WHITE PAPER

The Promise of WiMAX

Paul Sergeant, MOTOwi4,
Motorola Networks Global Marketing and Strategy

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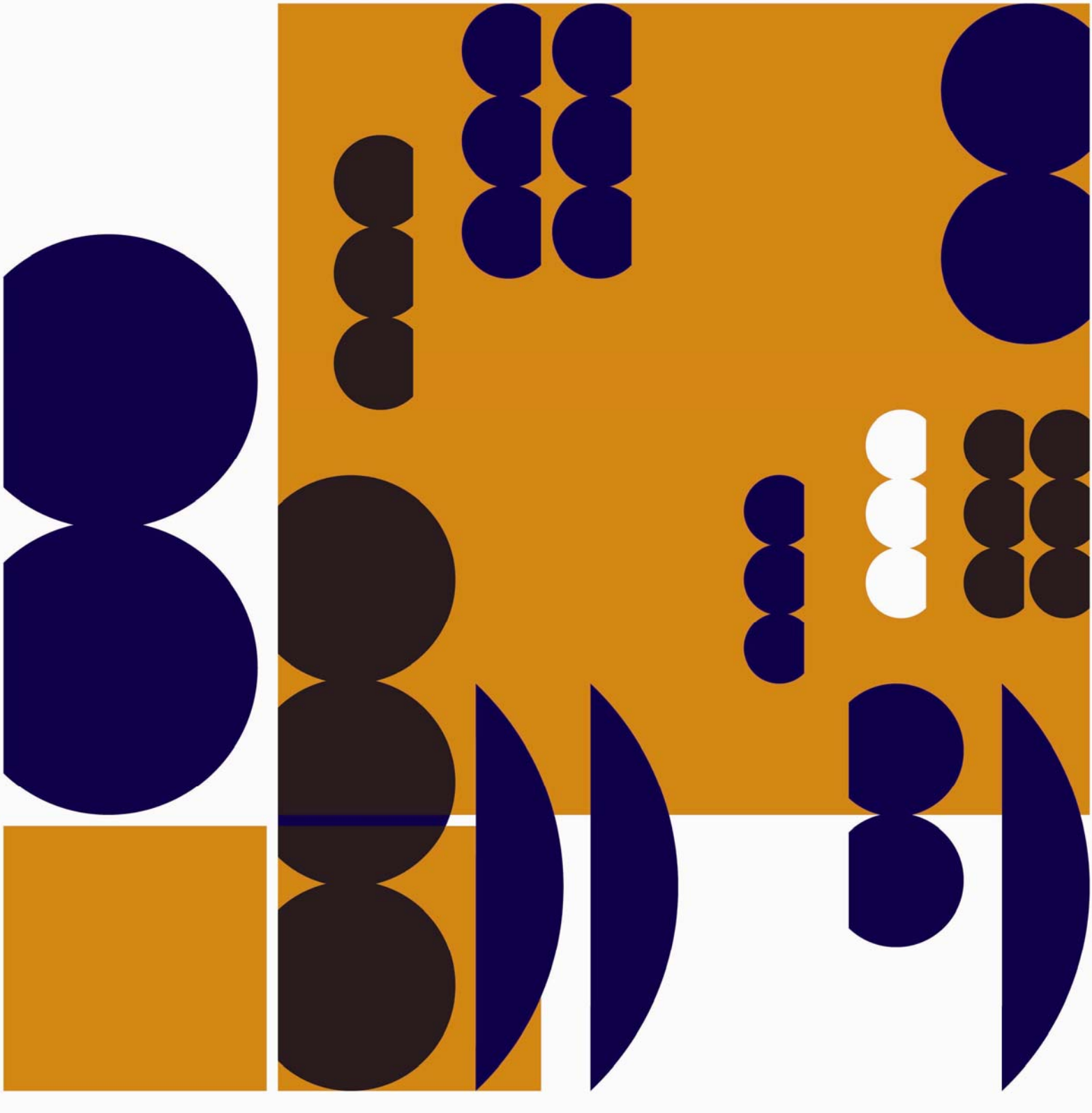

The Promise of WiMAX

Broadband Access to the Last Mile

WHAT IS WIMAX?

