hype; as such, it faces numerous technical and political hurdles. However, this hype and these hurdles notwithstanding, WiMAX does have a promising future in a number of markets in both sparsely and densely populated areas of the United States. This paper describes the purpose of WiMAX, its forms, the standardization process associated with it, and the impact that it will have on wireless broadband.

1. The Need for a Third Broadband Pipe

As use of the Internet grows, so does the need for additional pipelines, or ways to deliver Internet connectivity to businesses and individuals. According to Nielsen's NetRatings, from January to August 2005 the percentage of the U.S. population using broadband Internet service grew from 36% to 42%. The Nielsen report also suggested that August 2005 marked the point where more than 60% of Internet users in the United States used broadband as opposed to slower dial-up connections (Nielsen 2005). As this report reveals, Americans are increasingly willing to pay for faster Internet service.

In spite of the proliferation of Internet usage, many consumers do not have much choice when it comes to Internet providers. Charles Townsend, CEO of the Aloha Group,--presently the largest owner of 700 MHz Spectrum—explained in his recent Senate testimony that while "95% of homes can get at least 1 broadband provider," about "one out of four homes in rural areas have [sic] no access to broadband service" (2005). Townsend further noted that the divide created between people with and without access cannot be bridged with current access options such as cable and DSL (2005). Generally, though, the growth of broadband and the growth of the numbers of users signal that the Internet is becoming an extremely important part of American society.

1.1 The Development of Wireless Standards

The growth of the Internet notwithstanding, high-speed *wireless* Internet service has been slow to come to fruition since the widespread acceptance of the Internet. Only within the past few years have short-distance wireless networks such as IEEE 802.11 (commonly referred to as Wi-Fi networks) become a reality. Individual Wi-Fi access points have a range of roughly 70 feet for the highest data rates and a maximum range of about 300 feet (Broadcom Corporation

2003). In *Wi-Fi Planet*, a popular web-based business and technology source for Wi-Fi promotion, Tim Sanders explains that the key conceptual differences between IEEE 802.11 (Wi-Fi) standards and IEEE 802.16 (WiMAX) standards boil down to size, scope, and scalability. Sanders explains that Wi-Fi standards are meant for small LANs, whereas WiMAX standards are meant for metropolitan area networks (MANs) that could be city-wide. While the exact size limitations of WiMAX are, as yet, theoretical, few debate that WiMAX will have far greater reach and scope than Wi-Fi (Sanders 2005).

Today, the details of the WiMAX standards are still in flux. In fact, a powerful consortium of manufacturers is leading a major development and standard-setting initiative. For example, the influential WiMAX Forum, as noted on the forum's website, is "an industry-led, non-profit corporation formed to promote and certify compatibility and interoperability of broadband wireless products. Our member companies support the industry-wide acceptance of the IEEE 802.16 and ETSI HiperMAN wireless MAN standards" (WiMAX Forum Home 2005). In essence, the WiMAX Forum is promoting an industry-wide drive towards certification of interoperability. Although the metropolitan-scale objectives of WiMAX differ from the local-scale objectives of Wi-Fi, both standards seek interoperability and widespread consumer acceptance.

Indeed, broadband fixed wireless access has been available in the United States for quite some time in various incompatible, proprietary formats. In fact, over 2,400 Internet service providers (ISPs) use their own closed, proprietary technology; however, as the WiMAX Forum explains, "these operators have seen only limited customer interest. Two key factors have been blamed for this lack of enthusiasm: the equipment is proprietary and, as a consequence, too expensive" (Conti 2005). The initial wireless broadband technologies appeared around 1999-

2000 when companies like Teligent and Winstar were driven into bankruptcy because their proprietary technologies proved to be too expensive. However, in addition to cost factors, WiMAX has several advantages that make it much more likely to succeed on a large consumer scale than its proprietary predecessors. One advantage is WiMAX's technological superiority. WiMAX is based on Orthogonal Frequency Division Multiplexing (OFDM), a modulation technique developed to improve range and propagation quality of data signals. Furthermore, unlike Wi-Fi, WiMAX standards are built around a certain degree of mobility (as opposed to Wi-Fi's "portability," which allows for moving the units from one spot to another but not for "hand-offs" as one would experience with a mobile-phone). Another advantage is that open standardization and system "interoperability" are key components in WiMAX's design. Unsurprisingly, one of the leading drivers of the WiMAX Forum to borrow a page from Wi-Fi's success and "to ensure interoperability of IEEE 802.16 implementations … following the successful example of the Wi-Fi Forum" (Hazen 2005). Large, commodity manufacturing companies like Intel support WiMAX. Finally, unlike other wireless infrastructures already in place throughout the United States (e.g., point-to-point microwave links, cellular services, and satellite communications), WiMAX is specifically intended for de facto data communications such as Internet Protocol (IP), As more information is transferred via data packets and applications such as voice, video and data all utilize versions of the same open standard (e.g., Voice over IP protocol and IP TV), the greater the need for transmission designed for that purpose becomes evident.

Most existing data-transfer infrastructures were designed with a specific purpose in mind – a purpose that works for IP applications, but that is not optimized for them. For example, the cellular system was designed to provide a voice service, and consumer satellite connections are best suited for only for the transmission of data in one direction such as video broadcasting. Although Wireless Fidelity (Wi-Fi, described below) is a data-centric "pipe," it, too, was designed for a specific purpose: short distance networks in homes and offices. The stage has therefore been set for a new open standard for broadband data (and the associated applications for voice, video and data) over longer distances.

