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2007 Mobile WiMAX

By Steven Taylor and Joanie Wexler

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2007 Mobile WiMAX

Overview

WiMAX is a nickname for Worldwide Interoperability Microwave Access, a broadband wireless network defined by the IEEE 802.16 suite of standards. Mobile WiMAX, in particular, is specified by 802.16e-2005 standards and is ramping up as a mobile network to complement—and in some cases, compete with—current cellular networking alternatives.

Mobile WiMAX is considered a so-called "4G" network—a follow-on generation to existing 3G cellular networks. Unlike 3G networks, 4G networks inherently will support IP and packet switching only (no circuit switching) and will deliver rich multimedia services and cross-network roaming capabilities.

Mobile WiMAX capabilities and benefits can be seen as falling somewhere between Wi-Fi (802.11) local-area wireless networks and cellular wide-area networks. Wi-Fi, which runs in unlicensed frequencies, offers the attractive, multimegabit speeds of a traditional LAN—today, up to 54 Mbps of theoretical maximum throughput—but covers a radius of only about 100 feet from an infrastructure access point to the user's client device. So it is a technology most often used in fairly small geographical pockets.

Cellular networks run in licensed spectrum and stretch throughout an entire metropolitan area under the umbrella of a single cell tower. Inter-tower handoff technology is mature and, for the most part, imperceptible to users as they roam between towers. These attributes enable a single carrier to provide metropolitan, regional, and national coverage to subscribers. However, the highest cel-

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lular data networking speeds today are approximately 700 kbps downstream and 400 kbps upstream, which is significantly more limited than Wi-Fi bandwidth. As is the age-old law of physics, the greater the network transmission distance, the lower the network speed.

Mobile WiMAX offers something in the middle in terms of speed and reach. It provides up to 15 Mbps of capacity within a typical cell radius deployment of up to 3 kilometers, or about two miles. Mobile WiMAX service providers can divide that bandwidth among metro-area subscribers to deliver, in essence, a "mobile T1" or faster connection to each mobile subscriber, opening the door to rich media wireless applications. The technology is currently being deployed in the U.S. and is in trials in the U.K., Italy, and Japan. Commercial mobile WiMAX services have been available in South Korea for about a year.

The WiMAX Forum, an industry consortium that oversees WiMAX development and certifies products for standards compliance and interoperability, is set to begin equipment certification testing in the middle of this year. Such actions generally boost the use and deployment of new technologies by enabling the construction of mixed-vendor network environments and by accelerating industry-wide economies of scale.

The Survey in Brief

In January 2007, Kubernan surveyed the subscriber base of Webtorials[1], a leading educational Web site that covers broadband packet technologies, concerning mobile WiMAX deployment plans, expected uses, and implementation drivers and inhibitors. This report is a summary and analysis of those findings, collected from more than 275 Web-based survey responses. About 38% of the respondents described themselves as business customers or potential business customers of mobile WiMAX service. The service provider community represented 37% of the response base. The remaining respondents described themselves as "personal consumer" (8%) or "other" (17%) type of user.

For those respondents identifying themselves as service providers, questions about deployment plans were asked and answered in terms of when and how broadly the provider expected to deploy mobile WiMAX services. For those respondents identifying themselves as enterprise users, questions were asked and answered in terms of when they planned to adopt the use of mobile WiMAX services.

For additional detail on the survey methodology, see the "Methodology and Demographics" section in the Appendix.

Respondents' Scope of Influence

Seventy-six percent (76%) of respondents said they played a role in their organization's WiMAX purchasing and installation process, either as decision-maker, recommender, or influencer.[2] About 48% of respondents worked in companies with more than 2,000 employees.[3]

Key Findings

The Kubernan survey revealed the following mobile WiMAX deployment and usage plans:

- Fixed-line WiMAX services will go commercial this year. These services will be delivered using infrastructure equipment compliant with 802.16d-2004 standards. Full mobility services based on 802.16e-2005 standards for mobile WiMAX are expected to follow in 2008.

1 The editorial products and product distribution for Webtorials have been separated. The editorial products, including this and future state-of-the-market reports, are produced as Kubernan products, with the joint venture being led by Steven Taylor and Jim Metzler. For distribution of information, Webtorials remains unchanged

2 See Figure A1 in the Appendix for details.

3 See Figure A2 in the Appendix for details.

- The primary driver behind mobile WiMAX, according to the survey base, is mobile voice over IP (VoIP). Following VoIP, mobile Internet browsing, email, and traditional business application uses were cited equally as the second most compelling drivers.
- The perceived inhibitors to mobile WiMAX appear to be of a practical nature. Respondents cited potential high-cost devices as the No. 1 inhibitor, followed by service availability constraints. Many respondents also pointed to licensed spectrum scarcity as a possible sticking point.