Worldwide Interoperability for Microwave Access (WiMAX) is currently one of the hottest technologies in wireless. The Institute of Electrical and Electronics Engineers (IEEE) 802 committee, which sets networking standards such as Ethernet (802.3) and WiFi (802.11), has published a set of standards that define WiMAX. IEEE 802.16-2004 (also known as Revision D) was published in 2004 for fixed applications; 802.16 Revision E (which adds mobility) is planned for publication before the end of 2005.

The WiMAX Forum is an industry body formed to promote the IEEE 802.16 standard and perform interoperability testing. The WiMAX Forum has adopted certain profiles based on the 802.16 standards for interoperability testing and "WiMAX certification". These operate in the 2.5GHz, 3.5GHz and 5.8GHz frequency bands, which typically are licensed by various government authorities.

WiMAX, is based on an RF technology called Orthogonal Frequency Division Multiplexing (OFDM), which is a very effective means of transferring data when carriers of width of 5MHz or greater can be used. At carrier widths of 10MHz or greater, OFDM really shines. Below 5MHz carrier width, current CDMA based 3G systems are comparable to OFDM in terms of performance.

HOW WILL WIMAX BE USED?

WiMAX is a technology designed for Broadband Wireless Access (BWA), which traditionally operates in non-cellular frequencies above 2GHz. That spectrum includes the MDS bands between 2.3 and 2.7 GHz (used in North America), the international FWA bands between 3.3 and 3.8 GHz, and unlicensed frequencies such as 2.4 GHz and 5.8 GHz, typically used for WiFi and cordless telephony. Although current 802.16 standards support the entire frequency range between 2 and 6 GHz, the WiMAX forum has focused WiMAX certification on the 2.5GHz, 3.5GHz and 5.8GHz bands.

Broadband Wireless Access is used today for:

- Last mile access to residences for basic telephony services when wire line infrastructure doesn't already exist, such as in developing countries and rural areas.
- T1/E1 service for small businesses and enterprises
- Provision of Wireless Internet Service Provider (ISP or WISP) services
- Competitive access backhaul for businesses and cell sites
- Temporary backhaul for sporting events and tradeshows
- Provision of broadband backhaul for 3G cell sites

These applications are met today with either proprietary airlinks, or with other TDD standards such as TDD-UMTS. WiMAX will support similar applications with 802.16 Revision D.

With 802.16e (which adds mobility,) WiMAX will also be used for:

- Mobile telephony services using Voice Over IP
- Mobile multi-media services based on IP
- Low cost data downloads through "Hot Zones"

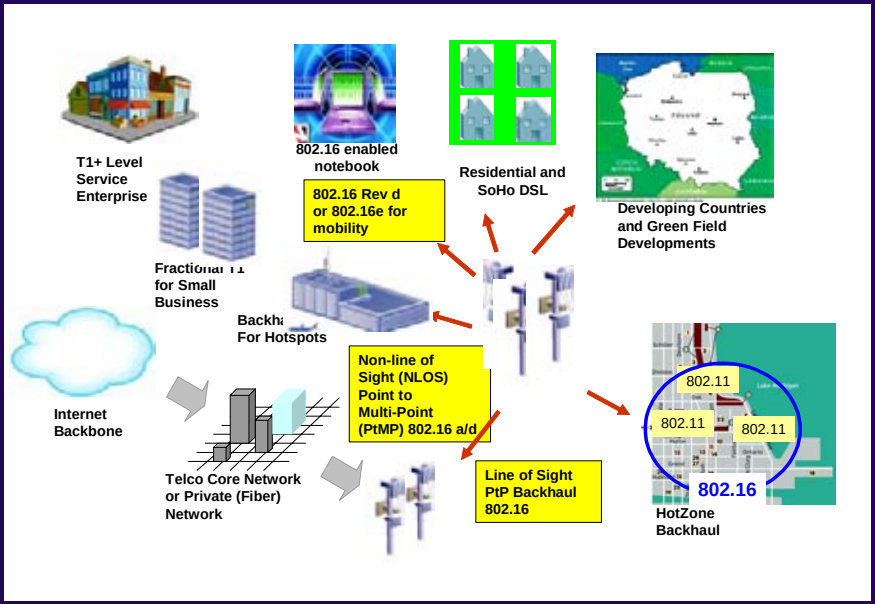

FIGURE 1
WiMAX addresses an array of access requirements[1]

WHY HAS INTEREST IN WIMAX INCREASED?