1.2 WiMAX Takes Root

IEEE "802" is the category within the IEEE for LAN and MAN standards. IEEE 802 standards generally focus on the lowest two layers of the Open System Interconnection (OSI) model—the physical and data link layers—and provide requirements that enable LANs and MANs to connect to one another without additional routing (IEEE 802 2005). Notable IEEE 802 standards include Ethernet (802.3) and Wi-Fi (802.11). However, the most recent focus (within industry and within standard-setting groups) is on IEEE 802.16 standards, which, according to the 802.16 Working Group, are being devised to "support the development and deployment of broadband Wireless Metropolitan Area Networks" (Marks "IEEE" 2005). The members of the 802.16 Working Group are IEEE engineers, and, unsurprisingly, the group's website emphasizes the importance of the standardization process (much like that of the WiMAX Forum). The IEEE Working Group cites Internet pioneer Vinton Cerf, who explained that "[p]eople often take the view that standardization is the enemy of creativity. But I think that standards help make creativity possible—by allowing for the establishment of an infrastructure, which then leads to enormous entrepreneurialism, creativity, and competitiveness" (2000). Thus, Cerf, the WiMAX Forum, and the IEEE 802.16 Working Group have all taken the position that proprietary formats (such as those used by defunct companies like Teligent and Winstar) will necessarily give way to open standards, thereby encouraging the entrepreneurial spirit that the Internet was built upon.

1.2.1 IEEE 802.16

Building on the technical work completed by other "802" groups, the WiMAX Working Group's first standard was 802*.16*, which initially specified WiMAX operation in frequencies between 10 and 66 GHz using OFDM technology on 10 MHz channels. Essentially, WiMAX supported only line of sight transmission because of its relatively low frequency range (over 10 GHz) where penetration of obstacles is not possible (Sanders 2005). Thus, the "a" designation in the ensuing IEEE 802.16a standard is essentially an update to the original 801.16 model, enabling WiMAX to operate within the 2 to 11 GHz range. As a result, the standard paves the way for operation in mobile applications (i.e., applications that move from one node to the next, like cellular phones), portable applications (i.e., applications that can move within a single node's range, such as with Wi-Fi), and other applications that work in "non-line-of-sight" situations where antennas may not necessarily "see" each other.

Other important features and designations have been added over time. For example, different IEEE working groups have made these WiMAX standards more capable of interfacing with other Internet standards such as Ethernet, asynchronous transfer mode (ATM), and general Internet protocols (Sanders 2005). There are, of course, additional variations on these core WiMAX standards. For example, the "c" designation (IEEE 802.16*c*) primarily "addressed issues such as performance evaluation, testing and detailed system profiling … [in order to] guide vendors on mandatory elements that must be met to ensure interoperability" (Sanders 2005). Current discussions about WiMAX often refer to the two most recent standards, "d" and "e." The "d" standard addresses *fixed* WiMAX and does not support any type of roaming handoffs, and the "e" standard supports mobility (Sanders 2005). Later, we will address the importance of this mobility feature within the market, but for now we should note that the "d" and “e” WiMAX standards currently are not interoperable (Griffith 2005). And to make matters more confusing, Korea’s so-called “Wi-Bro” standard is a version of the “e” designation that supports mobility (Sanders 2005). This lack of interoperability forces potential WiMAX customers to choose, of course risking that they will have invested in an unsuccessful standard.

1.2.2 Security

Security is an obvious concern for a wireless network just as it is for any data network; however, is magnified by ease of access to the medium (free space). Unfortunately, WiMAX will be subject to the same types of attacks as every other wireless technology (Cross, Orthman, and Browne 2005). Wired Equivalent Privacy (WEP), the most common form of security on Wi-Fi networks, has proven to be quite open to attacks; nonetheless, widespread safety concerns have not prevented people from using Wi-Fi (Geier 2002). However, both the IEEE and the WiMAX Forum view security as a potential problem with WiMAX adoption and have thus created a number of measures that will encrypt information over WiMAX using leading-edge technologies such as DES3 and AES (“What Is the WiMAX” 2005). Again, the WiMAX development process learned from Wi-Fi’s success, which is now suffering growing pains as new security standards are adopted and implemented, and as the Wi-Fi standard stretches to include applications that were not conceived of when Wi-Fi products were placed on the market. For example, many vendors believe that strengthening WiMAX security will facilitate consumer adoption and even help overcome some issues with the standard’s credibility deficit arising from release date setbacks (Wireless Watch 2005). Today, people have more concerns about security, privacy and hacking than they did with early wireless networks (Ryan 2005). Along those lines, WiMAX needs to provide a measure of security over and above that of the standard Wi-Fi network if WiMAX technology is to one day replace wireline data connections. According to

WiMAX.com (a promoter of the technology and therefore a biased source), a WiMAX connection enables a secure transmission of sensitive data [e.g., data protected by the Health Insurance Privacy and Portability Act (HIPPA)] between a base station and a client ("Is WiMAX" 2005). Regardless whether or not this claim is true, it is clear that privacy and security issues largely dominate discussions of WiMAX usage, and the integration of these concerns into the standard will be key elements to the standard's success.

2. Fixed WiMAX and Mobile WiMAX

2.1 Fixed WiMAX

As previously mentioned, IEEE 802.16d—sometimes referred to as 802.16-2004—is known as the *fixed* version of WiMAX and requires line of sight between the antennas. Not unexpectedly, many different sources make many different claims about potential data rates. Rupert Baines, Vice President of Marketing at PicoChip, explains that "[c]laims of 50Mbit/s over 50 miles are simply fantasy. A realistic system would get a few Mbit/s over a few miles, depending on terrain and frequency. At a similar frequency, in a similar environment, WiMAX will not be that different to other modern modulations, such as HSDPA [High-Speed Downlink Packet Access]" (Conti 2005). As industry expert Juan Pablo Conti notes, PicoChip specializes in "base station reference designs," and while the company's estimates are more conservative than many, that estimate provides a useful counterbalance to the "hype and exaggeration" born of many unfounded claims regarding WiMAX's technical capabilities (Conti 2005). Fixed WiMAX generally does require line of sight (or at least has minimum portability requirements and no mobility requirements) and uses a combination of various standards, including the original 802.16 specification and the evolutions thereof (i.e., 802.16a, 802.16b, and 802.16c).