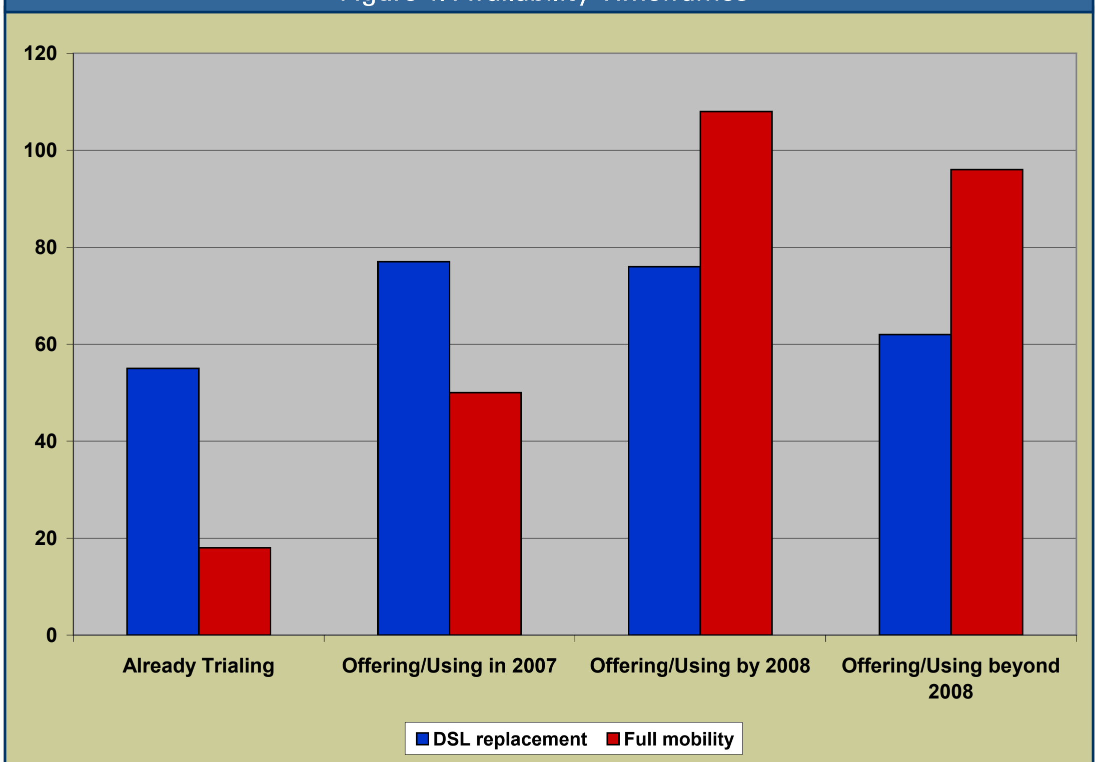
Analysis of Findings

Many of the Kubernan findings reflected the realities associated with deploying any new network services. Respondents astutely took into account the length of time it takes to build out entire new network infrastructures, initial high costs, and worldwide issues surrounding consistent spectrum availability.

- **Commercial service availability.** The 802.16e-2005 mobile WiMAX standards were ratified in December 2005, so providers have had only about 18 months to build out compliant mobile networks based on the final specifications. In August 2006, Sprint Nextel announced it would construct a mobile WiMAX network for delivering its forthcoming 4G services and intends to support 100 million U.S. subscribers by late 2008. Note that South Korea has had mobile WiMAX services since June 2006, under its WiBro brand (for "wireless broadband").

The "fixed-line" version of WiMAX that removed line-of-sight requirements for point-to-point broadband wireless access networks was standardized earlier, in 2004, so carriers are further along with building stationary last-mile wireless networks using 802.16d-2004 specifications. Compliant networks and commercial services are set to ramp up this year (see Figure 1). In addition, a number of "pre-WiMAX" wireless access networks and services based on near-final standards have already been in place for about two years.

Figure 1. Availability Timeframes



Fixed WiMAX, used as a last-mile terrestrial broadband replacement, will ramp up this year, while mobile WiMAX will kick into gear in 2008 in the U.S.

Most industry observers predict that, eventually, mobile WiMAX will eclipse the need for fixed WiMAX, given that the mobile version can be used in either fixed or mobile scenarios.

