Aspects Favoring the Deployment of 3G Long-Term Evolution (LTE) Technologies over Mobile WiMAX

Christopher Glaser
Graduate Student, Department of Interdisciplinary Telecommunications, University of Colorado
Boulder, Colorado

602 Saint Johns Road
Wapwallopen, PA 18660
(570) 379-1069

E-mail: christopher.glaser@colorado.edu

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Abstract

There has been much conversation over the past few years regarding the evolution of next-generation air interfaces supporting mobile broadband. One of the most talked about as far as promise is concerned is 802.16e, otherwise known as mobile WiMAX. In its advertised form, the standard can support data rates of tens of megabits per second while supporting many real-time user applications that cannot be supported by third-generation technologies. Although mobile WiMAX sounds promising as a next-generation technology, other factors do exist which will limit its overall success. Some of the factors that will be discussed in this paper will include the design challenges facing base-station architecture, competing third-generation long-term evolution (LTE) technologies, and costs to existing service providers to upgrade their networks. This paper is meant to demonstrate that from a service-provider's point-of-view, the upgrade path to mobile WiMAX may not be the correct solution.

Introduction

In August of 2006, an announcement was made by Sprint Nextel stating that the company will invest up to three billion dollars over the next few years in a joint venture with Intel, Motorola, and Samsung in the development of a mobile Worldwide Interoperability for Microwave Access, or WiMAX network. Represented as an IEEE 802.16e standard and expected to launch in the fourth quarter of 2007, this news was the first big announcement of a deployment in the newest fourth-generation mobile broadband technology, which is capable of delivering tens of megabits of data per second to any end user (Parker 2006). This announcement has sent shockwaves throughout the wireless industry and promises to start debate on the viability of the standard over the next several years. From a technical perspective, this mobile WiMAX standard provides benefits that rival any third-generation radio access technology (RAT) that is currently available, such as the high data rates that can be achieved, the high quality of service, the virtual immunity to multi-path fading scenarios, and high user capacity. However, there are other factors that will curtail future deployment of the technology as well. Some technical disadvantages of the standard include complex base station designs, high antenna usage, high bandwidth usage, and loosely defined synchronization requirements, all of which may affect the functionality of some real-time data applications. Other factors that will impact the deployment of 802.16e include the slow rollout of standards, competing third-generation wireless radio access technologies, and future costs to service providers of purchasing additional spectrum and infrastructure. These other factors have given third-generation equipment manufacturers a head start in developing technologies that will rival the 802.16e standard. This paper will illustrate all of the above reasoning as to why this standard will not be as readily used as first anticipated. The decision by Sprint Nextel has given the WiMAX industry plenty of credibility and capital to the extent that the technology will be used considerably in the future; however, as the above factors will illustrate, the overall deployment of the 802.16e standard will be fragmented and, at best, a niche technology.

Performance and Design Challenges Facing Mobile WiMAX

Although many technical aspects of mobile WiMAX are attractive to broadband users, the standard has some performance disadvantages that should be noted when being compared with some third-generation (3G) technologies. Some challenges that will be discussed include loosely defined synchronous requirements, complicated base station designs, and complex antenna schemes. Each of these factors could not only adversely affect overall system performance, but also prove to be more costly than third-generation networks as well. These factors may force service providers to rethink their plans in upgrading their networks to include mobile WiMAX if these challenges are too difficult to overcome.

Latency Disadvantages

One primary technical disadvantage of WiMAX in general is the possible latency disadvantages that must be considered when comparing 802.16 with other third-generation standards. Synchronization is less accurately defined in the 802.16 standards than, for example, a third-generation CDMA2000-based Evolution Data Optimized (EVDO) network. Although both EVDO and 802.16 systems can use Global Positioning Satellites (GPS) as their reference clock, EVDO allows synchronization only to within +/- 3 microseconds of a GPS timing source based on 3GPP2 specifications (3GPP2 C.S0032-A 2005). The 802.16 standards allow synchronization from within 5 to 25 microseconds of the timing source. In addition, the 802.16 standard allows for its reference clock to be based on the IEEE 1588 Precision Timing Protocol, which may be inexpensive to deploy; nonetheless, this protocol is less accurate than GPS (Dropping 2006). Although the differences in timing do not appear to be significant, the importance of synchronization lies in the fact that base stations may transmit voice or data packets into an incorrect time slot if the timing accuracy is not sufficient, obviously affecting data performance (Dropping 2006). Those deficiencies in synchronization will have direct negative effects on real-time applications such as gaming or Voice-Over-IP.

