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# WiMAX

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## A Global View on WiMAX and Mobile Broadband Trends


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# WiMAX: State of the Industry

*by Eliot Weinman*


*The last quarter of 2006 sees WiMAX at a tipping point, from which it looks set to emerge as a major platform.*

WiMAX has seized the headlines to such an extent in the past two years that it is has become almost synonymous with broadband wireless access. However, with certified products only coming to market in 2006 and even pre-certified 802.16 systems still newcomers on the scene, WiMAX is currently only a small part of the full BWA picture, let alone that of wireless systems overall. However, the last quarter of 2006 sees WiMAX at a tipping point, from which it looks set to emerge as a major platform and a likely key piece within the jigsaw that will be labelled '4G' – in other words, true mobile broadband, and fixed/mobile convergence to support high bandwidth IP applications on low cost devices.

## The new importance of BWA

Broadband wireless access (BWA) has been a niche sector, worth less than $1bn in equipment revenues worldwide in 2005, with specialized vendors selling products to a confined set of customer bases – largely oases of relative affluence in areas that are hard to serve profitably using wireline broadband, notably rural regions and urban or high income enclaves in developing economies.

Even without the impact of WiMAX, with its large vendor backing and resources, several factors have pushed up the profile of BWA since 2003, and will continue to do so, especially as WiMAX becomes fully mobile and a potential alternative, or complement, to 3G-plus systems.

The key factors are rise in demand for broadband, which is increasingly seen as a necessity rather than a luxury in developed economies, and as a means to stimulate growth in emerging nations; and the impact of Wi-Fi and the emergence of personal broadband. One important area where Wi-Fi has shown the way is in support for a personal broadband connection that is portable, and eventually mobile. Not only does this concept open up many new business opportunities for providers, but it changes the way that consumers operate.

These changes will see wireless increasing its share of the broadband market (excluding 3G) from 2% to about 17% in the early years of the next decade. By 2009 30% of the broadband consumer base will demand personal broadband (more in enterprise markets) and subscriber levels will reach about 50m, with a compound annual growth rate of 68% between 2006 and then.

Currently, mobile broadband is a small part of the BWA market, but as Wi-Fi mobilizes, 3G evolves with next generation architectures and 802.16e becomes a real world option, this area will be the chief battleground for the major vendors and service providers, as personal broadband applications like mobile TV become key to operator growth.

Wireless is not increasing its market impact purely because of consumer pull. The OFDM technologies, especially WiMAX, have also evolved rapidly

to become more suitable to support personal broadband services. For operator return on investment, the following technological developments are key:

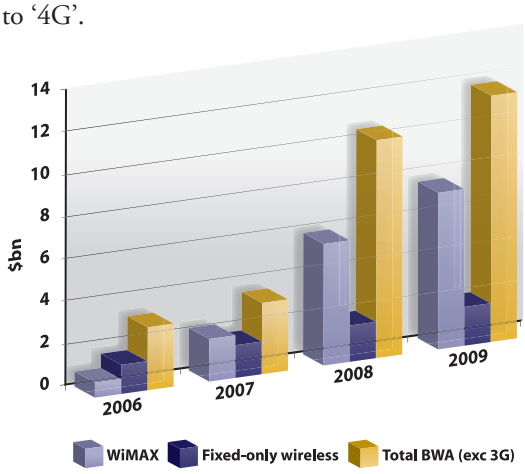
- OFDMA, the key PHY technology for next generation wireless, which supports advanced spectral efficiency, even coverage through the cell, mobility and non-line of sight
- Smart beamforming, advanced signal processing technology that reduces capex by up to 60% and opex by 50%
- MIMO, advanced signal processing technology that makes mobile operation more robust and increases capacity by up to 30%
- Simplified network architecture, a data centric network architecture that relies on the simplicity of IP-based networks to deliver lower cost per Mbps.
- Implementation of radios in CMOS and dual-radio handsets
- Lower powered devices for greater portability at lower cost.

Also critical to the economics of WiMAX is the self-install, plug-and-play customer premises equipment (CPE), evolving towards the embedded link in laptops, phones and consumer devices, which achieves the operator dream of a CPE with zero subsidy from the provider, and low or no (perceived) cost to the end user.

## WiMAX in broadband wireless

In the traditional BWA market, fixed and portable, WiMAX and Wi-Fi will become quickly dominant. In unlicensed spectrum, the key technologies will be Wi-Fi and – depending on whether WiMAX equipment emerges for 5GHz – 802.16-2004 or some strong proprietary offerings such as Motorola Canopy. In the 3.5GHz licensed bands, WiMAX will be dominant by 2008, with over 80% of new sales in this frequency range supporting 802.16 standards. The picture in the other major BWA range, 2.5GHz, is more complex because so many other technologies will also seek to have a place here, and this will be primarily a band for mobile broadband.

In the mobile broadband arena, and the sub-3GHz frequencies that best support mobility, there will be far tougher competition between different technologies to take a strong position. While there will be significant build-out of systems with at least a degree of mobility in 3.5GHz, the vision of large international networks supporting full mobility will mainly be realized – or not – in 2.5GHz and potentially spectrum regions below this. In this sector, the role of WiMAX is less assured. If mobile broadband is still treated as a distinct subsector, excluding 3G, 802.16e will be the dominant system, and the ability of Flash-OFDM and TD-CDMA to retain a viable share will depend on some key large operator decisions, such as Sprint Nextel's, in the coming year. However, by 2009, there will be widespread adoption of HSxPA and CDMA EV-DO Rev A and Rev B, the next generations of the current third generation cellular networks, and implementations of the ensuing upgrade for UMTS, LTE, will also be looming. At this point, the distinction between BWA and cellular technologies becomes moot, since the technological basis of 802.16e, LTE and the Qualcomm family of systems will increasingly look similar – based around OFDM, smart antennas, all-IP, non-hierarchical network structures and so on – and the importance of each system will be decided by commercial and political factors. In this situation, 802.16e will be an important part of the mobile broadband picture, but certainly not the largest part, and its success will mainly depend on its ability to complement 3G and GSM in operator business models, and perhaps to converge with LTE completely by the end of the decade as a prelude to '4G'.




source: Rethink Research

*This figure includes 802.16-2004 certified equipment and systems that have been built to the 802.16-2004 standard but not yet certified. Even if there is some certified equipment for 802.16e by year end, this will not impact revenues until next year, and pre-certified 802.16e systems are not included in the WiMAX figure. Instead, they fall into the portable broadband category, which comprises proprietary portable/mobile systems and outdoor Wi-Fi. This will account for 55% of revenues, with 21% going on fixed-only proprietary systems, mainly in 5GHz spectrum and in profiles not covered by WiMAX or Wi-Fi such as 900MHz.*

## Key predictions

By the end of 2006, 24% of the total BWA market by revenues for that year will be WiMAX. About $700m will be spent in total on WiMAX, the bulk of this in Europe, in a total BWA market of $2.9bn. Some of these investments will not be built out until 2007.

By 2008, fixed only wireless will have shrunk to 10%, WiMAX in both 802.16-2004 and 802.16e forms will take 45% and Wi-Fi plus portable proprietary systems will account for a further 45%. By the end of 2009, WiMAX will be the largest player with 63% share. Spending on WiMAX in the 2007-9 period will total $5.2bn with the figure weighted to the last year as the impact of large scale 802.16e personal broadband roll-outs start to be felt.

*While the availability of 3.5GHz spectrum around the world is fairly assured, WiMAX's success depends on this not being the only option.*

All these figures exclude UMTS, CDMA EV-DO and TD-SCDMA but include TD-CDMA and Flash-OFDM. Wi-Fi is included where it is used as a broadband access technology for outdoor metro-zones and home or enterprise connections, but not as an indoor network. In mobile broadband as a whole, including HSxPA, LTE, CDMA EV-DO Rev A/B and TD-SCDMA, we would expect 802.16e to take a 22% market share by the end of the decade.

In 2006-7, WiMAX spending will be first generation. It will be split between the following categories:

Extension or migration of existing proprietary BWA systems. The main drivers will be:

- To extend into new territories with greater cost effectiveness
- To support portability or Wi-Fi front ends
- To support new applications such as VoIP
- To replace aging BWA systems.

New holders of WiMAX spectrum building out for the first time. These will include:

- Start-ups
- Wireline ISPs looking to enter new markets and support portability
- Some large telcos and cellcos, though most of their activity in developed markets will come with the availability of new spectrum options such as 2.5GHz and with support for mobility. They will start to invest seriously when 802.16e is fully available, with their impact starting to be felt in the second half of 2007. However, many telcos in emerging economies will acquire 3.5GHz licenses
- Telcos and other players that have been sitting on BWA spectrum and are now being encouraged or forced to bring it into play (e.g. NextWave in the US)
- Some cable and satellite operators will acquire spectrum
- Public authorities.

From 2008, these trends will continue, and there will be a fresh wave of new WiMAX operators as:

- new spectrum licenses are allocated round the world
- 802.16e becomes proven and cost effective as a mobile technology and starts to attract additional adopters, especially from the telco, cellco and triple play community
- new business models such as wireless IPTV become practical using WiMAX, luring new converts
- proprietary BWA operators migrating to WiMAX will occur for the first time.

There will also start to be a second wave of spending by the original players, as they:

- extend their networks geographically
- service larger numbers of subscribers, involving additional base stations and CPE
- upgrade equipment to support new applications such as IPTV and high speed mobility.

There are risks of course, largely centered on regulatory policy and competitive technologies. An acceleration in the evolution of LTE and other non-WiMAX mobile broadband technologies could reduce cellco interest in 802.16e, even in countries where there is no investment yet in 3G networks, and could even attract new spectrum holders to these mobile technologies. Conversely, 802.16e is unproven as yet, and its early versions could disappoint in terms of performance, mobility and economics and deter further investment.

While the availability of 3.5GHz spectrum around the world is fairly assured, WiMAX's success depends on this not being the only option – especially if it proves difficult to make a business case for mobile broadband so high up the spectrum. Regulator and operator decisions in 2.5GHz, 1.9GHz, 700MHz and other bands will be critical, and many are currently hard to call.

If 802.16e is being widely deployed by the end of 2009 as a personal broadband technology, we would expect a major new wave of investment in it from 2010 as part of the move to the true fourth

generation converged IP networks. There are already some hopeful signs from the WiMAX point of view. Motorola said in June that it was responding to about 25 requests for proposals on WiMAX networks. Raghu Rau, senior vice president of global marketing and strategy, commented: "Some are nationwide. You get a lower cost per bit than you do with traditional cellular, and that's why it's popular in emerging markets." Rau said the company had even talked to potential customers about migrating from GSM networks to 802.16e.

For its part, Nortel is seeing the main demand for WiMAX coming from non-wireless operators in developing and rural markets, and in the cable industry. "We're talking to three companies that say they want to do nationwide roll-outs in the US, and only one of them is a traditional wireless or wireline carrier," said Mark Whitton, the company's head of WiMAX, in an interview. "The kinds of companies interested in WiMAX are new operators that want new business models - companies that want to take new media assets to market."