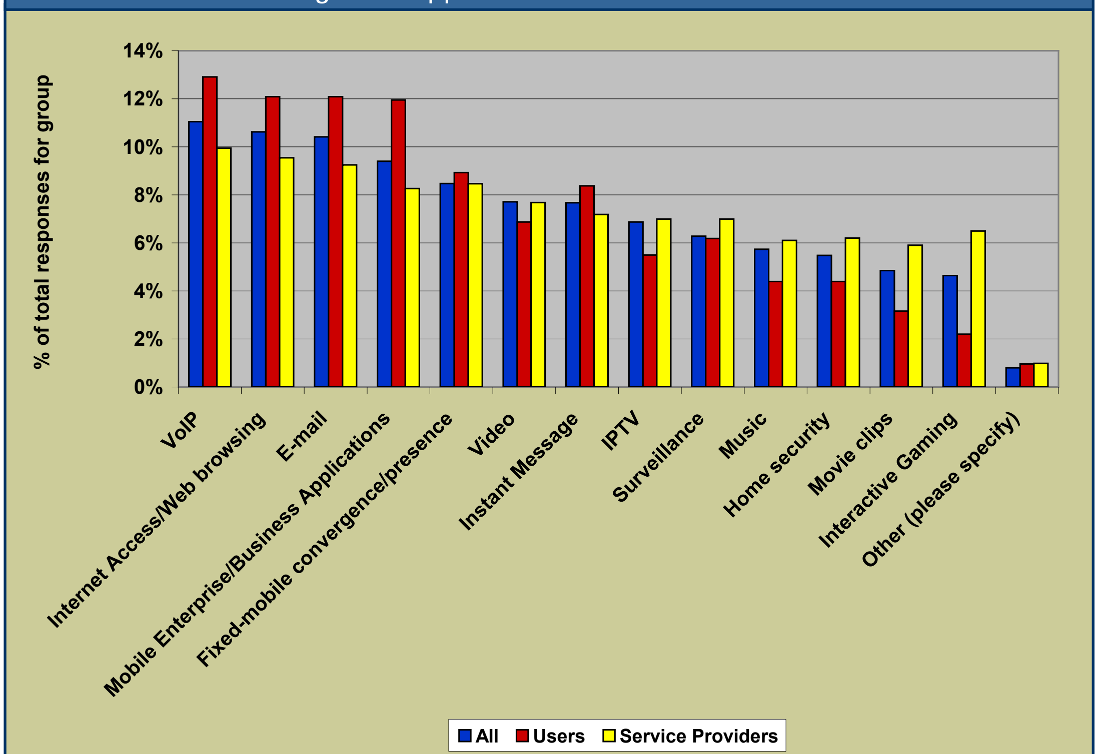
• **Application drivers.** The high level of interest in WiMAX for VoIP (see Figure 2) seems surprising, given the many possible ways that currently exist to make a phone call. One possible rationale behind the appeal of WiMAX for voice and other everyday communications and business applications could be the currently fragmented nature and restrictions of today's 3G cellular networks. For example, a number of multinational companies would like the option of a common wireless mobile protocol that their employees can use worldwide, and some IT managers in those companies are hoping that mobile WiMAX will evolve to do the job.

Cellular carriers currently require separate subscriptions for cellular voice and data applications; indeed, they are delivered on two separate infrastructures (a packet-switched data infrastructure overlays a circuit-switched voice infrastructure). Technically, VoIP is data, and telephony client software on the user's mobile device could be used to place VoIP calls over a subscriber's data service. However, most U.S. cellular operators, and some global operators, currently block VoIP from their data networks, because VoIP competes for minutes and revenue on the cellular voice network.

WiMAX, as mentioned, will use IP and support multimedia applications inherently, so the separate voice/data subscriptions should go away, and one network service should meet all communications needs. If WiMAX is deployed consistently throughout the world—and that's a big "if," particularly considering spectrum usage differences from country to country—it's possible that multinational users could have a single, consistent protocol for voice, data, and video that works wherever they go.

That's the utopian view: In practicality, the spectrum-consistency issues need to be worked out and whether WiMAX services will be interoperable across regions, nations, and carriers remains to be seen. Even though mobile WiMAX is based on a common set of standards, implementation specifics, frequency

Figure 2. Application Drivers for WiMAX



Voice and traditional business applications are driving interest in mobile WiMAX. One reason is that many IT organizations hold out hope that mobile WiMAX might represent an unfragmented, interoperable protocol that can be used consistently worldwide.