Complexity of Base Station Designs

Another technical disadvantage of WiMAX, or Orthogonal Frequency Division Multiplexed (OFDM) systems in general, is that both receiver and transmitter designs in both the terminals and the base stations become more costly and complicated than those designed for spread-spectrum radio access technologies, such as EVDO. The complexities in design of these transmitters or receivers are due to the higher peak-to average ratios (PAR) exhibited by OFDM carriers which limits transmission power efficiency (Aggarwal, Meng 2004). These limits in efficiency exhibited by these signals will create a performance versus cost question from a designer's standpoint. Most base station amplifier designs are of the non-linear variety, where tradeoffs in amplifier power efficiency are compromised in order to save on overall power consumption. Any amplifier nonlinearity causes inter-modulation products resulting in unwanted out-of-band power (Armstrong 2001). In general terms, the higher the peak-to-average ratio of transmitted signals yield a higher amount of spurious emission products outside of the desired carrier bandwidth. These products, if large enough, can create overall RF system performance degradation. To eliminate inter-modulation products as a whole, linear amplifiers would be needed with a large amount of dynamic range to prevent clipping of OFDM peaks. The problem with using these types of amplifiers is that they are very expensive and are very inefficient from a power consumption standpoint (Armstrong 2001). Of course, non-linear amplifier designs can be modified to accommodate for the increase of spurious emissions that may be generated from OFDM carriers. These designs can be accommodated through both hardware and software means, either at the amplifier level with improved component-level design or at the radio levels with software-defined PAR reduction techniques. The tradeoff that will be associated with these improvements in design will be cost, although not quite as much as there would be with linear amplifier designs. These influences in cost will most likely be passed on to the service providers and end users as well.

Costs of MIMO Antenna Techniques

The functionality that 802.16e promises will have a direct impact on cost. According to Julian Bright, editor of *3G Wireless Broadband,* initial costs of customer premise equipment (CPE) will be relatively high, as opposed to fixed WiMAX when smart antenna technologies are implemented (2006). To achieve the tens of megabits per second that 802.16e promises, MIMO or multiple-input, multiple-output techniques are used to increase spectral efficiency through spatial multiplexing and improved link reliability due to antenna diversity gain (Bolcskei 2006). This technique, in other words, requires systems consisting of a large number of antennas on each side of a wireless link which would improve system reliability by providing interference cancellation and coherent combining with no additional usage of power or bandwidth (Bolcskei 2006). As complicated as the previous definition sounds, there are supplementary costs that must be incurred by providing the multiple antennas needed for MIMO to be successful. Although not substantial, these costs are just another factor that service providers would have to think of when considering upgrading to mobile WiMAX.

Delays in 802.16e Standardization

In addition to the design and performance challenges that need to be overcome, there has been a slow rollout of the 802.16e standard, which is causing a delay in deployment of mobile WiMAX. According to its own website, the standard was formally adopted in December of 2005 and replaces 802.16-2004, which only addressed the fixed access wireless systems (2006). The current standard is essentially a two-layer specification, where the Physical layer and the Media Access Control layers are defined. In other words, both the radio access technology and the authentication/encryption layers of the standard are defined. An further problem that is causing delays in deployment is that the standard does not define connectivity at the network layer and above, which is yet to be defined by the WiMAX Forum, a consortium of approximately 350 member companies assembled to promote and certify a common 802.16 broadband technology (Axner 2006). Any WiMAX Forum member company that wishes to deploy an 802.16e system will need to have their systems certified by the forum to ensure that their systems will be compatible with networks from other service providers. Since the WiMAX

Forum is still in the early stages of certifying mobile networks as well as standards, the delays are magnified.