Such experiences reflect the feedback from early deployers and from the operator base at large firms as they weigh their options. Some key trends are clear. First, WiMAX's main potential lies in personal broadband, though not necessarily full mobility, where it will not catch up to CDMA systems for some time. Second, there has been a sharp defocusing on 5GHz WiMAX and certified equipment may never appear, leaving the field to products like Wi-Fi and Motorola Canopy. Therefore the only major license-exempt activity will be in potential new allocations where licensing is unnecessary or 'light' (such as the US 3.65GHz band). Finally, 2006-7 will not be the year when WiMAX becomes truly mass market – we must wait a few years for that – but it will be the year when clear patterns are set and it becomes a driving force for next generation mobile broadband technologies.

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*Market forecasts used in this article are from "WiMAX Global Map 2006-9" published by Trendsmedia/Rethink Research. For more information, please email: info@trendsmedia.com*

*2006/'07 will be the year when clear patterns are set and WiMAX becomes a driving force for the next generation broadband.*

# WIMAX: A GLOBAL MAP

*by Caroline Gabriel*

*Over the past three years, the emergence of Wi-Fi and the rising demand for ubiquitous broadband access, have converged to create a burgeoning market for public wireless networks.*

As 2006 draws to a close, it is clear that the early map of commercial WiMAX deployments and trials around the world is a very varied, and sometimes fragmented one. Regional contrasts are sharp, because of regulatory differences and varying levels of demand and competition. Some key drivers are clearly emerging, which will generate early growth – such as the metrozone boom and the prospect of WiMAX VoIP – but much of the hard revenue in the first year of certified WiMAX equipment is still coming from traditional backhaul applications. With a certified mobile kit around the corner, and some roll-outs of pre-certified 802.16e already underway, the focus is increasingly heavily on this aspect of the WiMAX standard, possibly at the permanent expense of the hopes for WiMAX as a license-exempt option for start-up carriers.

## The 5.8GHz spectrum

The bulk of early pre-WiMAX activity took place in 5.8GHz. Some WISPs are looking to take advantage of the scalability and falling costs of WiMAX to expand their networks quickly and seek to pre-empt the majors. Several US providers have embarked on major acquisition sprees, snapping up smaller players in underserved territories to try to cobble together regional or near-national networks where there is unmet demand for broadband and no immediate interest from the big names.

However, as the focus and the funds have shifted to licensed bands, few vendors have submitted their equipment for certification under the only current license-exempt WiMAX profile, 5.8/5.4GHz. It is a real possibility that 5.8GHz will remain the preserve of WiMAX-like technologies – such as Motorola Canopy, Alvarion BreezeAccess and some souped-up outdoor Wi-Fi technologies – and not gain any true 802.16 equipment after all. This is because, with mobility impossible at this frequency range, there is less interest from large carriers and less urgent requirement for interoperable standards, while the 5GHz vendors like Motorola are pushing down prices and incorporating many WiMAX-class features, so certification may become an unnecessary added complexity.

New license-exempt bands may open up that are of more central interest to the WiMAX community – if some of the US 700MHz band is kept license-free, for instance – and one driver that may reawaken activity around 5.8GHz could be the most voguish market for unlicensed wireless, the city metrozone networks, especially in the US, but with increasing numbers in Europe, Japan and elsewhere too. We see these metrozones as a key early growth element in the WiMAX global map, even if the core technology remains Wi-Fi.

Two key trends of the past three years, the emergence of Wi-Fi and the rising demand for ubiquitous broadband access, have converged to create a burgeoning market for public wireless networks. With 3G in the hands of a small number of carriers, other operators have turned to Wi-Fi hotspots and then to metrozones, which typically use Wi-Fi mesh to blanket a whole town with low cost access. Increasingly, some metrozone providers are looking to make their networks more robust, and to reduce the cost of backhaul, by combining Wi-Fi with WiMAX and even moving to an all-WiMAX system.

The mass market model requires low cost CPE and so is not suitable, in the first phase, to end-to-end WiMAX. However, in the future, operators will need the carrier class quality and higher bandwidth of WiMAX – whether in 5.8GHz or licensed bands, where available - to create new, differentiated services. These two trends are leading to the interim stage based on the hybrid Wi-Fi/WiMAX hotzone.

## Licensed bands: existing holders

With the main focus on spectrum license holders, early adopters have predictably been those already in possession of appropriate frequencies, notably start-up and traditional providers in European countries that have already issued 3.5GHz licenses, and a rising number of telcos and cellcos. In the US, the pat-

tern is peculiar because suitable spectrum is held by so few entities, but the way that broadband wireless is being adopted by a mixture of incumbent telcos, competitive carriers and at least one large start-up (Clearwire, with the possible addition of M2Z Networks if it plumps for 802.16 too) is indicative of broader trends.

The US competitive local exchange carriers (CLECs) that were allowed to compete with the incumbent Bell operators for local access have been largely unsuccessful at building market share against the entrenched network owners, especially now that there is no cap on what the incumbents can charge for access to their broadband lines. But wireless gives them an opportunity to bypass the Bells' networks altogether and approach subscribers with an offering that can promise advantages from future laptop and mobile support, and shorter waiting lists. WiMAX may also prove important for wired ISPs that are finding it tough to migrate their dial-up bases to broadband because of the dominance of the Bell operators' DSL networks and the cablecos, and recent FCC decisions that make it harder for independents to access those players' networks at reasonable cost. ISPs such as EarthLink and Covad are good examples, and are seeking spectrum partners to take them beyond WiMAX-like 5GHz technologies. Clearwire is the most aggressive start-up and is joined by Sprint Nextel, NextWave and other holders of 2.5GHz frequencies in proposing a quadruple play based almost entirely on broadband wireless (WiMAX or otherwise) as an alternative to the Bell operators.

The Bells themselves hold 2.3GHz spectrum and one of the objections to the AT&T-BellSouth merger was that this valuable asset would become too concentrated in a single body. BellSouth and Qwest are the most advanced in using BWA to reach customers that are beyond the reach of their wired networks, and to add portability to their broadband

*Regional contrasts are sharp, because of regulatory differences and varying levels of demand and competition.*

*Europe is the largest market overall for WiMAX-ready deployments and commercial trials, in terms of numbers of systems in place.*

bundles. BellSouth launched its first commercial services using Navini mobile broadband technology in Georgia in 2005.

Similar patterns of operator take-up will be seen in other regions, with wireline-only telcos eager to gain spectrum and so have a play in the fixed/mobile convergence market – the UK's BT being a prime example. Cellular operators will increasingly look to broadand wireless to provide a fixed line into the home and to swell the amount of spectrum they have to deliver advanced services – O2, T-Mobile and Orange have all made moves in this direction in Europe. And carriers with fixed and mobile interests, such as Telefonica or Japan's NTT, see WiMAX as a way to reach larger numbers of people, even in foreign countries, and add new services and functionality to both their 3G and wireline offerings.

Meanwhile, the start-ups – particularly common in Europe because of its fragmented and low cost licensing scheme – and some smaller ISPs and BWA providers, will use the cost efficiencies, nomadic support and technical advances of WiMAX to improve their business models and try to pre-empt or disrupt the major players.

## Regional trends

Europe is the largest market overall for WiMAX-ready deployments and commercial trials, in terms of numbers of systems in place, though the largest scale individual projects are in the US and parts of Asia. Australia is a very advanced market in terms of functionality, while strong signs of interest are seen in the nascent Africa and Middle East regions. Latin America has a strong tradition of broadband wireless access and should see steady growth, but while Europe will remain the cornerstone for some years because of its heavy allocation of 3.5GHz licenses, and possible opening up of the 2.5GHz band for non-3G technologies, it is the US where WiMAX will be seen as most immediately disruptive, and Asia where there will be the highest growth and most varied roll-out picture in 2007-8.

China, India and Russia are most commonly held up as the great battlegrounds for wireless technologies in the second half of this decade. But in broadband wireless in particular, we should not underestimate the significance of Latin America, which is in the forefront of WiMAX deployment and will have a strong impact on its future success.

Intel's own figures indicate that a quarter of first wave roll-outs are in Latin America. Rethink Research found that 12% of broadband wireless operators that are rolling out 802.16 or have firm plans to do so within two years are currently in Latin America, and this figure will increase to an estimated 18-20% by 2008 as more WISPs turn to WiMAX – more if some key countries like Brazil decide to make their 3G spectrum technology neutral, or to sideline 3G in favor of next generation networks.

In Europe, most of the large carriers are looking to roll out fixed/mobile convergence over the next few years, based on the IP triple play of VoIP, data and broadcast. Operators such as Deutsche Telekom, see the opportunity to supplement 3G spectrum with broadband wireless and adopt a wireless platform that should provide indoor, fixed coverage more effectively than 3G where wireline is not available.

Unlike in the US, spectrum for broadband wireless should be fairly plentiful because of widespread allocation of the 3.5GHz bands, though it is not clear how many regulators will permit full mobility in these, and in some countries such as the Netherlands, incumbent operators are excluded from holding these frequencies. This means that there is a far higher focus on licensed spectrum roll-outs than in North America, with many of them coming initially from start-ups.

Europe is seeing a spectrum goldrush reminiscent of that of 1999. The rising demand for broadband services, and the promise of low cost standardized WiMAX-style equipment, is starting to erase the memories of the failure of most of the operators that acquired licenses back then, in the key spectrum around 3.5GHz. A string of auctions and beauty contests have already been held, but the coming year will see activity from the largest markets, that could create a major surge in the broadband wireless access (BWA) market.

With the 3.5GHz frequencies suddenly in intense demand again, governments will need to resist the temptation to raise inflated revenues through free auctions. Most regulators, so far at least, are focusing on promoting competition and access in underserved areas, rather than maximum numbers of euros, but the policies set in the major countries will influence the overall economics of BWA in the European Union. They are also starting to examine options for freeing up additional spectrum for BWA, with 3.5GHz expected to come under pressure and the calls for frequencies that more easily support mobility – in other words, lower down the spectrum – growing in volume. Of course, regulators feel some obligation not to tread too firmly on the toes of the 3G operators, which paid such vast sums for their licenses during the telecoms boom, but increasingly they are veering towards opening up the competitive playing field. In 2006-7, we will see key decisions in the major markets, Germany, France, Italy and the UK.

WiMAX may see very gradual expansion in some developed telecoms markets, but it is experiencing a rush of deployments in its most natural early stage territory, developing economies with limited broadband infrastructure. The Middle East is a strong growth area, with its wealthy business and expatriate centers and often difficult terrain.

Much of the activity is coming from mobile operators, looking to expand their services into fixed broadband and data, especially where 3G licenses are not yet allocated. For instance, Mobily, Saudi Arabia's second GSM operator, is using Aperto pre-WiMAX equipment in four large cities to deliver fixed broadband services to complement its mobile offering.

Attention is also starting to shift to the least developed region of the world in telecoms and broadband terms, sub-Saharan Africa, with a battle set to develop in many greenfield areas between CDMA and WiMAX technologies.