Until recently, BWA systems have been proprietary. Since the relatively small, global BWA infrastructure market (about $660 million annually in 2004[1]) is split between many competitors and has no mobility, there has been little need for interoperability. No large BWA suppliers emerged to set de-facto standards.

Now, with the standardization of WiMAX in 802.16 and the pending addition of mobility, carriers are expressing a greater interest. In addition, Intel has mounted an effective marketing campaign around WiMAX touting the benefits of this technology. For example, WiMAX standards promise to lower costs by providing standardization and multi-vendor interoperability. Chip vendors such as Intel and Fujitsu will deliver chips in high volumes which will drive down the cost of end user devices by a factor of three or more, and will open the BWA market to multi-vendor competition.

We should note here however, that the vision is incomplete – the IEEE only defined the Physical (PHY) and Media Access Control (MAC) layers in 802.16. This approach has worked well for technologies such as Ethernet and WiFi, which rely on other bodies such as the IETF (Internet Engineering Task Force) to set the standards for higher layer protocols such as TCP/IP, SIP, VoIP and IPSec.

In the mobile wireless world, standards bodies such as 3GPP and 3GPP2 set standards over a wide range of interfaces and protocols because they require not only airlink interoperability, but also inter-vendor inter-network interoperability for roaming, multi-vendor access networks, and inter-company billing. Vendors and operators have recognized this issue, and have formed additional working groups to develop standard network reference models for open inter-network interfaces. Two of these are the WiMAX Forum's Network Working Group, which is focused on creating higher-level networking specifications for fixed, nomadic, portable and mobile WiMAX systems beyond what is defined in the IEEE 802.16 standard, and IEEE 802.21, which is looking at WiMAX to cellular interoperability.

WIMAX SPECTRUM AND PERFORMANCE

As previously discussed, there is no one piece of spectrum that is allocated for WiMAX. Even when people talk about WiMAX in the 2.5GHz or 3.5GHz licensed spectrum, they are really talking about multiple frequency bands. For example, in the USA, Canada and parts of Latin America, spectrum is available for BWA in the 2.3 GHz range and in the range 2.5 GHz to 2.7 GHz, but 2.4 GHz is unlicensed (and used for WiFi and cordless phones). The 3.5 GHz band is really a hodge-podge of frequencies ranging from 3.3 GHz to 3.8 GHz.