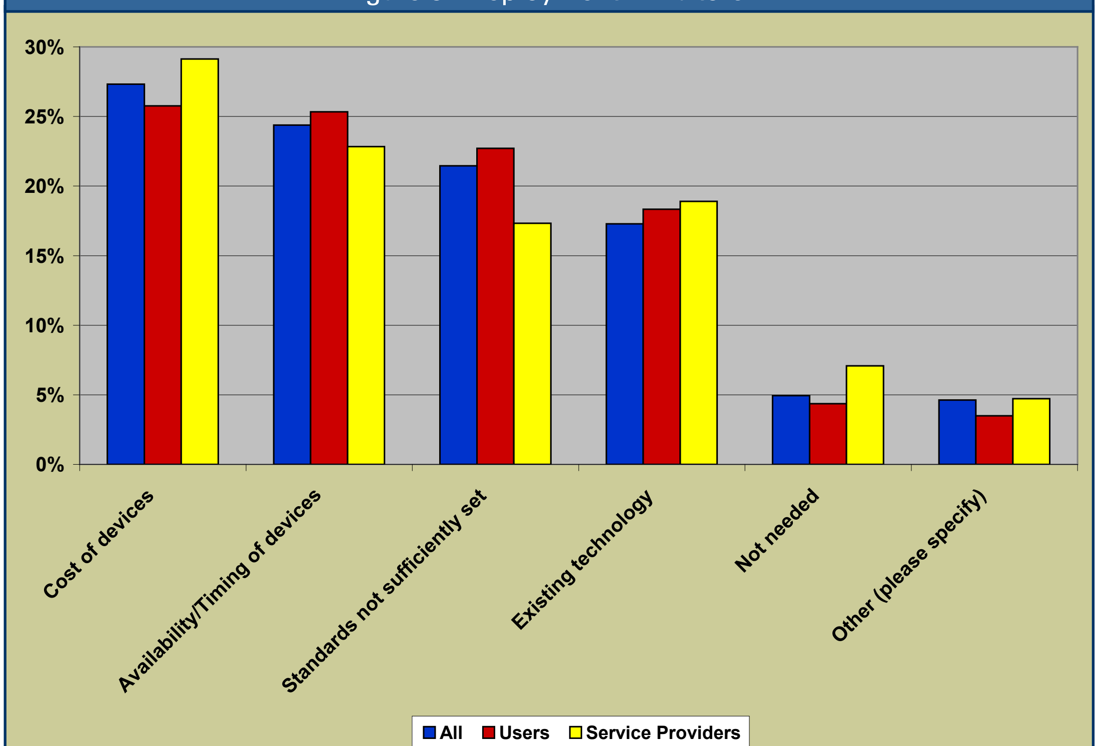
inconsistencies, and worldwide mobile network operator business models will play a role in how transparently mobile WiMAX rolls out around the globe.

Further inspection of Figure 2 shows additional application drivers beyond traditional uses that stand a good chance of ramping up if and when basic services catch on. Fixed-mobile convergence, or FMC, blends networks and applications using IP for seamless roaming. Video surveillance—whether in businesses or used for home security—also showed a respectable amount of interest. There is currently a push to put existing closed circuit television (CCTV) systems onto corporate networks using IP cameras and encoders so that video content can be stored, searched, and accessed from anywhere across the network. This makes a lot of sense for security personnel who, by definition, are often mobile and could end up with mobile WiMAX or other wireless devices.

- **Perceived inhibitors.** The potential for high-priced CPE and user devices is always a concern with new technologies that haven't yet benefited by mass economies of scale. In addition, subscriber devices going forward are likely to contain multiple radio connections—cellular, WiMAX, and Wi-Fi—to offer users the greatest possible access potential. In doing so, however, it is entirely likely that the cost of devices will rise, at least in the near term.

Similarly, service and device availability constraints are worrisome early in the life of any emerging network service that requires a new infrastructure build-out. Many large IT organizations would like to standardize, to the degree possible, on mobile technologies, devices, and providers worldwide. Doing so streamlines the number of carrier relationships, monthly bills, and types of gear that the organization must manage, thereby reducing operational complexity and expenditures. This degree of standardization is difficult, though, until interoperable services are available in all the locations where each organization's subscriber base requires them (see Figure 3).

Figure 3. Deployment Inhibitors



Subscriber device costs and the availability and timing of devices were most worrisome to would-be mobile WiMAX subscribers and providers.

A number of respondents penned in their own responses as to what they perceived to be the biggest mobile WiMAX inhibitor. Of those who did, about half cited "lack of spectrum availability" as a concern. This was an astute observation. Common wisdom has it that most mobile WiMAX deployments will be delivered in licensed spectrum bands, which are finite in their availability and for which mobile network operators must pay significant licensing fees to their federal governments. Licensed services are desirable, however, because they give the carrier licensee complete control over the use of the spectrum, thereby allowing that carrier to confidently offer service-level agreements (SLAs) that are enforceable.