The region is the closest the world comes to a virgin territory, and so offers an almost level playing field for new technologies such as WiMAX and new international players such as China's ZTE. It has massive growth potential in wireless because of its sparse wireline infrastructure and many of its economies are developing rapidly, with consequent growth of economic hotspots such as capital cities and expatriate business communities. The lack of any form of fixed infrastructure in many regions makes the potential enormous – penetration of fixed lines is only 2.8%, the lowest in the world. It will also be the focus of many internationally funded projects to start to bridge the huge digital divide.

As an example of the achievable growth curves in some countries, Nigeria's mobile subscriber base rose from 2.8m in 2003 to 8.6m a year later and should reach 23m by the end of 2007, according to BMI-TechKnowledge. This Africa-based research firm predicts that combined fixed and mobile capex for the continent will reach $61bn for the period 2000-2009. They point out that the combined mobile and fixed line subscriber base in Africa had risen to just under 100m, with 68% being mobile by the end of 2004 and with projections that mobile subscribers could easily reach 140m in the next five years.

*Most of the large carriers are looking to roll out fixed/mobile convergence over the next few years, based on the IP triple play of VoIP, data and broadcast.*

*Asia-Pacific is the most dynamic early market for WiMAX, largely because of the Wi-Bro roll-outs in Korea and the huge potential of China and India.*

Against this backdrop, it is hardly surprising to find the infrastructure makers jostling for position, and Intel working hard to promote WiMAX.

**Asia and Wi-Bro:**

Asia-Pacific is the most dynamic early market for WiMAX, largely because of the Wi-Bro roll-outs in Korea and the huge potential of China and India. The subscriber base for WiMAX services will reach 3.8m in the Asia-Pacific region by 2009, making this the largest world market with 45% of the global total.

There are hurdles to overcome, however, and Korea will have a disproportionate impact on the figures because of its early Wi-Bro roll-outs – South Korea will contribute an estimated 40% of WiMAX revenue in Asia-Pacific in 2009, followed by China on 34% and Japan on 17%, believes In-Stat.

In many countries, the main impetus will come from wireline carriers, and sometimes cellcos too, rather than start-ups, and will be heavily government backed.

However, Wi-Bro will have influence far beyond Korea and be the most important pre-802.16e technology to drive early adoption, gaining significance as a platform in its own right. Ever since Samsung and other Korean parties succeeded in getting their Wi-Bro personal broadband technology adopted as the basis of the WiMAX 802.16e standard, it has been clear that this was part of a broader effort by east Asian hi-tech countries to assert themselves in the wireless intellectual property race, thus reducing their dependence on western technologies, and their royalty bills, and driving the 4G agenda. The importance of the Wi-Bro in this mission was highlighted by the formation of an alliance of operators from the region to promote the technology and accelerate its development – the Wi-Bro and Mobile WiMAX Community (WMC), composed of Korea Telecom, Japan's NTT, Hong Kong's PCCW and Telekom Malaysia Berhad, all powerhouses of the east Asian telecoms market that have made a strong commitment to including WiMAX in their multi-network broadband roadmaps – plus the US ISP Covad.

Wi-Bro has already scored sufficient wins to convince that it will not be, as originally assumed, a technology specific to Korea, taking part in major trials with Sprint Nextel and Telecom Italia and with customer wins in Brazil, Venezuela and Croatia. NTT's mobile arm, DoCoMo, is also trialling Wi-Bro systems from POSdata.

The WMC claims a further 20 operators from 16 countries have signed up, although they have not yet gone public with their identities. Apart from the importance to vendors of these signs of a broad international market for Wi-Bro, this level of support raises hopes of a major roaming agreement between Wi-Bro providers, as they roll out – which could come significantly earlier than any similar deals using other forms of WiMAX. KT refers to the WMC as the basis of a "roaming belt" for Wi-Bro and later for full mobile WiMAX.

Since Wi-Bro is a direct migration technology towards 802.16e, these advances should be seen as beneficial, accelerating the WiMAX process rather than splitting it. But it also reflects that the global map for 802.16e will be very different from that to which we are accustomed in mobile networks, with Asia leading the way and, despite the frantic activity of European providers, far less impact from European vendors.

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# Alternative Solutions for Personal Mobile Broadband

*by Philip Marshall, Ph.D.*

Alternative mobile broadband technologies, like WiMAX, create opportunities for incumbent and new entrant service providers to deliver personal broadband solutions with a variety of non-traditional business models. Exhibit 1 illustrates fundamental elements that service providers must consider when bringing personal broadband solutions to market. It consists of technical, regulatory commercial and end user domains. The technical domain refers to the capabilities of the underlying network technology, control plane and service delivery infrastructure, which is required for the efficient service delivery. It also considers the standardization of the technology and the characteristics of the supporting supply chain. Of particular importance for alternative broadband technologies like WiMAX is adequate network performance, advanced service delivery ecosystems, and a robust supply chain for cost effective equipment.

The regulatory domain in Exhibit 1 is largely focused towards the availability of suitable radio spectrum to support the wireless technology and rights and obligations (such as the ability to offer mobile service) associated with the spectrum licenses. Currently radio spectrum availability and suitability is a significant challenge for the proliferation of personal broadband services like WiMAX. The spectrum that is being made available does not necessarily allow for mobile services, (such as 3.5GHz spectrum in Europe), and is not consistent across markets. The 1.5, 2.3, 2.5, 2.6, 3.5 and 5.8GHz frequency bands are currently being proposed for personal broadband services with varying combinations across different markets

The commercial and end user domains illustrated in Exhibit 1 focus primarily on the business models and go to market strategies for service providers. Traditional telecom business models are based on

**Exhibit 1. WiMAX analysis in the context of the telecom value chain**

Source: Yankee Group 2006

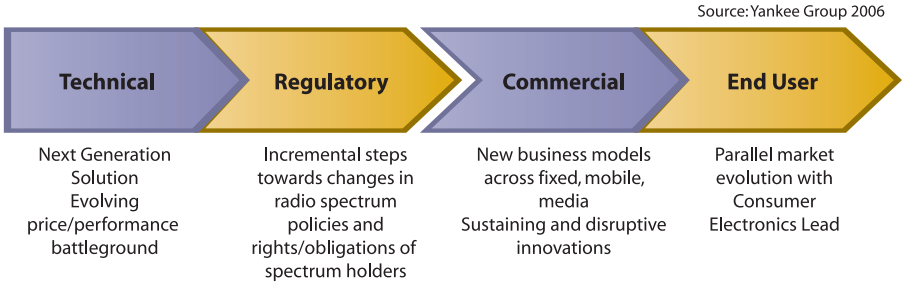



*Exhibit 1. WiMAX analysis in the context of the telecom value chain*

*Satellite companies and fixed operators that lack mobile assets see personal broadband technologies like WiMAX as a means to offer triple and quadruple play services, namely voice, video, telephony and mobile services.*

individual subscriber relationships, and predicated on a high degree of control over service and device distribution. By embedding broadband wireless capabilities, like WiMAX, in a plethora of consumer electronic (CE) devices ranging from music devices and laptops to USB dongles and set-top boxes, service providers can leverage independent distribution channels associated with the CE market. Alternative business models might capitalize on this independent channel by creating opt-in services and temporary subscriptions. These services might be offered when the device is activated, particular applications are used, or when there are opportunities to create mutually reinforcing networked communities, akin to the models created for the Internet by companies like eBay.

New entrant service providers, such as Clearwire are looking to leverage WiMAX to disrupt traditional telecom business models. A robust retail channel for personal broadband services is currently of particular interest to these players. However we believe that wholesale channels will become increasingly important as the market matures, and independent distribution strategies for content and applications, and embedded devices become more relevant. Traditional service providers that have both fixed and mobile network assets, are interested in developing parallel service offerings using personal broadband technologies like WiMAX. Typically these players are competing against a dominant mobile player in their market. The incentive to deploy a technology like WiMAX is to typically reinforce traditional business models, with an alternative technology that might offer incremental performance enhancements, and possibly some modest differentiation in the manner in which services are delivered.

Satellite companies and fixed operators that lack mobile assets see personal broadband technologies like WiMAX as a means to offer triple and quadruple play services, namely voice, video, telephony and mobile services. Many satellite providers are looking to offer a complementary terrestrial service that leverage existing infrastructure, such as retrofitting WiMAX transponders and low power base station infrastructure to existing rooftop satellite antennas. Personal broadband technologies are also capturing the interest of other types of service providers like electrical utility companies, who can leverage their existing tower and civil infrastructure, and possibly use other alternative backhaul technologies like broadband-over-powerline to create capital and operationally efficient network solutions. These players are considering technologies like WiMAX for internal operations such as meter reading, and wholesale and retail telecom service offerings. Various players are seeking radio spectrum to enable these alternative operations. For example in the US, M2Z recently petitioned to the FCC for a nationwide radio spectrum license in the 2.155-2.175GHz frequency band for this purpose.

Content and application providers, such as News Corp, Google and eBay are interested in opportunities to broaden the distribution of their offerings across consumer electronic devices with personal broadband services, and look for opportunities to broaden the community centric models, advertising and other alternative business models. These players are most likely to use other service provider networks on a wholesale basis as opposed to building out their own network infrastructure.

The significant interest in alternative broadband technologies like WiMAX has stimulated debate regarding the technical merits of WiMAX relative to 3G and other solutions such as 802.20. This is no surprise, since the stakes are high. However we believe that the real battle-lines are in the service offerings and business models stimulated by these technologies. In addition, we believe that it is important for these models disrupt the traditional telecom status quo for mobile data services, which to date continues to produce underwhelming results.

*Dr. Philip Marshall is the Vice President of Yankee Group's Wireless/Mobile Technologies and Wireless/Mobile Asia-Pacific Research and Consulting practices He can be reached at pmarshall@yankeegroup.com*

# Mobile WiMAX: A Performance & Comparative Summary

*by Doug Gray*

Another key WiMAX milestone has been reached with the approval of the Mobile WiMAX systems profiles in February 2006. Mobile WiMAX, based on 802.16e-2005, enables WiMAX systems to address portable and mobile applications in addition to fixed and nomadic applications. This article provides a brief overview of mobile WiMAX and presents performance data based on simulations as to how mobile WiMAX compares with HSPA and EVDO, capacity enhancements specified by 3GPP and 3GPP2 for W-CDMA and CDMA2000 mobile networks respectively.