Intel plans to support fixed WiMAX in its new chipsets, which is a huge step forward for the WiMAX adoption movement. In fact, pundits like Conti assert that "[a]ll analysts agree that Intel is the most influential player in determining how fast WiMAX fulfils its market potential … The company expects WiMAX to be available in some laptops by 2007, with PDAs and mobiles following by 2008-09" (Conti 2005). Whether or not Intel will be able to deliver on its promise is still an open question, but there is little doubt that Intel's formidable market power in computing will help promote the development of the technology.

One major service of fixed WiMAX is to provide Internet to the home in both rural and metro areas, thus making WiMAX variant on "last-mile" service. Many believe that WiMAX would actually be a fixed device on a structure like a point of presence of a digital subscriber line (DSL) connection (Gruman 2005, p. 36), meaning that WiMAX would be more like a traditional cable modem than a device in a computer. Thus, fixed WiMAX could be thought of as a potential competitor of cable and DSL. However, because the service would have to be essentially the same as cable or DSL in order to gain market acceptance, WiMAX would need some sort of cost or other advantage in order to make it attractive to consumers. This won't be an easy task—last year, vendors charged approximately $500 for WiMAX "customer premises equipment" (CPE), over ten times the cost of cable and DSL CPE. In fact, according to Monica Paolini, a wireless technologies analyst for Senza Fili Consulting, the price will have to "at or below $200 to get an attractive business case" (Conti 2005). As Mark Hazen notes, WiMAX will "steal significant market share from wireline-based competitors" only if its price is appropriate for local ISP markets (2005).

2.1.1 The Economic Benefits of Fixed WiMAX

The future of fixed WiMAX is uncertain due to the widespread current usage of DSL and cable products. However, even if fixed WiMAX does not earn great market share in the residential sector, its mere presence as a competitor in the market could nonetheless reduce the cost of Internet and cellular access. ISPs and cellular carriers purchase high-speed transport mechanisms for "backbone" purposes (i.e., carrying traffic from one point to another within a network). Currently, installation of a commonly used backbone format called a "T1" costs about $800, with approximately $700 per month in continued charges (Cross, Orthman, and Browne 2005). In 2005, cellular carriers spent about 20% of their operational costs on these backbone T1 lines (Cross, Orthman, and Browne 2005). A recent article in *Telecommunications* contends that cellular carriers could significantly reduce the cost of cellular networks if those carriers could use fixed WiMAX instead of a traditional wire-based T1. The same holds true for wireline ISPs: If they could use 802.16d connections instead of dedicated T1 lines to send data back to the main office, they could reduce their operating costs and thereby decrease the overall cost of service delivery and increase price competition.

The cost savings are not limited only to traditional Internet products. In fact, the costs of extending the local loop of a phone system can be reduced by using WiMAX because, as Thomas Cross, Frank Orthman, and Stuart Browne note, "[t]he local loop charge is the most significant capex [capital expenditure] in the budget. With WiMAX, there's a good chance an ISP can bypass the ILEC's [incumbent local exchange carrier's] copper for a majority of its subscribers" (Cross, Orthman, and Browne 2005). Cross, Orthman, and Browne further argue that the speed of extending new services increases because "it can take months of permitting, rights-of-way delays and significant cost to get across the street, [and] WiMAX systems can be collocated in or on a pedestal/terminal and service delivery can begin tomorrow" (2005). Thus, in addition to traditional market WiMAX products, other data systems are likely to benefit from reduced connection cost in difficult areas through standardized, commoditized pricing (Manners 2005). Such pricing has benefited the consumer electronics industry in general, but the proliferation of Wi-Fi in particular: Wi-Fi devices were first placed on the market for nearly $1000.00 per node, and within 18 months their cost was reduced to less than $200.00, and they can be purchased today for less than $50.00. There is little doubt that this success is a driving force behind the development in WiMAX.

2.1.2 Rural Deployments

In addition to fixed applications within existing networks, WiMAX offers a mechanism for providing broadband Internet access for outlying rural areas that currently have limited or no access to broadband Internet. A comprehensive whitepaper authored by members of the WiMAX Forum asserts that WiMAX may play a role in closing the "digital divide" (Cayla, Cohen, and Guigon 2005). As of 2005, approximately 25% of rural-dwelling Americans had essentially no access to broadband. In recent Senate testimony, the Aloha Group, owner of the largest share of frequencies in the "beachfront" 700 MHz range, argued that a version of WiMAX running in the 700 MHz range offers the best method of reaching out to rural America (Townsend 2005). One of the largest considerations in the rural environment is cost because subscribers are often separated by large physical distances. Townsend's testimony focused on the importance of the transition to digital TV in all markets as a means of opening up space in the 700 MHz range for this service. Contrary to general claims that rural areas have the most to lose from such a transition, Townsend believes that these areas in fact have the most to gain. Thus, organizations like the Aloha Group can begin to provide Internet service to areas previously left without any options (Cayla, Cohen, and Guigon 2005). Others concur that a key benefit of WiMAX is the ability to provide high-speed Internet service to rural areas that currently have access to only low-speed dialup or expensive proprietary options (Cross, Orthman, and Browne 2005).

2.1.3 New Orleans Recovery

Officials from the city of New Orleans, Louisiana, recently announced that a city-wide wireless network will be installed as part of a plan to make the hurricane-ravaged city more attractive to potential residents and tourists. At present, about ten square miles of the French Quarter have already been covered, and plans are in place to cover the rest of the city by the end of 2006 (Reardon 2005). However, city officials have chosen to implement Wi-Fi, not WiMAX, connectivity standards, a decision made because WiMAX purportedly cannot offer the cost-effective solutions the city needs. Proposed solutions, such as a fixed pre-standard WiMAX solution from Bell South and Verizon wireless broadband service, cost upwards of $60 a month, a price that city officials argue is too high for its citizens to pay (Reardon 2005). While New Orleans would arguably have been an ideal place to test WiMAX's potential, the officials' decision reinforces concerns about wide-scale deployment of WiMAX.