[1] Wall Street Journal, January 2005

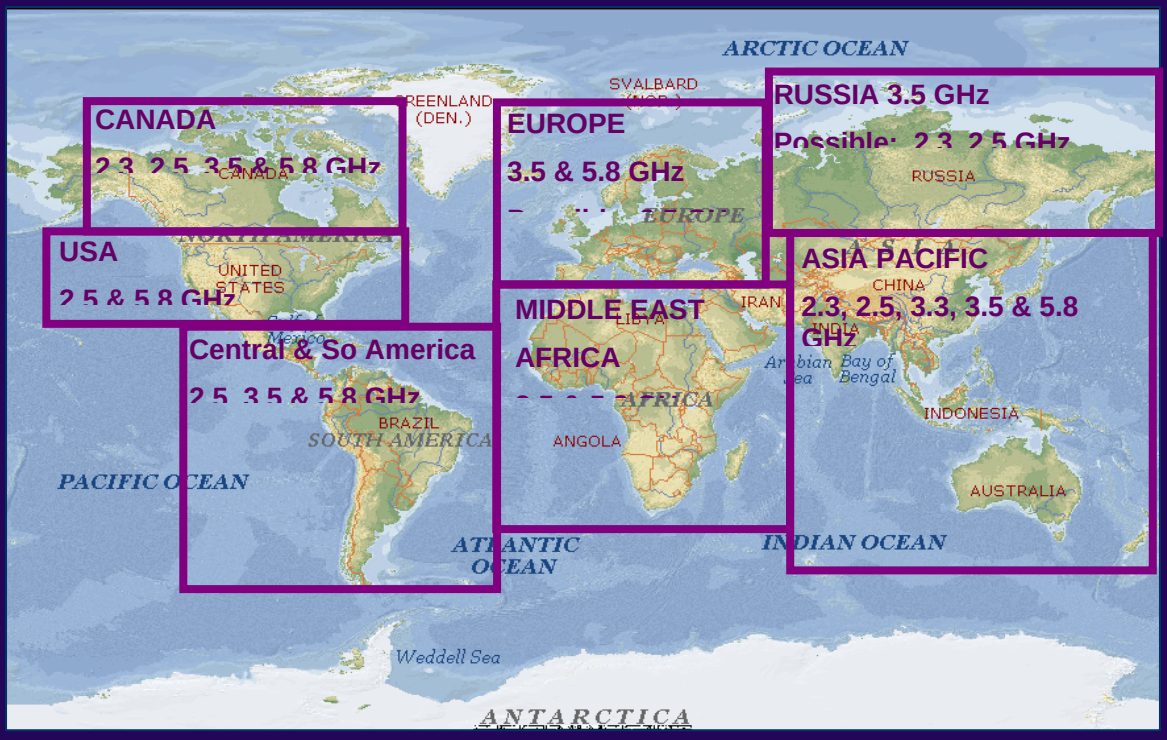

FIGURE 2
Global BWA spectrum Allocations[1]

TDD VS. FDD

Another issue is Time Division (TDD) verses Frequency Division (FDD). The WiMAX forum has defined TDD and FDD profiles for 3.5 GHz in Europe, and is proposing TDD and FDD for 2.5 GHz also. (***FIGURE 3*** and ***FIGURE 4***). What frequencies are allocated, and whether they are TDD or FDD is usually a political decision taken by the regulating authority.

Freq Band (MHz)	Duplexing	Channelisation (MHz)
3400 - 3600	TDD	3.5
		7.0
	FDD	3.5
		7.0
5725 - 5850	TDD	10

Profiles are for PMP systems only and are for 256 OFDM

FIGURE 3
2004 WiMAX profiles showing TDD and FDD options for 3.5 GHz and 5.8 GHz[2]

Freq Band (MHz)	Duplexing	Channelisation (MHz)
2500 - 2690	TDD	5.0 / 5.5
	FDD	5.0 / 5.5

FIGURE 4
Proposed 2005 WiMAX profiles showing TDD and FDD options for 2.5 GHz[3]

A decision to allocate spectrum as TDD eliminates from consideration all FDD-only technologies such as FDD-UMTS and CDMA2000, clearly something to be opposed by vendors who lack TDD solutions or operators with deep investments in other systems. TDD systems can use FDD spectrum, but it may be a tight and uncomfortable fit, and regulations may prevent deployment. However, FDD systems are generally more complex and expensive than TDD systems; it isn't clear currently how many vendors will develop FDD WiMAX given the complexities of supporting multiple national FDD spectrum allocations.

RF LINK BUDGET & PERFORMANCE

A lot of claims have been made about WiMAX performance – mostly around the maximum link performance of 70 Mbps and a range of over 30 miles. What are generally missed are the realities – that these are extremes, and both conditions cannot be met at the same time. WiMAX *can* deliver in excess of 70 Mbps under the following conditions – that the link be good enough to support a high level of modulation (which means nearby and line of sight), and that it supports 2048 sub channels sub channels in a 20 MHz wide band. It can deliver 2 or 3 Mbps over a range of 30 miles, if the link budget is good enough, which means at least near-line of sight, with no blocking obstacles, and highly directional antennas.