## Mobile WiMAX

Mobile WiMAX introduces OFDMA and supports several key features necessary for delivering mobile broadband services at vehicular speeds greater than 120 kilometers per hour, with QoS comparable to broadband wireline access alternatives. These features and attributes include:

- Tolerance to Multipath and Self-Interference with subchannel orthogonality in both the DL and the UL.
- Scalable Channel Bandwidths from 1.25 to 20MHz
- Time Division Duplex (TDD) is defined for the initial mobile WiMAX profiles for its added efficiency in support of asymmetric traffic and channel reciprocity for easy support of advanced antenna systems.
- Hybrid-Automatic Repeat Request (H-ARQ) provides added robustness with rapidly changing path conditions in high mobility situations.
- Frequency Selective Scheduling and subchannelization with multiple permutation options, gives mobile WiMAX the ability to optimize connection quality based on relative signal strengths to specific users.
- Power Conservation Management ensures power efficient operation of battery operated mobile handheld and portable devices in sleep and idle modes.
- Network-Optimized Hard Handoff (HHO) is supported to minimize overhead and achieve a handoff delay of less than 50 milliseconds.
- Multicast and Broadcast Service (MBS) combines the features of DVB-H, MediaFLO and 3GPP E-UTRA for:
  a) High data rate and coverage using a single frequency network
  b) Flexible radio resource allocation
  c) Low mobile device power consumption
  d) Low channel switching time
- Smart antenna support aided by subchannelization and channel reciprocity enables a wide range of advanced antenna systems including beamforming, space-time coding and spatial multiplexing.
- Fractional frequency reuse controls co-channel interference to support universal frequency

reuse with minimal degradation in spectral efficiency.
- 5 millisecond frame size provides optimal trade-off between overhead and latency.

*The frequency bands and channel bandwidths selected by the WiMAX Forum for the initial system profiles cover many of the worldwide spectrum allocations suitable for mobile WiMAX.*

## Release-1 Mobile WiMAX Profiles

The frequency bands and channel bandwidths selected by the WiMAX Forum for the initial system profiles cover many of the worldwide spectrum allocations suitable for mobile WiMAX. The following table summarizes these profiles. Other frequency bands, channel bandwidths and FDD will be considered for future profiles based on specific market opportunities.

| Channel BW | FFT Size | Other bands TBD | 2.3-2.4 GHz | 2.305-2.32, 2.345-2.36 GHz | 2.496-2.69 GHz | 3.3-3.4 GHz | 3.4-3.8 GHz |
|---|---|---|---|---|---|---|---|
| 1.25 MHz | 128 | | | | | | |
| 5.0 MHz | 512 | | TDD | TDD | TDD | TDD | TDD |
| 7.0 MHz | 1024 | | | | | TDD | TDD |
| 8.75 MHz | 1024 | | TDD | | | | |
| 10 MHz | 1024 | | TDD | TDD | TDD | TDD | TDD |
| 20 MHz | 2048 | | | | | | |

*Table 1: Release-1 System Profiles for Mobile WiMAX*

## Mobile WiMAX Timeline

WiMAX-certified products based on 802.16-2004 for fixed and nomadic applications are now commercially available and many of the existing fixed WiMAX trials will evolve into full commercial deployments in the coming months. A second WiMAX certification lab was announced in February and is expected to be fully operational in Q3-2006. The WiMAX Forum is working to a planned schedule for certification of Mobile WiMAX-based products starting in Q4-2006.

The first commercial portable/mobile application for WiMAX certified products is expected to take place in Korea with the launch of WiBro services. Products for WiBro services operate in the licensed 2.3GHz frequency band with an 8.75MHz channel bandwidth. This initial product launch will use SISO antenna configurations and support mobile speeds of more than 60 kilometers per hour. Additional deployments of Mobile WiMAX products are expected in the early 2007 timeframe.

| | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|
| 802.16-2004 Air Interface Standard Ratified | ● | | | |
| 802.16/HiperMAN Harmonization | | ● | | |
| 1st Certification Lab Opens (Cetacom, Spain) | | ● | | |
| 1st Certified Fixed WiMAX Products | | | ● | |
| 802-16e Air Interface Standard Ratified | | ● | | |
| Mobile WiMAX Rel-1 System Profiles | | | ● | |
| Mobile WiMAX Rel-1 Certification Profiles | | | ● | |
| 2nd Certification Lab Opens (TTA Labs, Korea) | | | ● | |
| Launch of WiBro services in Korea | | | ● | |
| 1st Mobile WiMAX-Certified Products | | | | ● |

*Table 2: WiMAX Timeline*

## Mobile WiMAX and 3G

Enhancements for CDMA-based 3G systems, EVDO and HSDPA/HSUPA (HSPA), offer 3G operators the opportunity to upgrade the throughput performance of CDMA2000 and WCDMA networks respectively. EVDO-Rev A and HSDPA are available and being deployed extensively. EVDO-Rev B and HSUPA will be available in the 2007 to 2008 time frame. The expected availability of mobile WiMAX in 2007 will provide existing and new mobile operators an added alternative to consider for the delivery of broadband mobile services.

## Performance Comparison

Using a commonly accepted 1xEV-DV evaluation methodology for 3G systems, mobile WiMAX can be compared to the 3G enhancements. Table 3 summarizes the multipath models used for the simulation. The simulation parameters for the comparison are similar except for the following:

- EVDO and HSPA are FDD implementations operating on a carrier frequency of 2GHz whereas mobile WiMAX is TDD operating at 2.5GHz.
- EVDO and HSPA assume a single Tx antenna and dual Rx antennas (1x2 SIMO) with RAKE receivers in both DL and UL. For Mobile WiMAX, 1x2 SIMO is assumed for one case and for a second case, 2x2 MIMO with Space Time Coding and Vertical Spatial Multiplexing with Adaptive MIMO Switching are assumed in the DL and two-user collaborative spatial multiplexing assumed in the UL. Maximum Likelihood Symbol Detection is assumed at the receivers in both DL and UL. Whereas the latter configuration represents the baseline functionality as specified in the Release-1 system profile for Mobile WiMAX, many early WiMAX deployments will be configured in 1x2 SIMO mode.

| Channel Model | # of Paths | Speed | Fading | # of Users per Sector |
|---|---|---|---|---|
| Model A | 1 | 3 km/hr | Jakes | 3 (30%) |
| Model B | 3 | 10 km/hr | Jakes | 3 (30%) |
| Model C | 2 | 30 km/hr | Jakes | 2 (20%) |
| Model D | 1 | 120 km/hr | Jakes | 1 (10%) |
| Model E | 1 | 0, $f_{Doppler}$ = 1.5 Hz | Rician Factor K = 10 dB | 1 (10%) |
| | | | Total Users per Sector | 10 |
| | | | Total Users per Cell | 30 |

*Table 3: Multipath Channel Models for Performance Simulation*

Figure 1 provides a throughput comparison and Figure 2 provides a spectral efficiency comparison of mobile WiMAX with EVDO and HSPA. EVDO-Rev A is deployed with a single 1.25 MHz carrier. For EVDO-Rev B, which supports multicarrier capability, a 3-carrier implementation is assumed to provide a more direct comparison to HSPA and mobile WiMAX with respect to the occupied spectrum.

The mobile WiMAX performance is presented for a DL/UL ratio of 1:1 and 3:1 to show the benefit of TDD with data-centric asymmetric traffic. This represents the range of DL to UL ratios supported by the mobile WiMAX Release-1 profile.

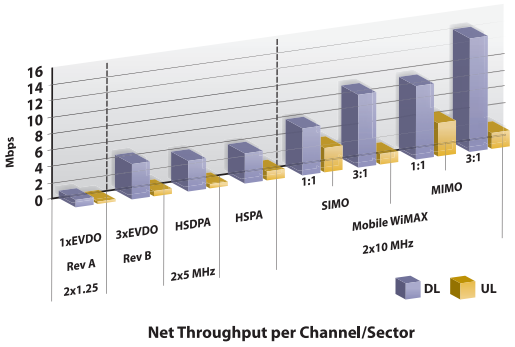



*Figure 1: Sector Throughput Comparison*

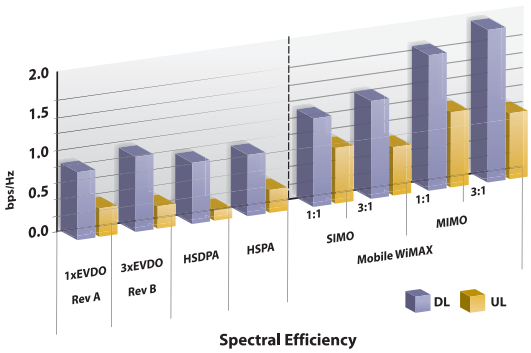



*Figure 2: Spectral Efficiency Comparison*

## Business Case Impact

From a business case perspective the throughput and spectral efficiency advantages of mobile WiMAX results in fewer base stations to achieve a desired data density. The example in Figure 3 summarizes the number of base stations required to achieve a DL data density of 215 kilobytes per sec per sq-km over a 129 sq-km coverage area. Fewer base stations greatly reduces the network capital costs for a given network capacity and, with lower equipment maintenance costs, results in lower operating expenses as well.

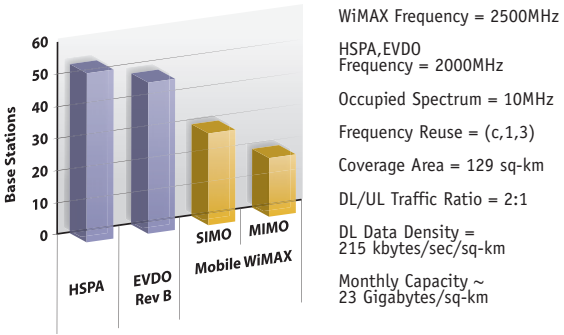



*Figure 3: Number of Required Base Stations*

The economic and performance benefits of mobile WiMAX will have great appeal to new greenfield operators as well as existing mobile and wireline operators. Existing 2G and 3G operators can consider mobile WiMAX overlays to existing mobile networks to add capacity for the delivery of new value added services. DSL and cable operators can use mobile WiMAX to cost-effectively extend the reach of existing wireline networks to address new customers.