Furthermore, the New Orleans decision highlights one of the basic realities of fixed wireless: people are used to roaming with their cellular phones, and they may not want to surrender that capability for data services. In other words, we live in a mobile world where most consumers do not value the benefits of fixed solutions. Ironically, in the case of WiMAX, a "fixed" solution actually just means that there is no mechanism for handoffs, so a wireless connection cannot seamlessly transition from one tower to another in the way that cellular phones do. In other words, the products may be "portable" (mobile within a given node, but no "hand-offs" between nodes), which interestingly, is also generally true with Wi-Fi connections.

However, depending on the frequency range, as discussed below, the antenna may in some cases actually need to be fixed in a specific location in order to maximize the quality of the connection.

2.2 Mobile WiMAX: Vaporware?

Mobile WiMAX is based on the IEEE 802.16e standard and was officially approved on December 7, 2005 (Marks "Going Mobile" 2005). Mobile WiMAX is expected to become commercially available within 12 months after certification of the standard (i.e., first-generation products should be available by late 2006 or early 2007); however, commercial deployment of mobile WiMAX is not expected to take place for another 24 to 36 months (Wilson 2005). Some are concerned that mobile WiMAX may be "vaporware," a term used to describe a product that receives much hype and then either fails to emerge or emerges after a protracted development cycle (Bayus, Jain, and Rao 2000).

As of late 2005, many question whether companies should implement fixed WiMAX, wait until the WiMAX Forum certifies mobile WiMAX technologies in coming months or years, or simply use proven Wi-Fi capabilities (even if Wi-Fi may ultimately prove inferior to WiMAX). The paths Sprint and Nextel have followed over the years provide interesting insight into differing company philosophies (Wilson 2005). Carol Wilson explains that Sprint has customarily relied on standards and the standard-setting process, whereas Nextel traditionally has made available technology work to suit the company's needs (Wilson 2005). In 2005, the two companies merged (forming "Sprint, together with Nextel"), and the jury is still out as to the technological deployment philosophy the new company will implement.

Since Nextel relies heavily on a Motorola infrastructure, however, it might prove useful to examine Motorola's decisions regarding WiMAX. Lindsay Schroth of the Yankee Group, a major high technology research and consulting firm, points out that "Motorola is saying they aren't going to rely on [the WiMAX Forum]." Instead, she notes, "they are going to make sure their customer has a solution in 2006 and then give them a software upgrade to the standard" (Wilson 2005). The Federal Communications Commission (FCC) has required the newly merged company to have 15 million customers in their licensed 2.5 GHz spectrum. This stipulation may force the new company to adopt a more Nextel-like approach that involves the use of Motorola's theoretically non-WiMAX compliant technology (when it becomes available) (Wilson 2005). However, even Peter Cannistra, Sprint Nextel's director of wireless broadband marketing, admits, WiMAX is "vaporware. We're testing everything from spectrum efficiency to cost so that we have a business case. We are trying to validate assumptions that we've made" (Luna 2005, p. 3).

Because of the promise of mobility—something that Wi-Fi and particularly cellular users have become accustomed to—most of the hype over WiMAX appears to be about the mobile standard rather than about the fixed standard. Cellular carriers (like Sprint Nextel) generally are interested in the mobile technology so that they can begin integration with their current networks. Some even argue that mobile WiMAX provides the possibility of a quadruple play: TV, voice, wireless, and data (Luna 2005, p. 2). Lynette Luna cites several features that make this quadruple play possible: high data rates up to 75 Mbps, no line-of-sight requirement, and high-speed handoffs, as well as Intel's role in WiMAX (Luna 2005, p. 2). She likens Intel's WiMAX strategy to the company's Wi-Fi strategy, which involved the highly successful development of Wi-Fi friendly laptops. In the WiMAX case, she notes, "[t]he company plans to embed WiMAX in its laptop chipsets, effectively seeding the market for service providers" (Luna 2005, p. 2).

Initial commercial rollouts of third generation, or 3G, wireless technology went fairly smoothly and seemed to meet expectations, unlike mobile WiMAX, which, as writer Galen Gruman notes, is "at best several years away, and some analysts feel it may never fulfill its promoters' promises" (2005, p. 32). Gruman quotes Roger Entner, an analyst from Ovum, who explains that "WiMAX is just another technology doing the same thing as 3G. … Deploying comparable WiMax coverage could cost from $5 billion to $15 billion" (p. 36). Other industry experts point out that the cost of mobile WiMAX deployment would prevent companies already providing 3G service from rolling out mobile WiMAX, which is a problem since it will be third to market (Gruman 2005, p. 36). Basically, the point here is that at first glance Mobile WiMAX does not seem to have a strong place in the near-future market. A study conducted by Datacomm Research and Rysavy Research determined that "OFDM utilizes multiple channels to send and receive data, which results in less interference than a 3G cellular data system" and thus makes OFDM better suited to high-speed applications ("Wireless Broadband" 2005). However, even 4G (fourth-generation wireless) is expected to use OFDM, meaning that the next generation of wireless (after 3G) may be based on WiMAX or a similar technology (Gruman 2005, p. 37). Some believe that mobile WiMAX can compete with DSL. While, ultimately, little differentiates DSL and fixed WiMAX, mobility gives users a reason to purchase WiMAX as opposed to traditional ISPs.

Strong proponents of WiMAX see a more positive picture of the standard's future. One key component is speed of certification. Despite 3G's seeming advantage of being first to market, the WiMAX Forum has a significantly faster certification process, with the goal of reasonably competing with 3G (Meyers 2005, p. 40). The current technology probably does not support the high expectations that many proponents have for mobile WiMAX. However, the wait is not yet over for the mobility standard. Like any technology, mobile WiMAX must undergo a growth cycle. As of June 2004, Charles Townsend believed that WiMAX was in a stage of infancy much like that of the cellular telephone in 1985 (roughly 10 years away from major adoption) (Mark 2004). Though he may have overestimated the period of time needed to bring the technology to market, he nonetheless makes an important point: as yet, we do not recognize the fundamental capabilities and limitations of this technology. Louis Frenzel is correct in pointing out that "WiMAX is sure to find a niche" (2005 p. 58).