The latest 802.16e standard does not also provide for backward compatibility with the previous versions of 802.16, so any developments in WiMAX infrastructure by equipment vendors prior to 802.16e will have to include these incompatibilities, which would have to be provided by the vendor as well. This lack of interoperability will cause an inherent delay in integrating these networks due to these differences. These delays have caused the deployment of mobile WiMAX to lose the time-to-market advantage that was once hoped it would achieve. The deployment of mobile WiMAX completion isn't slated until 2007 or 2008; therefore, third-generation long-term evolution (3G LTE) will be well established (Korhonen 2006). In addition, technologies such as EVDO Revision B could deal a significant blow to mobile WiMAX since data rates would be comparable (Axner 2006). In addition, the research firm Yankee Group states that mobile WiMAX will not become standardized until early 2008 (Bright 2006). The main reason that the firm believes this trend is that service providers are frustrated by the standards creation process and when the standard will truly emerge. The group also believes that service providers will want to wait for the full spectrum of capabilities to be provided by mobile WiMAX before investment in the technology is to occur (Bright 2006). The potential threat that is created by this type of delay is that mobile broadband access is already beginning; therefore any further delays in the rollout of mobile WiMAX could be hampered by actions of service providers who may elect to use current mobile broadband technologies.

Competing Mobile Broadband Technologies

The slow rollout of the 802.16e standard in addition to the delayed decisions by telecom regulators to issue spectrum has given third-generation long-term evolution (LTE) technologies a chance to penetrate further into the high-speed data market. These technologies, otherwise known as 3.5g technologies, are evolved from existing third-generation data networks and are in the process of being launched within commercial networks currently.

HSDPA/HSUPA

One of those 3.5g technologies that will compete with mobile WiMAX in many areas is HSDPA. Otherwise known as High-Speed Downlink Packet Access, this radio access technology (RAT) was evolved from third-generation UMTS, and in its current form (Release 5) can provide a maximum downlink data rate of 14.4Mbps (Poole 2006). The uplink portion of the RAT, otherwise known as HSUPA, will be commercially available in 2007 and can provide uplink data rates of to 5.8Mbps in Release 6. The first commercial deployment of HSDPA occurred in November of 2005 by Manx Telecom for use in the Isle of Man. In addition, T-Mobile is in the process of currently launching networks in Austria and Germany (Poole 2006). In addition, HSPA technologies are being integrated into many notebook PCs at this time throughout Europe. Manufacturers such as Hewlett-Packard, Dell, Lenovo, Acer, and Panasonic are integrating modems that support HSPA. The research firm In-Stat/MDR has indicated that by the end of 2007, over three million laptops will be equipped with HSPA modems (Conti 2006). The usage of HSPA will be favored heavily in Europe as can be seen by the European

Union’s decision in July 2005 to block frequency allocation for WiMAX in both France and Finland. This move was made in order to protect European manufacturer’s heavy investment in HSDPA and HSUPA (Axner 2006).

CDMA2000 1x-EVDO

The majority of North American investment in 3.5g will come from 1x-EVDO radio access technologies. This IS-856 technology has been integrated into CDMA2000 networks and in its current Revision 0 format it can support downlink data rates up to 2.4Mbps while supporting uplink rates of 153.6kbps within a 1.25MHz carrier bandwidth (3GPP2 C.S0032-A 2005). In the second half of 2006, Revision A of this standard will be commercially deployed and can support downlink data rates of up to 3.1Mbps while supporting uplink data rates of up to 1.8Mbps within a similar 1.25MHz carrier bandwidth (Dropping 2006). In 2008, or roughly about the time the mobile WiMAX will be begin to deploy into commercial networks, Revision B of the 1x-EVDO standard will begin to launch as well. The data rates of this standard are exceedingly higher than Revision A, where multiple 1.25MHz carriers can be utilized with a 64QAM modulating scheme. Theoretical data rates of EVDO Revision B can go from 4.9Mbps for one carrier and up to 73.5Mbps on the downlink and 27.5Mbps on the uplink while utilizing a maximum of 15 carriers of 1.25MHz bandwidth (Axner 2006; WiMAX Forum 2006).