It is presumed, then, that services in licensed spectra will be of higher quality and reliability than those in unlicensed bands where different services, operators, and devices compete for access. Some WiMAX services have been slotted for the 5 GHz, unlicensed band (also a Wi-Fi band), which lowers costs and gets services up and running quicker. On the other hand, with unlicensed spectrum, all users of the spectrum are considered equal, and this makes it difficult for operators to control the effects of interference generated by other operators' services and additional outside sources.

IEEE 802.16e-2005 technical specifications allow for the use of mobile WiMAX in a number of spectrum frequencies. However, different countries have different governmental usage permissions. Note, too, that there is no uniform global licensed spectrum for WiMAX.

In the U.S., for example, mobile WiMAX revolves largely around the 2.5 GHz band. Most of the 2.5 GHz spectrum already has been assigned, primarily to Sprint Nextel and Clearwire. There is a possibility that the U.S. might eventually also open up the 700 MHz band, currently assigned to analog TV, for WiMAX use in the U.S.

In other parts of the world, the most prominent WiMAX bands used will be 3.5 GHz and 2.3/2.5 GHz.

4G and WiMAX Perceptions

There is a lot of complex terminology in the wireless industry, and Kubernan thought it would be a good exercise to determine if there was any consistency in how survey respondents defined elusive terms such as "4G." Interestingly, the largest group of service providers, nearly 25%, defined 4G as "WiMAX." About 20% of users picked that definition, too, though slightly more—about 21%—chose the more generic "multimegabit end user speeds" as their top definition.

When the question was asked in reverse, however—when respondents were asked to equate what they most closely associate with the term "WiMAX"—most respondents chose "mobile broadband," not "4G." (See Figures 4 and 5.)

Obviously, inconsistent perceptions abound. To clarify, as noted in the introductory "Overview" section, WiMAX is a specification for a particular type of network. 4G, rather than defining a network per se, defines network capabilities such as IP, packet switching, multimedia support, and inter-network roaming. WiMAX, then, represents one type of a 4G network. There will be a number of others, including the emerging Third Generation Partnership Project's (3GPP's) Long-Term Evolution (LTE) network, which is based on existing 3G Universal Mobile Telecommunications System (UMTS) cellular standards.