3. WiMAX and Wireless Spectrum

Although WiMAX is intended to operate in specified frequency ranges, it is a specification or standard designed operate over various frequencies. Radio waves have frequencies between 3 kHz and 300 GHz, although legal and regulatory definitions vary slightly between Europe and the United States at the very-seldom-used low end of the frequency spectrum (Proposal 2000; U.S. Frequency Allocation Chart 1996; and *NTIA Manual* 2000). Radio waves are—put quite simply—*just waves*, although their propagation characteristics vary greatly as a function of their frequency. For example, some high-frequency radio waves are useful only for fixed, line-of-sight uses (not unlike light waves). Other frequencies (lower frequencies, generally below 5 GHz) may penetrate obstacles and are thus used for mobile environments like Global System for Mobile Communication (GSM) phones, FM radio, or other "mobile" uses. Understanding the distinction between these "fixed" and "mobile" functions as a matter of physics is critical to understanding the regulatory problems that confront the spectrum and how WiMAX fits into it.

3.1 “Fixed” and “Mobile” Uses

3.1.1 Fixed Uses

Generally, fixed radio frequencies from 3 GHz to 300 GHz are for line-of-sight use, which means that the two devices must be able to “see” each other. One practical example is microwave radio, where two microwave dishes are pointed at each other and do not have any obstacles (e.g., buildings, mountains, or trees) between them. A basic illustration of a microwave radio is provided in Figure 1. This figure illustrates a typical fixed application, where the two antennas must have a line of sight with each other in order to function. Often, antennas such as these are used for long-range, high-capacity “backhaul” (the transmission of data to network cores). Depending on the frequency used, these towers may be several dozen km to even 100 km apart. Any obstruction placed between these two antennas (e.g., a building or even an airplane flying through) can disrupt the communications between the two points.

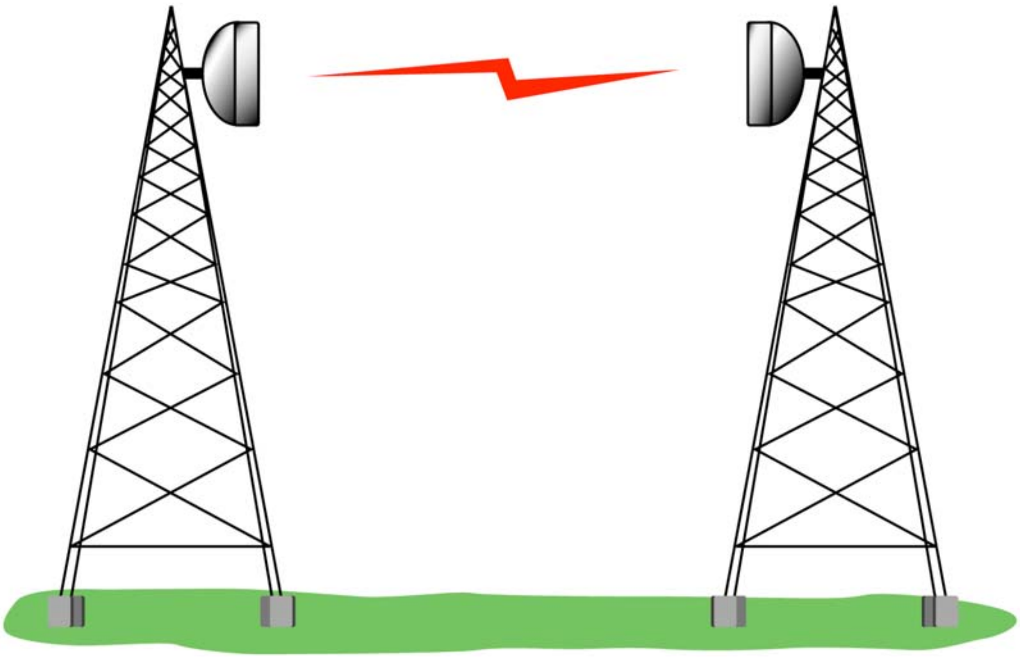

Figure 1. A Typical Fixed Application

Fixed wireless frequencies serve an important purpose. They can provide very high transmission data rates, and certain forms of broadcasting do not require mobility. In Europe and in the United States, hundreds of large "television towers" are located in the middle of urban areas. These towers are often outfitted with microwave-like antennas and function via line of sight, where the transmissions are focused on another antenna located at a different location.

3.1.2 Mobile Wireless Use

The most important characteristic of *mobile* wireless use is the ability of the frequency to penetrate obstacles, such as walls, trees, and the concrete and steel of cityscapes. Diffraction (i.e., bending around obstacles) is also important, because certain frequencies have different characteristics that allow them to receive and transmit signals (propagate) behind and at the edges of obstacles (e.g., buildings). Examples of mobile uses include FM radio, mobile communication technologies, and indoor wireless LANs. FM radio signals, for example, can be received indoors as well as outdoors (Prindle 2003). In other words, an FM radio antenna does not need to "see" the broadcast antenna; if it did, people would not be able to listen to the radio while indoors. People who use mobile communication technologies [e.g., GSM, cellular, Personal Communications Service (PCS), paging, 3G, and Enhanced Specialized Mobile Radio (ESMR)] can also receive signals and use these technologies both indoors and outdoors.

Figure 2 shows an illustration of a typical mobile application. With indoor "wireless LAN," the computer can be taken from one room to another without losing the signal. This illustration of a typical mobile application depicts communication between a mobile phone and a base station (or "cell tower"). At any given time, generally two channels (also called a "paired channel") are used. The communication from the device to the tower is called an "uplink," and the communication from the tower to the device is called a "downlink." Range is mostly restricted by the uplink because the power levels of mobile phones are far inferior to the power coming from a tower (e.g., due to the phones' battery limitations). The uplink and downlink must be in sync (also called a "link budget"); otherwise, a mobile phone caller may be able to hear a person on the line who is receiving data to his or her mobile phone via the downlink), but the person may not be able to hear the caller (who uses a lower-power uplink).