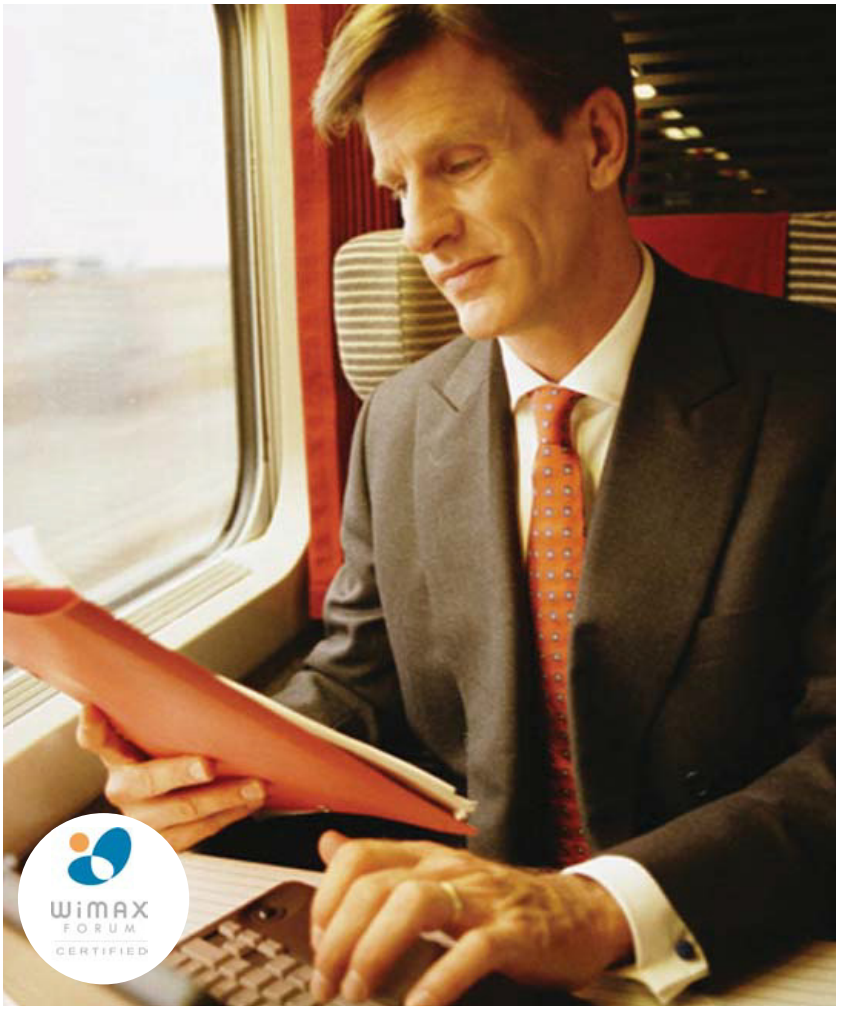
## Conclusion

WiMAX technology continues to evolve with the WiMAX Forum's approval of the Release-1 mobile WiMAX system performance profiles based on the 802.16e-2005 amendment. With OFDMA, mobile WiMAX can meet the stringent requirements necessary for the delivery of broadband services in a challenging mobile environment. Performance simulations show that mobile WiMAX provides superior throughput and spectral efficiency compared to planned 3G CDMA-based enhancements, EVDO and HSPA. These advantages will provide operators with added network capacity for the support of value added services with fewer base stations than alternative approaches thus resulting in lower network capital and operating costs.

*This is an excerpt from a report published by the WiMAX Forum in July 2006. The original paper, including all references can be found at www.wimaxforum.org*

*With OFDMA, mobile WiMAX can meet the stringent requirements necessary for the delivery of broadband services in a challenging mobile environment.*

# Redline communications – Leading the WiMAX Revolution

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# Spectrum and Regulation: Worldwide Trends

*by Adlane Fellah*

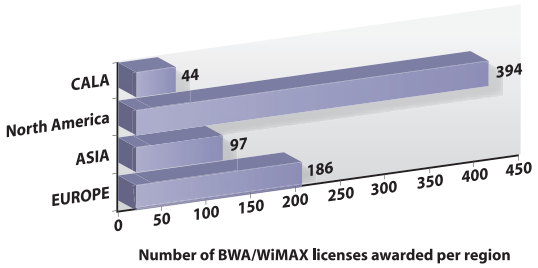
When it comes to WiMAX, 3G/4G and other broadband wireless services, a lot is being written about standards and capabilities, and which technologies and equipment vendors will 'win'. However, little attention is being paid to the equally important spectrum allocation aspects of broadband wireless services.

The fact is that, unlike Wi-Fi, carrier networks need to be deployed in licensed frequency bands. Most of the world has made 3.5GHz the primary allocated band for broadband wireless access (BWA) and/or WiMAX, but in the US, the FCC has determined that BWA/WiMAX will use the 2.3GHz and 2.5GHz frequencies. This article reviews the current spectrum licensing and regulation worldwide and provides some insights of the most important challenges ahead for the WiMAX industry.

*Unlike Wi-Fi, carrier networks need to be deployed in licensed frequency bands.*

## BWA/WiMAX licenses: plenty and regional!

A total accumulated 721 BWA/WiMAX licenses exist today, net of licenses returned or resold in the countries surveyed. North America is by far the leading region in terms of number of BWA/WiMAX licenses awarded, with a total of 394, against 186 licenses in Europe, 97 licenses in the APAC region, and 49 licenses in the CALA region.




*Source: ClearSpectum Database-Maravedis*

Across the world, most BWA/WiMAX licenses are regional licenses. This situation did not prevent large players such as Sprint-Nextel from consolidating regional licenses to achieve a national footprint.

However, those numbers do suggest that BWA/WiMAX markets may become more fragmented and less predictable than cellular/3G+.

## The US Situation

The BWA bands have been allocated in the U.S. for a decade—the 2.3GHz band for Wireless Communication Services (WCS) and the 2.5GHz band for Broadband Radio Services (BRS)—although very few networks have been deployed.

This year will also see spectrum auctions and reallocations in the 1.7/2.1GHz band, and the 2.4–2.6GHz band, both auctions resulting from 2005 FCC rulemakings covering BRS and Advanced Wireless Services (AWS).

In short, 2006 and 2007 promise to be important years. Build-out deadlines are looming, and lower cost, soon-to-be-certified equipment is entering the market; both these factors could constitute real drivers for broadband wireless networks in the US.

While the US currently lags behind Europe in terms of 3G frequency allocation, the FCC says it is adopting a "neutral approach" as far as which technology can be used in the new frequency bands that it is freeing up.

## Fixed/portable WiMAX services

Indeed spectrum in India represents a serious challenge for large scale WiMAX deployments as license holders have 12MHz spectrum on average, and it is believed that 20MHz is a minimum bandwidth requirement for supporting most operators' business cases.

Among other obstacles is the lack of harmonization of the spectrum in countries like Russia where the available frequencies for broadband wireless (2.4GHz or 6GHz) are not compatible with WiMAX band profiles (3.5GHz, 2.5GHz and 5.8GHz). Those are important obstacles for the proliferation of fixed WiMAX in strategic emerging countries.

In the vast majority of countries however, the total amount of BWA/WiMAX spectrum acquired by license holders by region is respectively at 49MHz (North America), 49MHz (CALA) and 42MHz (Europe), which is plenty to support fixed services.

## Mobile WiMAX Services

Most regulators have not kept pace with the progress of technology that makes fixed/mobile convergence a reality. 77% of regulators still limit 3.5GHz usage to fixed-only applications. More importantly, the 2.5-2.9GHz band remains locked to BWA/WiMAX in most European countries, but the pressure on regulators to include BWA/WiMAX in the IMT2000 definition will increase over time, once 802.16e systems become commercially available. Sweden has already opened a public consultation to allow the 2570-2620MHz band to be technology agnostic.

## WiMAX and 3G compared

The low cost of the BWA/WiMAX spectrum compared to 3G is a clear driver for service providers to enter the field of wireless services with BWA/WiMAX. This difference in cost/Hz is particularly significant in Europe, where the average 3G spectrum cost/Hz is 1,000 times higher than the average BWA/WiMAX spectrum cost/Hz.

It is important to highlight that the aggregate 3G spectrum is in lower frequency bands than the aggregate BMA/WIMAX spectrum. However, even with that adjustment it is clear that the BMA/WIMAX spectrum is more economical, particularly when it is mapped to trends of devices to mitigate spectrum bands and modulation schemes.

This crowded environment will result in a highly fragmented, unpredictable and more competitive market, open to smaller and cost-aggressive players.

The low-cost spectrum has also attracted players that have fewer resources than the large mobile operators. One must remember that the BWA spectrum was initially allocated for fixed-only applications and remains so in many countries.

While 3G, with the emergence of enhanced 3G technologies like HSDPA/HSUPA, Scalable Band-width EV-DO, 3.9G and Super 3G, is expected to reinforce its headstart over mobile BWA/WiMAX in terms of performance, it appears clear that 3G carriers will have to compete with new players once BWA/WiMAX mobile technology is embedded in cellphones and reaches attractive price points and significant volume sometime in 2008.

*Adlane Fellah is founder of Maravedis Inc. He can be reached at afellah@maravedis-bwa.com*





## High Hopes For Low Frequencies

The 700MHz band, including the spectrum occupied by UHF TV channels 52 through 69 (698MHz–806MHz) is exceptionally attractive to wireless broadband operators because low frequencies propagate farther than higher frequencies, penetrate through trees and buildings and bend around obstacles. This reduces the cost of deployments compared to systems operating at higher frequencies. At low frequencies, digital video broadcast and mobile broadband services can be made very cost effective, despite relatively narrow spectrum bands. The 700MHz spectrum is increasingly being developed for use of orthogonal frequency division multiplexing (OFDM) technologies. For example, Qualcomm has shifted from use of CDMA to OFDM as the core technology in MediaFlo. Qualcomm purchased Flarion (including its roughly 100 patents) in order to strengthen its OFDM patent position. OFDM will be the PHY layer of both WiMAX and 4G. As TV broadcasters migrate away from the 700MHz frequencies (around 2009), the vacated and relicensed spectrum could become the decisive factor in how quickly and extensively broadband wireless development unfolds 3G and WiMAX spectrum compared


# WiMAX Certification

*by Monica Paolini*

WiMAX is a wireless broadband technology based on the IEEE 802.16 and ETSI HiperMAN standards that combines cost-effective, interoperable equipment with advanced performance. To ensure that equipment conforms to these open standards and is interoperable, the WiMAX Forum has established a certification program that plays a central role in its efforts to promote the worldwide adoption of the technology.

The open standards approach and the interoperability fostered by certification will lead to more intense competition in the market, and to economies of scale that will lower equipment prices. Operators will also benefit from greater flexibility, reduced dependence on individual vendors and backward compatibility. Vendors will gain access to a wider market and enjoy lower production costs.

The first fixed WiMAX Forum Certified™ products were announced in January 2006 and are based on IEEE 802.16-2004. As of May 2006, 14 products have already been certified. While still in its early stages, the program is rapidly growing to include certification of mobile WiMAX equipment which is expected to be introduced in the marketplace early in 2007.

WiMAX testing requirements are defined by system profiles and certification profiles. There are currently two system profiles, one for fixed WiMAX and one for mobile WiMAX. Fixed WiMAX currently supports five certification profiles, which define classes of products that interoperate with each other on the basis of spectrum band, channelization and duplexing mode. To date, five certification profiles have been defined in the 3.5GHz band—where both time division duplex (TDD) and frequency division duplex (FDD) can be used—and the 5.8GHz TDD band. New certification profiles may be added in response to demand from vendors and operators.

As of May 2006, equipment is certified under Release 1, which focuses exclusively on testing for mandatory features. Release 2 will include three optional modules: QoS (Quality of Service) for improved support for real time applications, AES (Advanced Encryption Standard) for advanced security and ARQ (Automatic Repeat reQuest) for improved link budget.

## Why choose WiMAX Forum Certified equipment?

Interoperability is the most immediate reason for a network operator or a subscriber to buy WiMAX Forum Certified equipment. However certification brings additional advantages that extend well beyond interoperability and that create the basis for wide scale adoption of the technology.

The overall market dynamics are affected by a robust and trusted certification program that enjoys wide support from vendors and operators.

The WiMAX Forum Certified program:

*Defines how standards will be implemented* in products. Fixed WiMAX is based on IEEE 802.16-2004 and ETSI HiperMAN, but WiMAX certification requirements narrow even further the scope of the standards to certification profiles defined by spectrum band, channelization and duplexing.