Figure 4. 4G Definitions

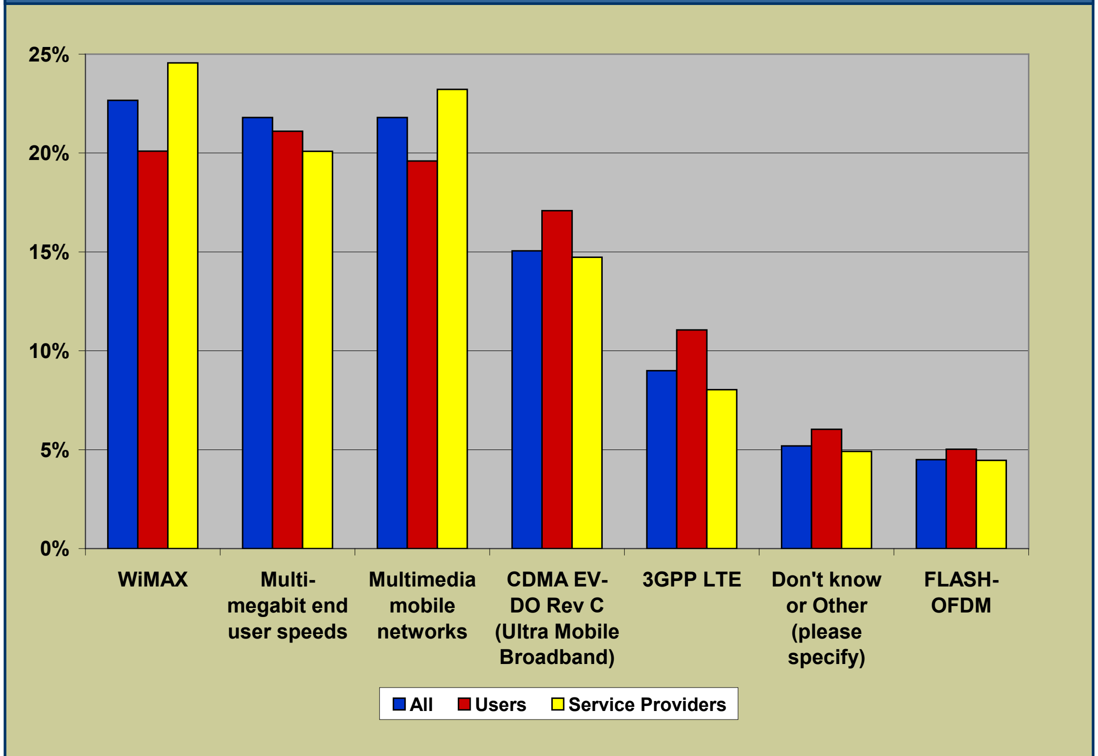
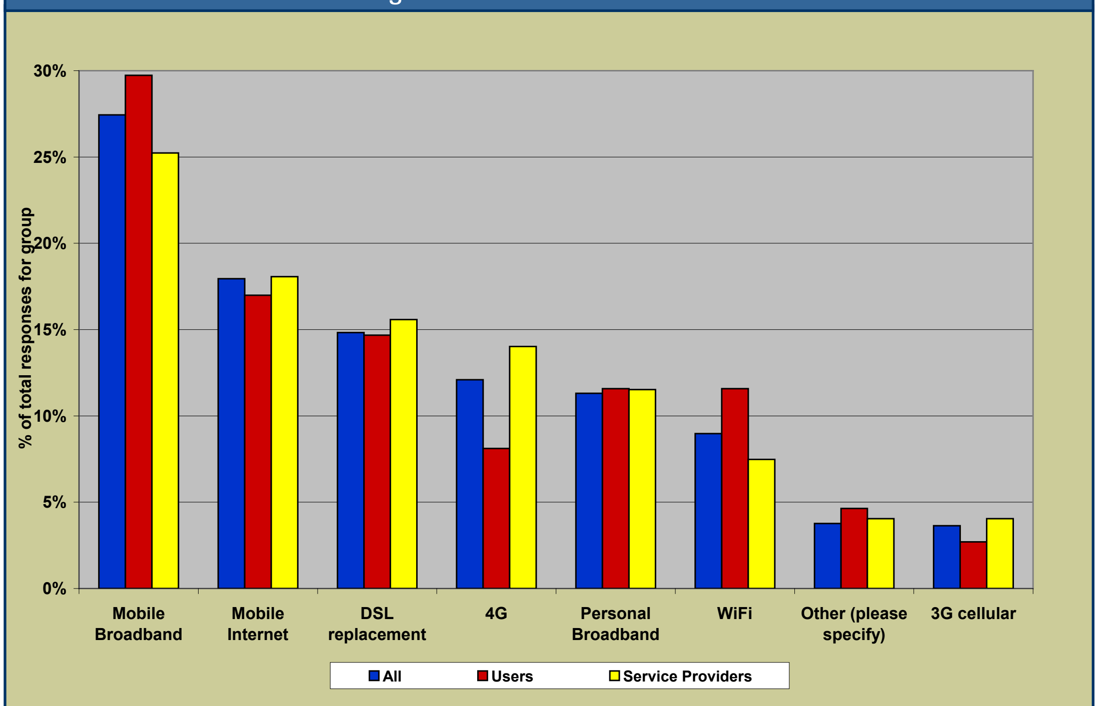


Figure 5. WiMAX Definitions



Most respondents define 4G as "WiMAX," but the reverse isn't true. "Mobile broadband" is what survey-takers associate most with the term "WiMAX."

Summary and Conclusions

The success of mobile WiMAX is currently a wild card. Falling in between the speeds and reach of 802.11-based Wi-Fi wireless LANs and cellular networks, mobile WiMAX will be both a complement and competitor to today's cellular networks. Kubernan survey respondents indicate particular interest in the technology for VoIP, perhaps because of current restrictions on 3G cellular networks that block VoIP traffic. Anything could happen, however, to 3G operators' terms and conditions between now and when mobile WiMAX becomes widely deployed.

The technology has the potential to deliver mobile broadband connectivity and application services consistently worldwide—mobile WiMAX's possible leg up on existing cellular alternatives, which are fragmented across technologies and varying generations of common technologies. However, it is doubtful that mobile network operators who have spent millions in cellular licenses will rip out and replace their 3G networks with WiMAX. Rather, devices going forward are likely to contain multiple radio connections—cellular, WiMAX, and Wi-Fi—to provide users with the greatest access potential. Survey respondents were right to be concerned about the potential high cost of subscriber devices; multiple-radio support will likely kick up device prices, at least in the near term.

As one of what will be several 4G network options, mobile WiMAX still must go through the growing pains of infrastructure rollout, ramp-up, and subscriber buy-in. The most reliable, high-quality services will be delivered using licensed spectrum, over which the licensee has complete control. However, as Kubernan respondents pointed out, spectrum in some areas is currently scarce, which could limit competition. Meantime, however, it is possible that new bands will open up in regions such as the U.S. for mobile WiMAX use.