In sum, these mobile applications provide the most attractive consumer technologies available today. Mobile technology is also where the money is: One need look no further than the billions spent at the recent 3G auctions in Europe or, indeed, than the "hype" associated with the potential of WiMAX.

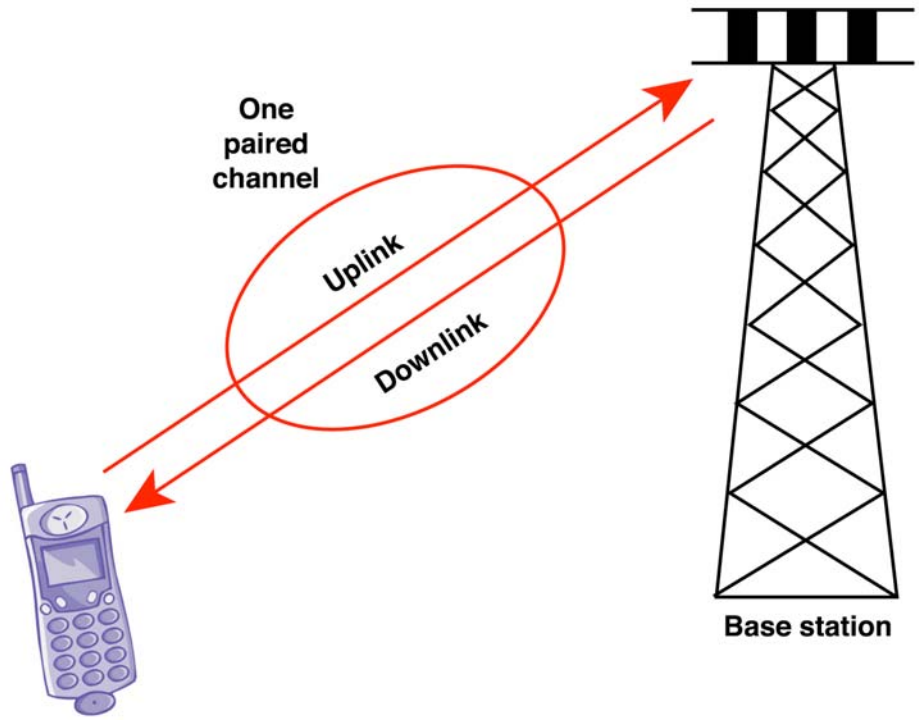

Figure 2. A Typical Mobile Application

3.2 Fixed Applications Operate in Mobile Frequencies, but Generally Not Vice Versa

In order to fully understand some of the hot topics related to today's regulatory landscape (e.g., the relative value of broadcast TV, radio, and mobile frequencies, as well as the difference between fixed and mobile WiMAX), then it is important to understand that fixed (i.e., line-of-sight) applications *can* work in mobile frequencies below 3 GHz. It is, however, equally important to recognize that the corollary *is not true*: mobile use (particularly any technology that requires wall, building, or obstacle penetration) generally will not work within the "fixed" domain above 3 GHz (or in some cases 5 GHz, where there is a "marginal flexibility curve" between 2 GHz and 5 GHz and where frequencies have some obstacle-penetrating capabilities, depending on the "link budget," power factors, and the density of the obstruction) (Snider *Citizens* 2003). According to numerous experts, many fixed applications that presently occupy the valuable mobile frequencies below 3 GHz (which were allocated in the 1920s, when we knew only a fraction of what we know today) are not properly allocated.

So, for purposes of this discussion, mobile frequencies are those that have less than 3 GHz. The frequencies between 3 GHz and 5 GHz are "semi-mobile" and can penetrate obstacles, but with more difficulty. Those beyond 5 GHz have practically no mobile value and must be set up for line-of-sight uses. This critical distinction helps to explain why mobile frequencies are so valuable. Figure 3 provides a high-level overview of various devices and their mobile frequencies. This illustration provides a simple depiction of the value of mobile frequencies. Those devices whose frequencies are below 2 GHz are the most valuable because they are in the "permeable zone" and thus can penetrate obstacles. Devices with frequencies between 2 GHz and 3 GHz also share this capability, though the capability diminishes quickly—particularly between 3 GHz and 5 GHz. Frequencies beyond 5 GHz are almost completely useless for mobile applications and must have line of sight with other antennas (i.e., they must be outdoors, fixed, and aimed at each other to function).

However, fixed and mobile WiMAX (which is a technology standard) is not the same as fixed and mobile spectrum (which describes the propagation characteristics of waves) . Technically, fixed WiMAX will likely find a home in the semi-mobile parts of the spectrum. However, fixed WiMAX in the literal sense only means that a device is designed only to communicate with one base station at a time—without handoffs—and will therefore have to disconnect before reconnecting to another base station. In a more practical sense, there may be a more fixed nature to the physical antenna used in order to fully utilize the connection to the network. The mobile version of WiMAX, unlike its fixed counterpart, will allow handoffs, enabling the user to travel large distances and never lose the connection as the device travels from tower-to-tower.

[See Figure 3 on Next Page]