Certification profiles are required for interoperability (all equipment within a profile interoperates), but they also define which product classes will dominate in the market and how the technology will be implemented in real deployments. A stable technology roadmap reduces the complexity and risk involved in investing in a new technology.

*Reduces overall costs* by promoting economies of scale. The converging focus of the industry towards one technology will lead to wider adoption and reduced fragmentation. Coupled with the rapid increase in demand for wireless broadband access, this approach will create the needed economies of scale to quickly drive down equipment prices.

*Increases competition in the market.* An open standards approach coupled with interoperability testing greatly encourages the entry into the market of low cost and high volume component and equipment vendors, which will lead to further price reductions. Furthermore, vendors will be able to specialize in the development of specific products (for instance, just base stations, or specific types of subscriber stations). An equipment vendor, for instance, may decide to focus on the development of high end base stations and exit the subscriber unit market which can be more cost effectively served by a high volume vendor.

Service providers, in particular, stand to benefit greatly from choosing certified equipment. They will have:

- No dependency on a single vendor. Service providers can choose equipment from multiple vendors, thus gaining additional flexibility in planning or extending their deployments. Proprietary solutions tie operators to the technology roadmap of a single vendor and increase the financial risk of the deployment. Adoption of certified products will enable operators to transition smoothly to a different vendor, without having to replace the equipment already deployed.
- Lower pricing. Increased market competition and economies of scale will put pressure on equipment pricing.
- Backward compatibility. The assurance that new products will work with existing ones facilitates network planning and reduces the financial risk for operators.

*Overall market dynamics are affected by a robust and trusted certification program that enjoys wide support from vendors and operators.*

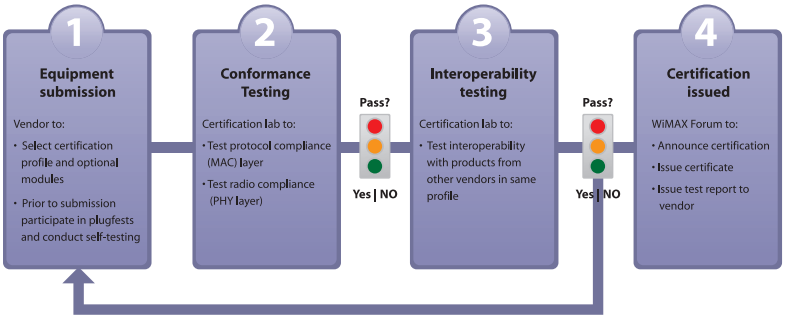



*Figure 1. The WiMAX Forum certification process*

Open standards and certification create a virtuous circle that benefits component and equipment vendors as well. They allow the industry to:

*Gain access to a wider market.* Lower prices, increased market competition and more flexibility for operators will greatly increase the demand for WiMAX equipment and create a larger opportunity for vendors.

*Benefit from lower production costs.* Lower prices do not lead to reduced profitability, as they are balanced by lower production costs due to economies of scale and higher sales volumes.

*Address requirements from network operators.* Operators often demand vendor interoperability as a condition for deploying a technology. Certification makes it possible to meet this requirement without additional, expensive ad-hoc tests.

*Establish interoperability early.* Certification allows vendors to address any interoperability issues before bringing a product to the market, when they are easier and less expensive to resolve.

Certification testing is conducted in independent labs. Cetecom in Spain was the first lab to test WiMAX equipment. Recently, the Telecommunications Technology Association (TTA) in Korea was added as the second certification lab. The WiMAX Forum plans to announce additional labs to meet demand from vendors and operators.

Upon successful completion of all tests, vendors receive a WiMAX Forum Certified certificate and a test report, and can list their certified equipment on the WiMAX Forum Certified Product Registry, available at: www.wimaxforum.org/kshowcase/view

## Conclusions

The WiMAX Forum Certified program is at the core of the efforts at the Forum to promote the worldwide adoption of WiMAX through ensuring standards conformance and interoperability for IEEE 802.16 equipment. The certification program defines which WiMAX profiles will be implemented in commercially available products, thanks to industry-wide support from component and equipment vendors committed to submitting their equipment for testing, and from service providers requiring certified equipment for their deployments.

WiMAX certification is still in its early stages, but is rapidly evolving with the introduction of new releases for fixed WiMAX and of a new program and certification profiles for mobile WiMAX. Evolution in the certification program is necessary to ensure that WiMAX retains its flexibility and technological edge, and supports an increasingly wide range of features and services.

The need to update and extend the certification program has to be carefully balanced with the need to preserve continuity in the marketplace and to allow deployed equipment to continue to interoperate with new equipment. To ensure this, the WiMAX Forum is committed to preserving backward compatibility for all WiMAX Forum Certified devices.

Network operators and vendors stand to benefit greatly from an open standards approach and a robust certification program. To operators, certification brings increased competition in the market that will result in lower prices, less dependence on vendors and greater flexibility when planning a network. Certified products will enable vendors to meet the requirements of network operators and to take advantage of the reduced production costs that result from the rapid worldwide adoption of WiMAX.

*Monica Paolini is President of Senza Fili Consulting. She can be reached at monica.paolini@senzafiliconsulting.com*

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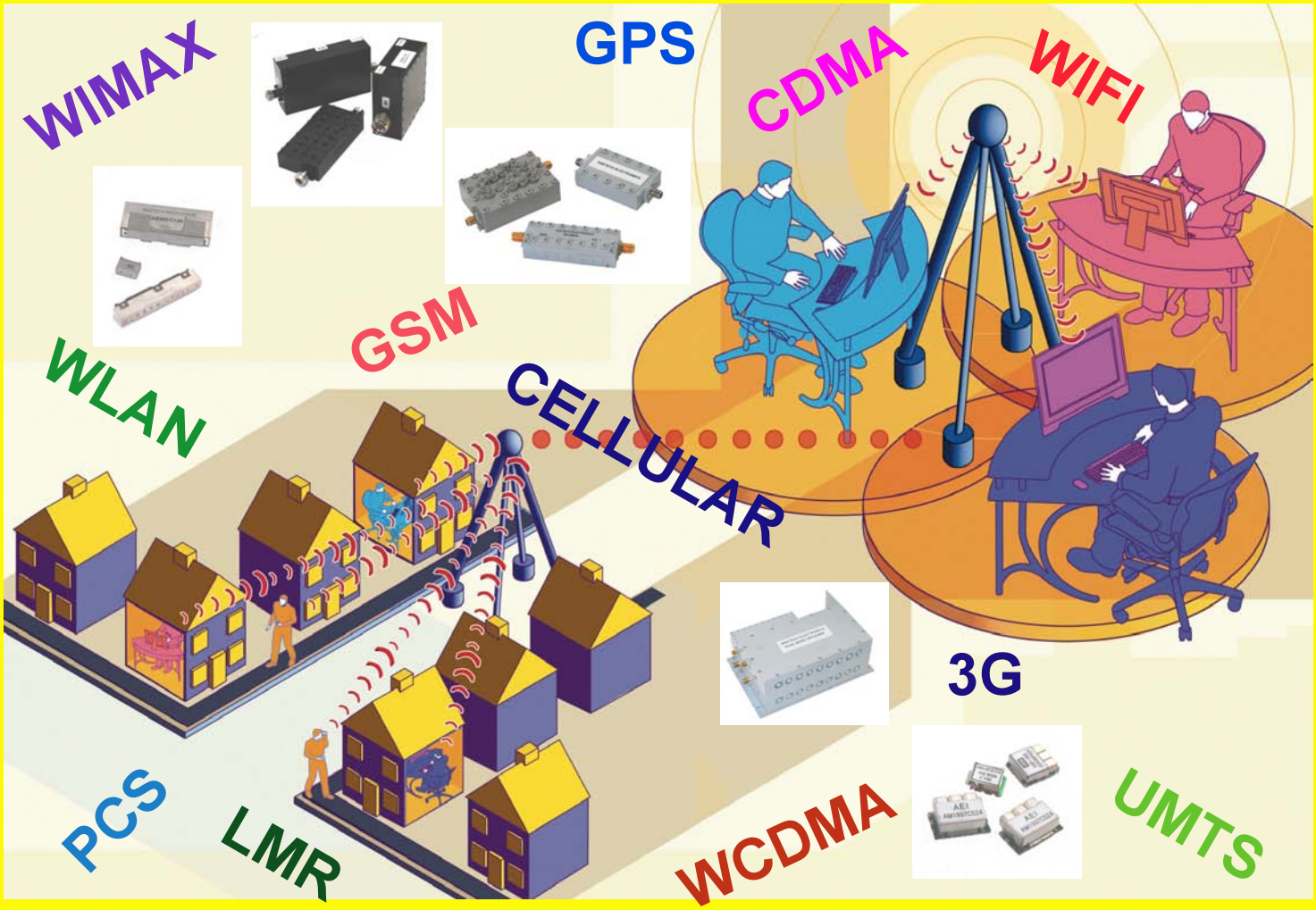



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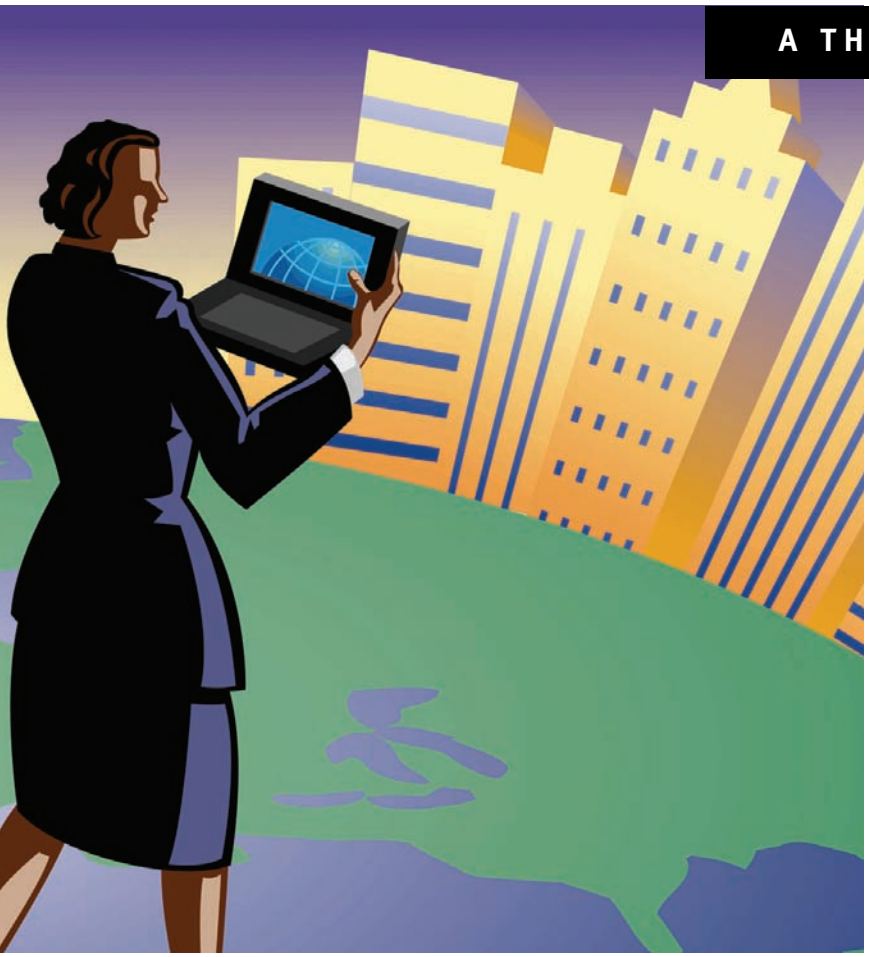
# WiMAX & the Road

## A THOUGHT LEADER ANALYSIS



*by Craig J. Mathias*

It probably seems at least a little odd to be discussing 4G wireless systems when 3G still represents only a small (although, granted, rapidly growing) segment of the industry. But wireless is nothing if not a hotbed of innovation, quite remarkable for a technology that can trace its roots to Benjamin Franklin and his at least somewhat apocryphal kite. Suffice it to say, at least for the moment, that 4G is a little ways off – but WiMAX is already pointing the way, and may become one of the first production 4G technologies to achieve meaningful market penetration and success.