Qualcomm's Influence in 3G Long-Term Evolution (LTE) with Flash-OFDM

In addition to the competing technologies listed above, another major player in the telecommunications industry is doing their best to quash the efforts of the growth in Mobile WiMAX. Qualcomm, who was one of the primary originators of CDMA technology and its third-generation data technology called 1x-EVDO, owns a competing standard with 802.16e, called Flash-OFDM. Last year, Qualcomm purchased Flarion Technologies, a small startup company who had patented this technology and is a variation of the 802.16 OFDM standards that is being pursued by most companies currently (Mackie 2006). The main difference between the standards is that in Flash-OFDM, traffic is limited over a 1.25MHz carrier bandwidth and therefore limits peak data rates to about 3Mbps currently on the downlink. These limitations in throughput are as opposed to the data rates that can be achieved with bandwidths up to 20MHz offered by 802.16e. In addition, the company acquired approximately 100 patents related to OFDM technology, which have the potential to influence how 802.16e is developed since Flash-OFDM technology is proprietary and not related to the WiMAX Forum's developments in any way (Mackie 2006). Qualcomm's presence in mobile broadband technology remains strong although Flash-OFDM has not been widely deployed to this point in time. The company will benefit from royalties generated in 1x-EVDO deployments. At this time, providers such as Sprint Nextel are still deploying large amounts of 1x-EVDO Revision A networks even though Flash-OFDM was not chosen by the company as a next-generation alternative in the 2.5GHz frequency range. The royalties generated with these deployments will allow Qualcomm to compete with mobile WiMAX.

NGMN Forum

As stated in the previous sections, there are several long-term evolution alternatives to mobile WiMAX that will provide plenty of competition to the success of the 802.16e standard. In addition, there is a consortium of twenty-six companies that was recently created to explore the possibilities of the future of 3G long-term evolution. Companies such as T-Mobile, Orange, Vodafone, KPN, China Mobile, NTT Docomo, and even Sprint Nextel are active participants of the Next-Generation Mobile Networks (NGMN) Forum, whose primary focus is to "provide an evolutionary path for the next generation of mobile networks beyond HSPA and EVDO" (NGMN Forum 2006). In addition, this consortium was created to act in a similar fashion as the WiMAX Forum, which is essentially to come up with a unified approach in standards creation.

Future Costs to Service Providers in Deploying Mobile WiMAX

Right now, service providers such as Sprint-Nextel and Clearwire are pursuing the mobile WiMAX evolutionary path because they own a large amount of spectrum in the 2.5GHz range to support the development. One of the major differences between the fixed and mobile versions of the 802.16e standard is that in the mobile technologies require spectrum to be licensed in order to be used where fixed WiMAX does not require licensed spectrum. Therefore, other North American carriers who do not own that spectrum in the proposed frequency ranges must either purchase new spectrum for mobile WiMAX or will have to pursue 3G LTE towards mobile broadband. Since regulators in North America and worldwide are only considering mobile WiMAX spectrum to be licensed in the 2.3GHz, 2.5GHz, and 3.5GHz ranges, service providers will not be able to reuse their existing spectrum for upgrades to mobile WiMAX. If this is the case, carriers who do not own or do not want to pay the billions in license fees to the FCC once again will opt to choose the LTE path instead. Choosing the LTE path means that no additional round of licensing is to be held by governments nor is there the need to rip out and replace core networks because the evolutionary path is based on current invested infrastructure with a clear upgrade path on the existing network elements (Niri 2006). Providers can reuse their existing 3G spectrum that they spent billions of dollars for just a few years ago. Bruce Gustafson, director of WiMAX marketing for Nortel Networks, even believes that mobile operators will hang on to their existing 3G networks since WCDMA/HSDPA and CDMA2000/EVDO are closer to deployment than mobile WiMAX (Chappell 2006). "I don't believe you will see 3G operators throwing out their 3G networks and deploying WiMAX instead. You won't even see WiMAX as an overlay network," Gustafson says. Since at this time most 3g network operators do not own spectrum in the proposed mobile WiMAX frequency ranges, the scenario proposed by Gustafson will most likely be the most logical choice by these operators unless significant investments in spectrum are made.

Conclusion

It has been shown that there are many obstacles that will prevent mobile WiMAX from becoming that dominant mobile broadband technology over the next several years. The obstacles presented in this paper, however are more likely to be taken from the perspective of wireless service providers who own circuit-switched networks, where the costs associated with upgrades to packet-based mobile WiMAX networks may not be practical. For the existing service provider, there are just too many options to consider when choosing a particular broadband migration path. Conversely, for any newer service provider who is looking to create a network from the ground up, mobile WiMAX may be a good place to start. Further investigation will need to be performed on this whether mobile WiMAX is a suitable option for startup companies. At this point in time, mobile WiMAX appears to be the next radio access technology that will fragment the industry even further instead of clarifying it. Time will only tell which market forces will determine the evolution of mobile broadband radio access technologies; yet for the next several years, mobile WiMAX will not necessarily be the solution.

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