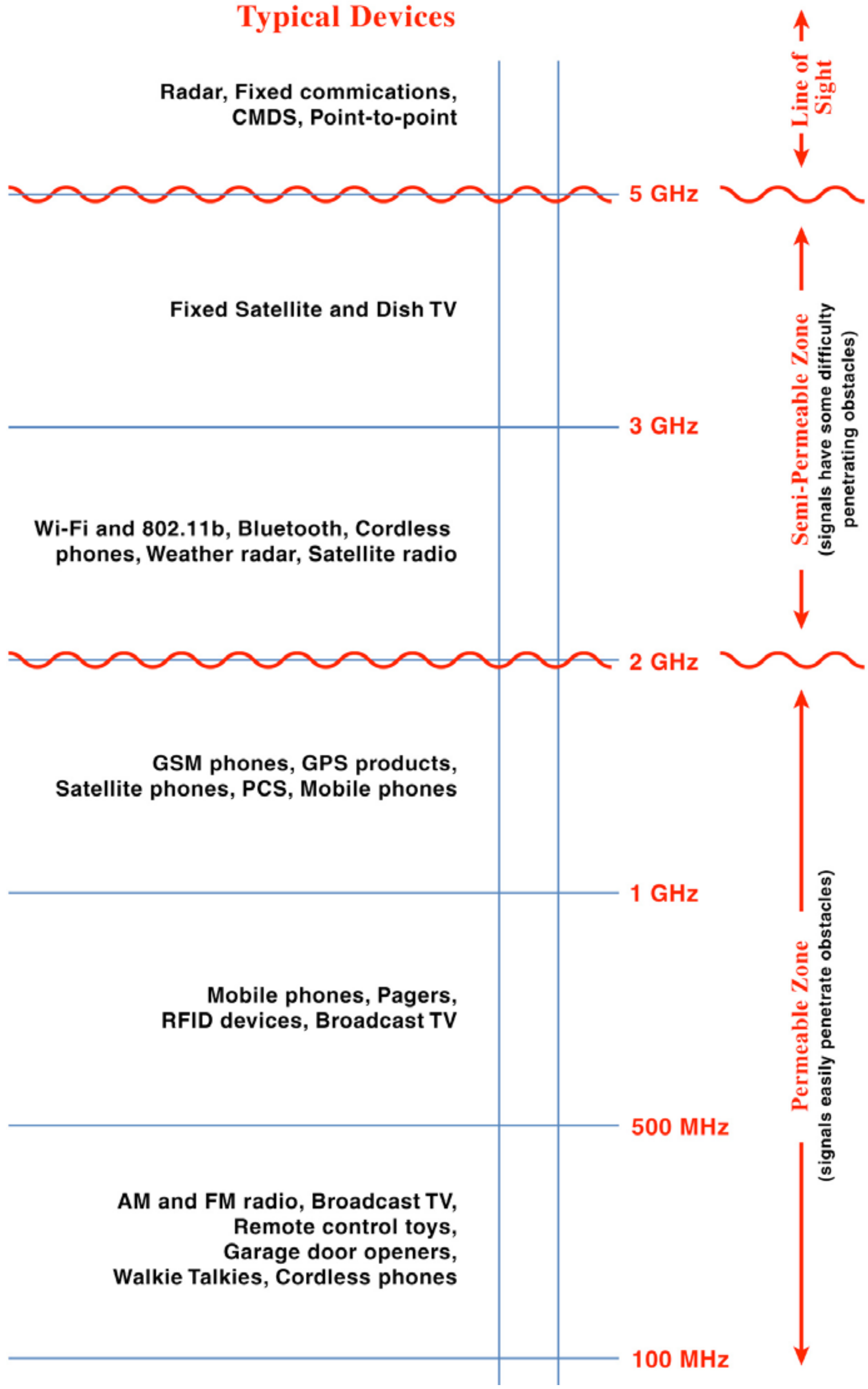

Figure 3. The Value of Mobile Frequencies

3.3 Is there a such thing as "WiMAX Spectrum?"

The current 802.16 standards support ranges from 2-66 GHz. Some of these frequencies are licensed; others are not. In addition, a number of proposals mentioned above do not even use frequencies within this specified range. Moreover, the term "WiMAX" incorporates the phrase "worldwide interoperability," thus adding an international relations component to the equation since different governing bodies regulate their own airwaves. While such international issues are largely outside the scope of this paper, an examination of the difficulty in implementing WiMAX in the United States will provide a glimpse into the challenges inherent in the idea of worldwide interoperability. Nonetheless, from a technical point of view all of the frequencies above 10 GHz are useful only for point-to-point links because making an omni-directional antenna is nearly impossible using standard technology for high frequencies. Furthermore, free space loss increases with the frequency and, as such, requires higher-gain antennas like dishes, which are directional (Alvarion). As previously described, propagation distance increases dramatically as the frequency decreases.

The specification 802.16d allows for WiMAX radio options between 2 and 11 GHz, but details about which parts are not specified by the standard (Conti 2005). There are implementations of WiMAX test networks at 450 MHz, 700 MHz, 1.9 GHz, 2.3 GHz, 3.5 GHz, 4.9 GHz, and 5.8 GHz (Conti 2005, p. 42). It is, of course, possible that a compromise could be reached so that a common set of frequencies is used throughout the world. Unfortunately, as Conti points out, the United States has no frequencies to allocate for wireless broadband. A popular frequency used in a number of countries in Europe and Asia is 3.5 GHz. As a result, 2.3 to 2.5 GHz and 5.8 GHz will be most likely be used in the United States (Frenzel 2005, p. 55). However, unlicensed portions of the 2.3-2.5 GHz range are already crowded with a number of things (baby monitors, garage door openers, microwave ovens, etc), including the common “b” and “g” Wi-Fi standards. Sprint Nextel’s licensed spectrum is in the 2.5 GHz range, but if the devices are made for 2.5 GHz in their spectrum, then they will essentially have market control because of the exclusive, licensed nature of this spectrum. Another option involves the use of the lower frequencies owned by the Aloha Group (700 MHz), but this solution partially relies on the transition to digital TV broadcasting to avoid interference (Townsend 2005). Furthermore, the WiMAX standards do not go below 2 GHz, so products would have to be certified under something newer than 802.16e, which could slow down the technology development even more. Ultimately, it seems that the goal of worldwide interoperability may be difficult to achieve, especially if WiMAX is relegated to small sectors of white space in the spectrum. It will take more than just multi-band radios to accommodate the different frequencies.