Okay, so what is 4G? First, a little history. 1G was analog cellular, famous for highly variable connection quality, but doomed by a fundamental lack of spectral efficiency. The correction of this problem – improving capacity by three to seven times, and sometimes more, was the goal of 2G (digital) cellular, as opposed to enhanced data services or improved voice quality. The goal was simply to get more (mostly voice) users on the air per unit of bandwidth and time. 3G extended this trend with improved management, and, most visibly, higher data throughput – raw performance from 144Kbps to 2Mbps was the very definition of 3G. With 3G, wide area wireless has gone broadband. Indeed, near term extensions to today's 3G services will boost raw data rates to as high as 3.1Mbps (in 1xEV-DO Rev A) and 14.4Mbps in High Speed Downlink Packet Access (HSDPA). It would seem that, with such throughput on the horizon, we're basically done. Why move on to 4G at all?

The definition of 4G, as might be expected at this point, is a bit imprecise. Most from the cellular vendor community are focusing on 100Mbps downlink (from a cell to a subscriber) and 50Mbps on the uplink. We believe, however, it is misleading to talk only of throughput, especially numbers such as these. Since, largely due to the highly variable nature of the radio channel, only a small percentage of peak throughput can be realized, especially on a per user basis, it is time to stop mis-setting subscriber expectations and instead focus on the core services made possible the architectural evolution that we believe will accompany successful 4G deployments.

Specifically, we think 4G will have four key characteristics, as follows:

**Wireless:** Well, obviously, but we will come to depend upon 4G as the default vehicle for the triple play – data, voice, and video – essentially everywhere, at work, in the home, and on the road. 4G networks will require tremendous capacity to make this vision a reality, and basic improvements in radio technology, including Multiple Input Multiple Output (MIMO) antenna arrays.

**Mobile:** WiMAX suffers from a bit of split personality, and by design. Today's WiMAX spec, based on the IEEE 802.16-2004 standard, deals only

with fixed wireless broadband access. While interesting, we believe that the world is going mobile, and that most access applications in five years (in terms of number of units) will be mobile. Imagine a mobile subscriber unit, most likely in a cellphone form factor, which provides broadband everywhere, and can even be docked with a wired or WLan infrastructure to provide access to multiple users in a given location. Assuming a reasonable price, cable and DSL might feel at least a little heat from such a scenario, and mobile WiMAX, based on IEEE 802.16e-2005, might just be the vehicle to bring this concept to life. Regardless, users want access any time and anywhere, not just when near wired connectivity.

**Broadband:** While an imprecise term, to be sure, broadband is most often assumed to refer to throughput of 1Mbps or greater, and offering some form of multiple access to support both multiple users, and multiple applications per user, simultaneously. Is 100Mbps reasonable as a goal? In one sense, sure – the forthcoming IEEE 802.11n standard for high speed WLans will most certainly achieve 100Mbps as a minimum. But keep in mind that, because of the nature of radio propagation and restrictions on transmit power, always a factor in regulated radio spectrum, longer range necessarily results in lower throughput. Add in a greater concentration of users and constant demands for traffic in the larger cells likely to be used in WiMAX installations, and throughput bottlenecks are all but certain to develop. This is a core challenge for anyone deploying wide area wireless access; regardless, we believe that 3-5Mbps should be a goal for per user effective throughput in 4G systems.

**Support for time-bounded traffic:** Finally, we're assuming that 4G will finally break with legacy SS7/circuit switched technologies and go all-IP. With VoIP clearly the direction for the future on wire, it stands to reason that a similar path should be taken in 4G wireless. Being able to have all traffic managed in the same way will allow better load balancing among traffic types, and should also result in lower costs for operators. While it can be argued that WLans have already reached this nirvana, it will be many years before cellular systems convert to VoIP – there is simply too much expensive infrastructure installed, and amortization periods yet to expire.

Mobile WiMAX very clearly meets the above definition of 4G is every respect. But this does bring up an interesting question regarding the competitive landscape – will specific technology really matter? After all, consumers (including business consumers) buy capability, not implementation. Only geeks are concerned about the technical details of how a given service works, and then only for reasons of performance or the support for specific services. Cellular operators are pushing ahead with their own development of 4G technologies. On the UMTS side, the UTRAN LTE (UMTS Terrestrial Radio Access Long Term Evolution) work under development by the Third Generation Partnership Project (3GPP) is shooting at the 100/50Mbps goal noted above, and the CDMA2000 crowd is moving ahead with EV-DO Rev B, promising throughput of 73.5Mbps – about that of mobile WiMAX. And, as we noted above, WLans deployed on a metro scale should be able to achieve per user throughput of 1Mbps or more in many cases. Add in the possibility of an IEEE 802.20 standard and perhaps other proprietary broadband efforts (such as Qualcomm's Flarion), and the landscape gets really complex.

Even so, it certainly stands to reason that the demand for 4G is going to materialize in a big way, and mobile WiMAX must be considered, at the very least, as a major player in the this evolution to what might be mobile communications and networking nirvana.

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*Wireless is nothing if not a hotbed of innovation, quite remarkable for a technology that can trace its roots to Benjamin Franklin.*

# Clash of the Titans

## WiMAX & 4G: The Battle for Convergence

At few times in the course of international business development have major industries come together in such a way that they become hinged upon the same enabling capabilities and market dynamics. The stage is now set for major players in the fields of wireless mobile communications, information technology, and media entertainment industries to challenge for leading roles in next generation mobile networking (NGMN) converged wireless broadband.

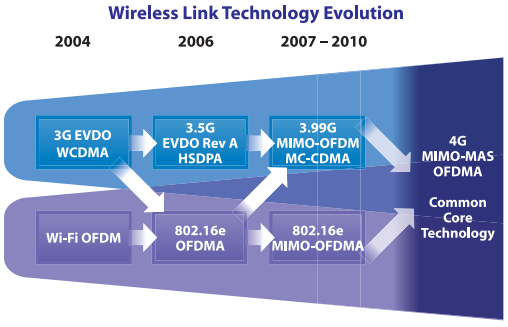
The broadband data that comprises the entertainment, information and programs, and increasingly richer mobile communications is fundamentally similar: the bytes and packets of data are organized around IP/SIP, granularly transmitted across wireless networks. The data streams differ primarily in bandwidth and degree of quality needed to satisfy the applications, voice, or video entertainment. In a real world sense, these all care little about how they are delivered and more about the ease of use, cost and value of the content. The overriding data transport requirements drive to the use of most effective wireless broadband systems. In addition, that drives the industry forward to the use of similar sets of technologies and network delivery methods.

Intel and over 350 other corporations have helped champion WiMAX under the banner of the WiMAX Forum association. WiMAX has developed upon the IEEE 802.16 framework standard for wireless broadband systems based on MIMO-OFDMA and other advanced technologies. Over the past several months, this set of technologies have become recognized as the wireless platform technology for NGMN, or 4G. The emerging field of technologies comprises a major shift from technologies used in 3G wireless mobile systems. This also represents a major shift away from Qualcomm's core CDMA intellectual property, which has come to dominate much of the landscape of wireless communications.

## The Most Significant Shift in Wireless, Networking and Entertainment Since the Creation of Cellular Wide Area Networks

This is the first major shift in core wireless technologies used for wide area wireless systems since the emergence of CDMA over 15 years ago. The overriding motivation for such a shift is the requirement to deliver increasingly higher bandwidths at reasonable cost. In addition, such a shift must deliver a large improvement to justify the cost of starting on a new upgrade path that makes prior generations incompatible and sometimes obsolete. A look at system performance features such as the core spectral efficiency might lead to a conclusion that a shift from WCDMA to OFDMA based systems would bring relatively marginal improvements: less than needed to justify such a move.

The reason both the emerging wireless broadband field and incumbent cellular industry is shifting from WCDMA to MIMO/MAS-OFDMA is the 'total performance package' and evolutionary roadmap that this enables.

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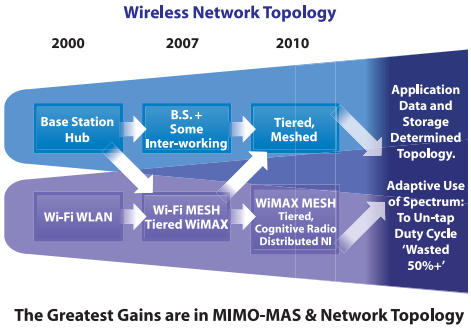
The fields of wireless have contributed to each other along their increasingly convergent paths of development. Both tracks have been enabled by the field of high speed, highly integrated semiconductors and design capabilities and component developments. The Wi-Fi/WiMAX track has started out from humble beginnings just a few years ago but has benefited from an open, competitive market and development environment to see rapid sales growth and uptake of new technologies. The wireless mobile industry has continued the huge growth trend to deliver hundreds of millions of handsets to new and existing users. Moreover, it has improved upon systems performance to enable broadband wireless access to millions of customers. Although WiMAX has benefited greatly from technologies, components and methods developed for mobile cellular systems, the field has

*The wireless mobile industry has continued the huge growth trend to deliver hundreds of millions of handsets to new and existing users.*

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increasingly spawned developments that are pushing the other way: MIMO/MAS and MESH networking which are rapidly adopted by Wi-Fi and WiMAX will find their way into commercial use in cellular systems moving forward.

Figure one points out that convergence of wireless systems technologies is taking place and will align on a similar set for new systems that emerge for wide scale cellular deployments by 2010. It is important to note that WiMAX will arrive first in terms of technology implementation and that the development tracks occur over a period of several years. Rome was not built in a day and neither are new fields of wireless development.