About the Authors

Steven Taylor is a co-founder of Kubernan and Editor/Publisher of Webtorials. An independent consultant, author, and teacher since 1984, Mr. Taylor is one of the industry's most published authors and lecturers on high-bandwidth networking topics.

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From the Sponsor

NORTEL

Nortel WiMAX 802.16e Portfolio

WiMAX (Worldwide Interoperability for Microwave Access) enables Wireless Broadband Access anywhere, anytime, on virtually any device. WiMAX (802.16e) bridges broadband access at home and in the office, allowing end users to take the Internet with them everywhere they go, making the device of tomorrow as connected as the cellular phone of today.

WiMAX, based on the IEEE 802.16-2005 standard, is a superset of the Fixed WiMAX standard (IEEE 802.16-2004). It adds mobility. Multiple Input Multiple Output (MIMO) into WiMAX devices and base stations for superior performance, and a number of other key feature enhancements like security and QoS. WiMAX 802.16e delivers significant improvements in speed, throughput and capacity that will enable Real-Time Services and bandwidth-intensive applications and services such as streaming music and video, video surveillance, Voice over IP (VoIP) and video conferencing.

Cellular operators, wireline carriers, cable operators, greenfield operators, government agencies and other new entrants will deploy WiMAX-based networks to offer Wireless Broadband Access. Beyond the consumer service value, WiMAX provides unprecedented spectral efficiency, conservation and extension of scarce radio resources — all important benefits for service providers.

WiMAX utilizes Orthogonal Frequency Division Multiple Access (OFDMA), the most efficient technology available for wireless access and the key enabler of all next-generation wireless technologies. With the addition of Nortel's leading edge MIMO antenna technology (which was selected by the WiMAX industry for the IEEE 802.16-2005 standard), WiMAX will deliver up to five times the efficiency of today's 3G cellular networks for wireless data. This means broadband providers can deliver five times the speed, or service five times as many customers, or buy one fifth of the spectrum, leading to lower costs and higher revenue.

Nortel's differentiators

Nortel is the only WiMAX vendor with extensive experience across all other wireless technologies including CDMA, GSM, GSM-R, Wireless Mesh and WLAN, with more than 300 wireless networks deployed in over 70 countries by the carrier service providers. Nortel owns significant IPR in the technologies underlying the WiMAX standard (OFDM and MIMO)

Figure 1. How does WIMAX compare to other wireless technologies?

Differentiating wireless technologies

	3G Cellular	WLAN / 802.11n	WiMAX / 802.16e
Coverage	Ubiquitous	Hotspot / campus	Zone / regional
QoS	Controlled	Shared spectrum	Controlled
Mobility	Full, vehicular	Very limited	Fixed, portable, full mobility
Range	Miles	100 to 500 ft	Miles
User speed	50 to 700 kbps	1 to 10 Mbps	1 to 10 Mbps
Architecture	Hierarchical	Flat, IP	Flat, IP

and its leadership in this space led to Nortel's patented OFDM/MIMO technology being accepted by its peers as the basis for the 802.16-2005 WiMAX industry standard. Nortel is an industry leader in scale and scope and is prepared to deliver end-to-end WiMAX solutions globally.

Nortels WiMAX 802.16e solution delivers:

- **Three times the bandwidth at one third of the cost of Advanced Antenna Systems (AAS) solutions** — This is enabled by MIMO, an antenna technology that leverages interference of signals to its benefit to drive greater throughputs than any other antenna technology.

- **Flexibility and lower operating costs** — Nortels WiMAX solution is built on Next Generation Architecture designed to provide maximum flexibility in deployment with the smallest footprint for a variety of frequency bands defined currently by WiMAX Forum - 2.3 GHz, 2.5 GHz, 3.5 GHz and many more to come. With Advanced Power Amplifier technology, the BTS uses the power most efficiently and provides up to 50 percent savings in power consumption vs. the competition. Nortel's BTS portfolio offers options for remoting the radio head to compensate for the RF cable losses as well as tower top low noise amplifiers (TLNA).

- **Lower installation costs** — Nortel's WiMAX 802.16e solution is a high-powered macro-cellular solution that leverages the existing cellular infrastructure and cell sites. Rather than building new cell sites, Nortel's solution takes advantage of existing infrastructure to lower the cost of implementing a WiMAX network using MIMO technology. In addition, Nortel's WiMAX BTS is lightweight and small in volume (under 1.6 Cu Ft), providing flexibility in deployment and maximizing the real estate cost savings. With standard antennas for MIMO, a service provider can realize further savings in avoiding bulk antennas that are required for AAS besides reducing the number of cables between BTS and antennas.