For inter-vendor interoperability, the WiMAX Forum requires testing in the mandatory mode using 256 FFT (Fast Fourier Transforms, which equates to the number of sub channels), it does not require interoperability testing with the optional

[2] WiMAX Forum, September 2004

[3] 2.3GHz is also being considered

Channel Bandwidth	Modulation & Code Rate						
	QPSK 1/2	QPSK 3/4	16QAM 1/2	16QAM 3/4	64QAM 1/2	64QAM 2/3	64QAM 3/4
1.25 MHz	1.04	1.56	2.08	3.12	3.12	4.16	4.68
1.75 MHz	1.45	2.18	2.91	4.36	4.36	5.82	6.55
3.5 MHz	2.91	4.36	5.82	8.73	8.73	11.64	13.09
5.0 MHz	4.16	6.23	8.32	12.47	12.47	16.62	18.70
7.0 MHz	5.82	8.73	11.64	17.45	17.45	23.27	26.18
10.0 MHz	8.31	12.47	16.62	24.94	24.94	33.25	37.40
20.0 MHz	16.62	24.94	33.25	49.87	49.87	66.49	74.81

Figures in Mbps. Assumes 1/32 Guard Time. Excludes MAC and preamble overhead.

Farthest from Base Site ⟷ Closest to Base Site

FIGURE 5
Worldwide WiMAX subscribers by Region[1]

1024 and 2048 sub channel modes. This means that inter-vendor interoperability cannot be guaranteed in the higher FFT modes of operation.

It should also be noted from the earlier discussion that most WiMAX profiles are for much smaller bandwidths than 20MHz (3.5 MHz or 7 MHz in 3.5 GHz spectrum, and 10 MHz at 5.8GHz), which will further limit performance in the real world.

Mobile WiMAX based on 802.16e appears that it will be limited to 10 MHz, which gives a “best performance” figure of 37 Mbps, although the specification has not yet been finalized. In 5MHz WiMAX should offer peak speeds of 18.7 Mbps, which is comparable to the maximum performance for UMTS Revision 5 (High Speed Downlink Packet Access) with 14.4 Mbps in 5 MHz.

WiMAX offers much higher spectral efficiency than WCDMA. In most cases however, spectrum availability or regulation will limit carrier deployment of WiMAX to higher frequency deployments in the 2.5 GHz or 3.5GHz bands. Due to the physics of RF propagation, these bands have poorer performance than 1.8, 1.9 or 2.0GHz. As a general rule of thumb, doubling the frequency halves the range for a given power level, resulting in a quadrupling of the number cell sites. WiMAX will have to have superior RF performance compared to 3G just to cover the poorer propagation due to spectrum.

When WiMAX at 3.5 GHz is compared to WCDMA at the 2.0GHz IMT-2000 bands, WiMAX’s superior RF performance allows it to offer competitive subscriber performance despite inferior propagation from the high frequency. This will enable cellular operators to re-use existing cells sites to provide coverage while limiting the need for new sites; it will also allow new operators to plan on leasing existing sites while providing competitive network performance.

WiMAX’s spectral efficiency permits operators to offer higher average performance to a similar number of subscribers (compared to WCDMA), or to offer comparable service to as many as twice the number of subscribers in a given frequency allocation. As an All-IP, all packet radio technology, WiMAX will also minimize a problem where most of the forward link power is consumed by voice circuits (which get priority), leaving little for data, which thereby suffers.

Simulations have shown that WiMAX performs extremely well, and appears to be able to deliver performance that will make it a worthy compliment to 3G in the mobile wireless market, as well as continuing to provide benefits in the wireline replacement, or traditional BWA market.

NEW REVENUE OPPORTUNITIES

WiMAX offers wireless and wireline service providers with new revenue opportunities.

1) Wireless carriers can use WiMAX to provide fixed telecommunications services to businesses and residences, using seamless mobility applications to offer unified service and billing. These services include T1/E1 or faster services using IPSec Quality of Service to maintain Service level agreements (SLA) for businesses, while making excess capacity available to residences to compete with Digital Service Line (DSL) and Cable broadband Internet Service Providers (ISP). Wireless carriers are very well positioned to offer this type of service thanks to their

extensive portfolio of cell sites, and existing customer marketing relationships.

2) Wireless carriers can use WiMAX as a less expensive way to backhaul cell sites, especially 3G cell sites, which will rapidly require multiple T1 or E1 links as 3G data traffic increases. This backhaul can be carried in either licensed or unlicensed spectrum, and since it is fixed at both ends, can use WiMAX standards in licensed bands or proprietary airlinks, such as Motorola's Canopy ™ wireless broadband for its excellent interference rejection in unlicensed spectrum.