### A New Evolutionary Wireless Platform Is Needed

A major reason for the shift to MIMO/MAS-OFDMA is that a new evolutionary wireless platform is needed. The next generation wireless platform must have the ability to evolve and adopt new methods of network organization and technologies that enhance overall performance well beyond that of the core wireless link technologies employed in either CDMA or OFDM based systems. This not only requires core wireless broadband technologies that are able to deliver high spectral efficiencies, and manageable Quality of Service, QOS, but new methods to use and co-habitat spectrum in a wide range of arrangements and must support growth of system architectures from point to multipoint, point-to-point, tiered and mesh networks. Data centric NGMN systems must meet diverse sets of requirements that structure information storage and network intelligence as close to the user as practical.

Figure 2 displays a commonly ignored aspect of wireless industry evolution: the 'Network Topology' or system architecture that is enabled from the low-level segmentation of spectrum and increasingly cognitive and selective use.

Cellular wireless systems have developed on the needs of the huge voice communications market: primarily as a base station to user or 'hub and spoke' communications network. NGMN's will meet a variety of different sets of needs. Moreover, they will communicate increasingly rich and high bandwidth data to and between users and applications. This shifting nature of end user demands is what is pro-

pelling the adoption of technology platforms that can better evolve to meet them over an evolutionary path of several years.

Not surprisingly, NGMN/4G wireless systems are similar to wired networks: data storage is increasingly needed at the 'network edge' and networking optimization starts to be organized at the discrete byte and data packet level. "Network Intelligence" or NI is as much a buzzword for NGMNs as it is for new generations of wired networks.

The greatest gains in wireless systems performance will be delivered by advancements that effect network topology rather than core wireless link efficiencies. This is the reason for the shift to MIMO/MAS-OFDMA from incumbent cellular technologies. The evolutionary path gains compel the costly, disruptive change.

## Clash of the Titans as Industries Converge

Qualcomm helped to usher in an era of digital methods of wireless communications: they hammered through that data could be spread out over spectrum, making for more robust, tolerant and efficient wireless networks. Full commercial deployments of their CDMA systems gained momentum by 1993. Along the way, the company filed key enabling patents that overcame crippling limitations of prior CDMA for use in wide area cellular systems. Subsequently, Qualcomm has been able to validate their patent position in courts and has successfully negotiated royalties for use of CDMA with all major suppliers.

The shift to MIMO/MAS-OFDMA has only recently been acknowledged by Qualcomm: they acquired Flarion, a leader in mobile OFDM systems and have rapidly filed for patents related to the field. Qualcomm must play a role in NGMN or their future revenues are in jeopardy.

Intel has become the world's largest semiconductor supplier by delivering products that increase user's performance and add entertainment value. As the network becomes wirelessly enabled and increasingly intelligent, Intel must likewise shift this role to deliver the increasingly integrated wireless processors and controllers for wireless systems, network management and devices.

The 'Clash of the Titans' is real and is now being joined on several fronts.

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*The greatest gains in wireless performance will be delivered by advances that affect network topology rather than core wireless link efficiencies.*

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WiMAX FORUM

# The Role of WiMAX in the Evolution of Municipal Networking

*by Roberta Wiggins*

With broadband becoming increasingly critical for economic growth and information access, municipal government organizations, including public safety, educational institutions and transportation departments, are among the first users of broadband wireless. Today this activity is based primarily on Wi-Fi and Wi-Fi mesh. With the standardization of 802.16 technologies, what role is WIMAX likely to play in the municipal broadband space?

There are about 200 municipal wireless projects operational or with issued RFPs in the US today. Municipal initiatives are spurred by government connectivity requirements and other community based applications and a real or perceived broadband service deficiency or unaffordable pricing. While early networks were designed for a single application (e.g. public safety), the focus has shifted to multi-purpose networks designed to:

- Meet local fixed and mobile connectivity requirements
- Increase public safety and efficiency of municipal workers
- Bridge the digital divide
- Drive economic development and enhance tourism
- Create a competitive broadband services market.

Coinciding with this trend is a shift in away from the municipal ownership to public-private partnerships. Via a competitive bidding process, a municipal contract is awarded to the selected service provider who funds and owns the broadband network. Municipalities generally require the prime to establish an open service model that allows access for multiple service providers to encourage broadband competition.

The service model is mutually beneficial for both parties: the municipality is an anchor tenant for municipal applications, while the service provider can leverage existing municipal infrastucture to reduce costs and time to market. Public private partnerships create a role for non-traditional content/service providers like Google and Earthlink. They bring business competence, technical expertise and operational support, information services/content and legacy customer base. To date, Earthlink is building out in Philadelphia, Anaheim and New Orleans with vendor partners, Tropos and Motorola, and has teamed with Google in San Francisco to offer free, advertising-supported WiFi as a complement to their premium fee-based Internet access service.

The municipal broadband movement initially spurred intense backlash from the private sector. Incumbent telcos and cable companies, however, are now beginning to embrace the opportunity of adding broadband wireless to their service bundles, by teaming with vendors to respond to municipal broadband RFPs. For example, Embarq – the local communications carrier recently spun out of Sprint Nextel, has partnered with the City of Henderson, Nevada to launch a Wi-Fi mesh broadband network for use by city officials, businesses, individuals, and first responders such as fire and police officials. Comcast, the largest US cable MSO, has invested in mesh vendor BelAir which has developed a product that can be deployed on cable plant.

The key to a successful public private partnership is a viable business case for service providers built on achievable revenues from wholesale and retail residential and commercial broadband wireless services. Municipal applications and public safety can generate good revenues; in the public access domain the revenue model is less certain. Many cities are requiring no or low cost service in low income residential areas to bridge the digital divide. However, service providers need to realize a profit on commercial services. Value added content and services such as IP telephony, location based advertising and localized information (such as bus schedules with real time updates) will stimulate consumer usage and revenue.

The development of municipal broadband in European cities is unfolding differently from that of the US, from an application, technology and business model perspective. Networks use a mix of Wi-Fi hotspots, mesh and WiMAX technology. Municipal applications are focused on creatively

*Incumbent telcos and cable companies, are now beginning to embrace the opportunity of adding broadband wireless to their service bundles.*

**GLOSSARY OF TERMS**

**WiMAX —** The brand name for the emerging broadband wireless standard, which consists of a set of profiles based on a subset of the IEEE 802.16 standards. The governing body is the WiMAX Forum, which manages certification, testing, branding and promotion as well as defining the profiles.

**802.16 standards —** These are devised and ratified by the IEEE. There have been various iterations of 802.16 but the important ones for WiMAX are 802.16-2004, finalized last year as a specification for fixed and portable usage; and 802.16e, which should be ratified in late 2005 for mobile applications. IEEE standards govern the PHY (physical) and MAC (media access control) layers of the radio network. Higher layers such as network (routing) are handled by other standards bodies such as IETF (Internet Engineering TaskForce).

**Wi-Fi —** The brand name for the wireless LAN standard, based on the IEEE 802.11 specifications. The main variations are 802.11b, 802.11g, 802.11a and the upcoming 802.11n, for WLANs above 100Mbps.

**WMAN and WLAN —** Wireless metro area network and wireless local area network.

**ETSI HiperMAN —** A standards development under the auspices of the European Telecommunications Standards Institute, focusing on wireless MANs. This work has been harmonized by the WiMAX Forum with IEEE 802.16.

**OFDM —** Orthogonal Frequency Division Multiplexing. The key technology in the physical layer of WiMAX and the 802.11a and 802.11n Wi-Fi variants. It supports strong spectral efficiency and high data rates.

**Mobility and portability —** Definitions vary. In this supplement, mobility refers to applications where there is seamless hand-off between base stations during a call. Portable or nomadic applications require a second log-in when a user moves between base stations.

**Frequency bands —** In theory, 802.16 networks can operate in any frequencies up to 11GHz and probably beyond. WiMAX profiles are currently devised for certain key areas of the radio spectrum. These are license-exempt 5GHz (mainly 5.8GHz and, for Europe, 5.4GHz); 3.5GHz; 2.5GHz, also known as MMDS (Multichannel Multipoint Distribution System), ITFS (Instructional Television Fixed Service) or BRS (Broadband Radio Service) in the USA; and in future, 2.3GHz, also known as WCS (Wireless Communications Service) in the USA. Other profiles will include 700MHz.

**Wi-Bro —** A broadband wireless technology created in South Korea by Samsung and others. It has been deployed in 2006 and will be harmonized with the 802.16e standard.

**CPE —** Customer premises equipment, or subscriber station (SS).

**Mesh —** A method of creating a wide ranging network by routing traffic in 'daisychains' of short hops between many access points. It has come to prominence particularly through the use of Wi-Fi mesh in citywide metro-zones. In future WiMAX mesh will also play a role in these zones.

**3G —** The third generation of cellular networks, which is based on two main technologies, UMTS (Universal Mobile Telephony System) and CDMA2000 (Code Division Multiplex Access). The latest iterations of these technologies, which may complement or compete with WiMAX, are HSDPA (High Speed Downlink Packet Access) and CDMA2000 1x EV-DO (Evolution Data Only). The industry bodies behind these standards are 3GPP (3G Partnership Project) for UMTS and its extensions, and 3GPP2 for CDMA networks.

Source: Rethink Research

managing urban congestion via traffic management, crime prevention and intelligent transportation schemes. Providing services and subsidized equipment in schools is a starting point to bridge the digital divide and foster economic development. In some instances, a new breed of ISPs are building citywide networks of Wi-Fi hotspots through co-operation between public sector organizations, private companies and home users with no centralized investment or public funding. While in the UK, British Telecom has taken the lead in proactively designing a muni broadband strategy targeted, initially, toward six cities.

Today's municipal broadband projects in are heavily focused on Wi-Fi technology, but there is increasing interest in WiMAX or WiMAX/Wi-Fi hybrids for these deployments. Wi-Fi was the initial technology of choice because it is readily available and affordable as an access technology embedded in all client devices. Mesh networking extends Wi-Fi beyond the limitations of hotspots, but still has range and bandwidth limitations. Networks should be able to incorporate emerging technologies such as WIMAX as they mature.

Today's leading municipal broadband vendors all recognize the need to incorporate WiMAX into their Wi-Fi mesh architectures, initially for backhaul and ultimately at the access layer, when Intel provides a hybrid WiMAX/Wi-Fi chip. In many Wi-Fi mesh solutions, vendors already opt for pre-WiMAX point-to-point and point-to-multipoint connections offered by companies such as Motorola (Canopy) and Alvarion (BreezeMAX). WiMAX vendors, including Navini, Redline, Aperto, Airspan and Alvarion, provide fixed wireless access for municipalities today in the licensed 3.5GHz band, and the 5.4GHz and 5.8GHz unlicensed bands, and will promote the evolution to portable 802.16e.products. In the meantime, municipalities will be able to take advantage of Wi-Fi/WiMAX hybrids such as Airspan's municipal/public safety solution that combines 802.11 access with 802.16 backhaul over 5.8GHz and 4.9GHz. WiMAX access modules will become a reality as the 802.16e standard is integrated into mobile client devices in the 2007-2008 timeframe.

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