Business and policy issues further complicate the situation. Companies that recently paid billions for 3G licenses will lobby against WiMAX space allocations, fearing competition with 3G, making WiMAX start up companies have a difficult time even getting their products to the market (Conti 2005). The political pressures involved in opening up other parts of the spectrum also pose an enormous challenge. Among others, broadcasting companies CBS, ABC, and NBC have signed a complaint to the FCC about maintaining spectrum integrity (Donovan 2005). Calling themselves the Coalition for Spectrum Integrity (COSI), these television giants and others cite the Communications Act of 1934 to support their argument that opening up parts of the spectrum to unlicensed use would destroy standard broadcasting as we know it and tear away at the very reason why the FCC’s exists. For example, COSI has complained that a transmitter within 75 feet of a TV would overload the TV tuner, creating unacceptable interference for all 73 million broadcast TV watchers (Donovan 2005). As Donovan notes, other complaints include

"Impairing the digital transition," "[i]nterference with public safety communication," "[u]ndermining newsgathering and sports programming production," "[i]nterference with theaters, churches, and school events," "[p]ermanently chill[ing] investment and impair[ing] the value of the spectrum for the public," and "[i]nterference to cable service" (Donovan 2005). The intent here is not to debate these complex issues, but instead to provide a high-level overview of the political difficulties involved in obtaining the spectrum necessary for successful WiMAX implementation. In all probability, though, COSI's claims are untrue, overstated, or easily resolved through technical means (Marcus, Kolodzy, and Lippman 2005). In fact, the New America Foundation claims that if the same extreme worst-case scenario conditions were created that the broadcasters likely used to come up with their list of complaints, there would be "no digital TV, no digital radio, no unlicensed consumer devices (such as Wi-Fi and cordless phones, of which there are hundreds of millions) and practically no innovation in spectrum utilization" (Snider "Myth" 2005).

The question, then, becomes how to overcome the political difficulties. COSI's claim that the spectrum should continue to be regulated under a 70+ year old document does not take into account the vast changes in technology that have occurred since 1934. For example, New America and Freepress published a report that shows approximate white space in the TV spectrum after transitioning to digital broadcasting. Of the 22 markets examined, the smallest amount of white space was 30% in Trenton, New Jersey, and the largest amount was 82% in Fargo, North Dakota (Scott and Calabrese, 2005). As a result, there is at least a partial solution to the spectrum difficulties. Use of technologies like Ultra Wideband and Smart Radios may also provide a solution, though such a solution is not currently covered under the WiMAX standards. Ultimately, however, political challenges, no matter how daunting, will not prevent future implementation of WiMAX.

4. Conclusions

WiMAX technology is still in its early stages of development. Potentials uses include broadband access for rural areas or for areas that have no other reasonable broadband access; reduced cost transmission lines such as backhauls from cellular sites or cross-town links; and competition for something beyond existing cellular, the so-called “3G,” or even an emerging 4G cellular standard. WiMAX makes data connections better for those who already have them and makes Internet connectivity possible for entire groups of people who previously had no access. Extremely high bit rates will not be the “killer app” that will ultimately convince people to use WiMAX. Indeed, WiMAX’s throughput promises nothing more than cable’s or DSL’s ability to provide users with high-speed connectivity, and WiMAX will have a difficult time challenging Wi-Fi’s (here, 802.11g) purported 54 Mbit/s. WiMAX’s promise boils down to a combined promise of cost savings (commoditized equipment using unlicensed and licensed spectrum), improved access (both rural fixed and mobile applications), and the ability for the technology to fulfill the advertised potential and the concomitant security promises. As the technology matures, Wi-Fi-like 50 Mbit/s rates will become more possible, the same way the cellular phone quality and features have improved dramatically over the last decade.

Eventually, then, rural areas will have wireless broadband, and, if widely accepted by the market (as Wi-Fi has been), WiMAX may become affordable enough to enable widespread usage (e.g., if the Aloha Group’s proposal at 700 MHz with large propagation distances is accepted). Today, many people use the Internet, and these users are now embracing the Internet for lifeline services like voice telephony; as such, it is almost a social responsibility to extend service to areas where it is currently not available or affordable, in much the same way that such services as electricity and the telephone were made available to U.S. citizens nationwide. If universal broadband service is a goal of this country, WiMAX will be an essential part of achieving that goal in areas where other methods of Internet access is just not feasible.

Economics will determine where and when WiMAX will replace transmission and backhaul lines. If the technology can become inexpensive enough, it could significantly reduce operational costs for cellular carriers as well as other point-to-point connections that may currently be prohibitively expensive. Bell South's offering of pre-WiMAX connectivity for $69 a month, for example, is significantly cheaper than the average cost of a T1 line, but for now the reliability and actual data rates necessary to begin replacing T1s cannot be achieved.

Most seem to agree that WiMAX will have its greatest chance of success with its mobility standard because, as in the New Orleans situation, fixed wireless does not offer the advantages that many people seek. Mo Shakouri, vice president of marketing for the WiMAX Forum explains, "[b]y adding mobility to WiMAX, it would be a unique capability to complement DSL and compete with DSL" (Luna 2005, p. 3). As Shakouri further notes, WiMAX will compete with cable/DSL by providing mobility in addition to a high-speed connection (Luna 2005, p. 3). WiMAX cannot truly compete for 3G data services unless a company like Sprint Nextel ends up using WiMAX equipment and immediately builds a nationwide infrastructure for it. WiMAX may be a 4G technology because its modulation techniques make more efficient use of radio spectrum; as a result, higher data rates are possible than with any of the 3G technologies. The process of certification will be essential in making the transition to WiMAX possible. Some question whether or not companies or individuals should invest in equipment that will be made by companies like Motorola because there is no assurance that such equipment will actually become part of the WiMAX certification. However, equipment investment enabled the Wi-Fi standards to become a reality, and the same holds true with WiMAX. Thus, WiMAX will remain in its early stages until the certification process begins. However, Intel's commitment to making WiMAX a reality will likely speed the process along (much like what happened with Wi-Fi).

WiMAX is a technology of the future, and it appears that mobile WiMAX should be ready to roll out sometime between 2008 and 2010. When it does, it will be an essential part of data communications in the United States. Right now, its full potential is unknown, but as the technology matures we will learn more about the potential so-called "killer applications" for WiMAX. Concerns about spectrum management will continue to play out over the next few years, and the transition to digital TV broadcast will occur in this same period. Therefore, WiMAX should enter the market at a time when spectrum will be available.

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