3) Wireless and wireline carriers can use WiMAX to backhaul public WiFi (802.11) hot spots, and to extend coverage. The business case for public WiFi has not been highly successful so far, mostly because the high cost of backhauling the many, many sites required due to WiFi's poor coverage. The only successful carrier models so far have been using private hot spots (in coffee houses and the like), where the backhaul costs are covered by private operational requirements, and then excess capacity is leased to a carrier. Using inexpensive wireless backhaul on WiMAX has the potential to change the WiFi business model.

4) Existing wireless carriers can use WiMAX revision E as an alternative to cellular 3G deployments, especially where 3G spectrum has not been allocated, or has not been won by a 2G operator. WiMAX telephone devices that support Voice over IP are on the drawing board from Motorola's Mobile Devices business, as well as from other vendors. Intel expects that notebooks will begin to incorporate WiMAX technology during 2006 or 2007, and handsets for mobility will be available by 2007 or 2008. WiMAX's superlative RF performance and lost cost of deployment make it a viable and lower cost alternative to using 3G spectrum for data downloads, or range limited WiFi hot spots.

5) Greenfield carriers can use WiMAX revision E to deploy competitive wireless mobility networks using high frequency spectrum. The superior link budget performance of WiMAX allows operators in higher spectrum bands such as 3.5GHz to compete well with those in traditional 2G and 3G spectrum, and VoIP WiMAX devices will support voice telephony as well as data centric multimedia applications.

6) Cable and DSL operators can use WiMAX as an alternative to laying additional copper lines, while making use of their existing IP core networks. These operators can also extend their service areas into hard to reach areas, such as rural areas (taking advantage of government rural broadband subsidies to do so), or into other territories for which they lack wireline presence. For example, in many countries cable companies and telephone operators enjoy a monopoly in one territory, but are locked out of others because competing companies own wireline operating rights in those territories. WiMAX offers a way to offer broadband services in these other territories using wireless.

COST OF OWNERSHIP

WiMAX is an All-IP, all packet technology with no legacy circuit telephony, which makes the operational expenses very low, thanks to the transport efficiency of Internet Protocol (IP) for short bursty traffic such as data connection, and single direction traffic such as voice. The use of All-IP means that a common network core can be used, without the need to maintain both packet and circuit core networks, with all the overhead that goes with it.

A further benefit of All-IP is that it places the network on the performance growth curve of general purpose processors and computing devices, often termed "Moore's Law". Computer equipment advances much faster than telecommunications equipment because general purpose hardware is not limited to telecommunications equipment cycles, which tend to be long and cumbersome. The end result is a network that continually performs at ever higher capital and operational efficiency, and takes advantage of 3rd party development from the Internet community.

INTER-OPERABILITY AND QUALITY OF SERVICE

WiMAX is a layer 1 (PHY or Physical layer) and layer 2 (MAC or Media Access Control layer) technology that does not define connectivity at the network layer, or layer 3. IEEE leaves 3rd parties to innovate and standardize at the higher layers.

The result is that WiMAX is positioned to connect to a wide array of legacy systems, either the IP cores of wireline carriers, or the IP cores of wireless operators. In particular, IP Multimedia Subsystem, or IMS based cores based on 3GPP standards offer a clear opportunity to provide inter-network roaming, compatibility with 3G cellular, IP-based Quality of Service and common application while leveraging investments made in existing core networks. Connectivity at the IP layer also makes WiMAX a natural extension of other networks using Seamless Mobility.

CONCLUSION

WiMAX offers benefits for wireline operators who want to provide last mile access to residences and businesses, either to reduce costs in their own operating areas, or as a way to enter new markets. 802.16e offers cost reductions to mobile operators who wish to offer broadband IP services in addition to 2G or 3G voice service, and allows Greenfield operators to enter new markets with competitive services, despite owning disadvantaged spectrum. The capital outlay for WiMAX equipment will be less than for traditional 2G and 3G wireless networks, although the supporting infrastructure of cell sites, civil works, towers and so on will still be needed.

WiMAX's all-IP architecture lends itself well to high bandwidth multi-media applications, and with QoS will also support mobile voice and messaging services, re-using the mobile networks IP core systems. WiMAX appears to have what it takes for market success.

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