- **End-to-end WiMAX solution** — Nortel's solution delivers the base station, IP Multimedia Subsystem (IMS) core, Access Service Network (ASN) gateway, Network Management System, services and an ecosystem of devices that interoperate with its WiMAX network

Figure 2. Nortel WiMAX BTS 5000

The Nortel WiMAX 802.16e solution

Nortel offers an end-to-end solution for WiMAX 802.16e that includes the complete ecosystem including base stations, core network, network management system, devices and services.

Base Stations:

The WiMAX BTS 5000 Family

The WiMAX BTS 5000 portfolio is the world's first MIMO-powered solution.

Highlights

- Flexible portfolio:

  > MIMO base station: 2X2 MIMO (2 Tx 2 Rx per sector) delivers up to 70 Mbps peak rate and 50 Mbps capacity with an upgrade path to 4X4 MIMO (4 Tx 4 Rx per sector) as the capacity grows in the network.

- One to six-sector BTS

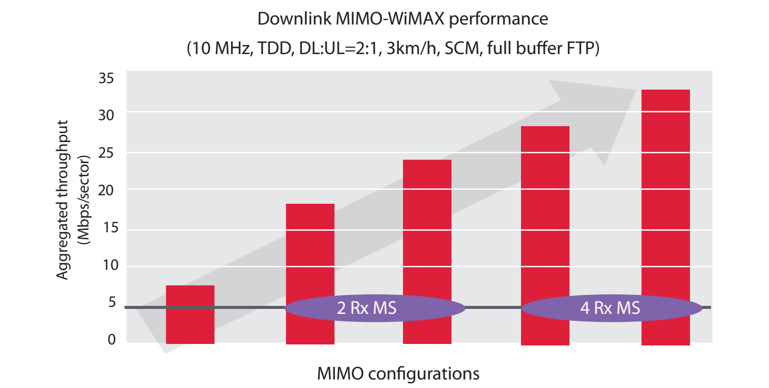
- 28 W of transmit power per sector (2.3/2.5 GHz) / 16 W per sector (3.5 GHz)

Key ingredient to high capacity: MIMO

The key value proposition of WiMAX is the ability to access the Internet everywhere. WiMAX is more spectrally efficient than other wireless technologies and delivers greater bandwidth at the lowest cost per megabit. A key ingredient to delivering this value to operators is the antenna technology in WiMAX called MIMO.

The primary WiMAX antenna technologies are Adaptive Antenna Systems (AAS) and MIMO. Nortel has a long history in both technologies and understands them equally well. With over 10 years of experience in prototyping, building and selling Adaptive Antenna Systems (AAS) and a number of partnerships in this space, Nortel has discovered the drawbacks of AAS. As a result, Nortel has shifted its investment to MIMO over the past six years.

Figure 3. MIMO delivers 2x-5x increase in throughput/capacity



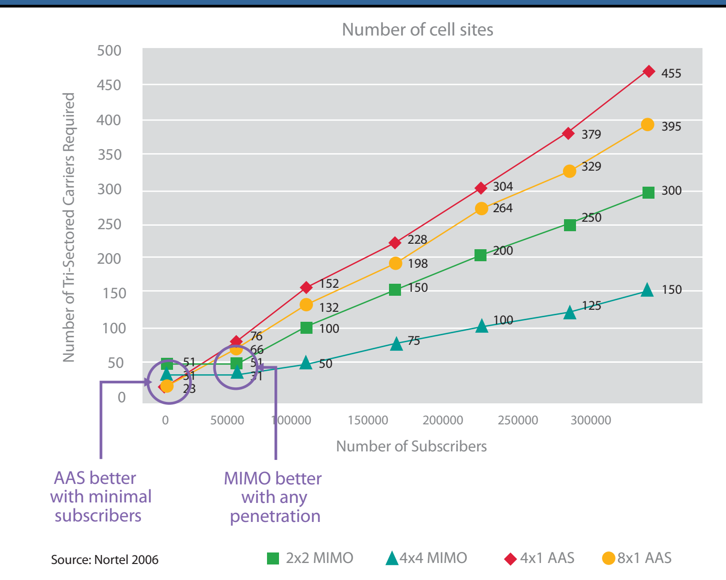
What is MIMO?

MIMO stands for Multiple Input Multiple Output and is an antenna technology that:

- Improves reach
- Thrives on multipath
- Drives greater bandwidth and spectral efficiency
- Uses off-the-shelf antennas

MIMO works by creating multiple parallel data streams from the transmitter to the receiver, utilizing propagation multi-path and interference to its advantage. In dense urban areas, signals bounce off the walls of buildings and MIMO combines all these signals into a single stream, enabling greater throughput.

Figure 4. Business Case: City of Atlanta



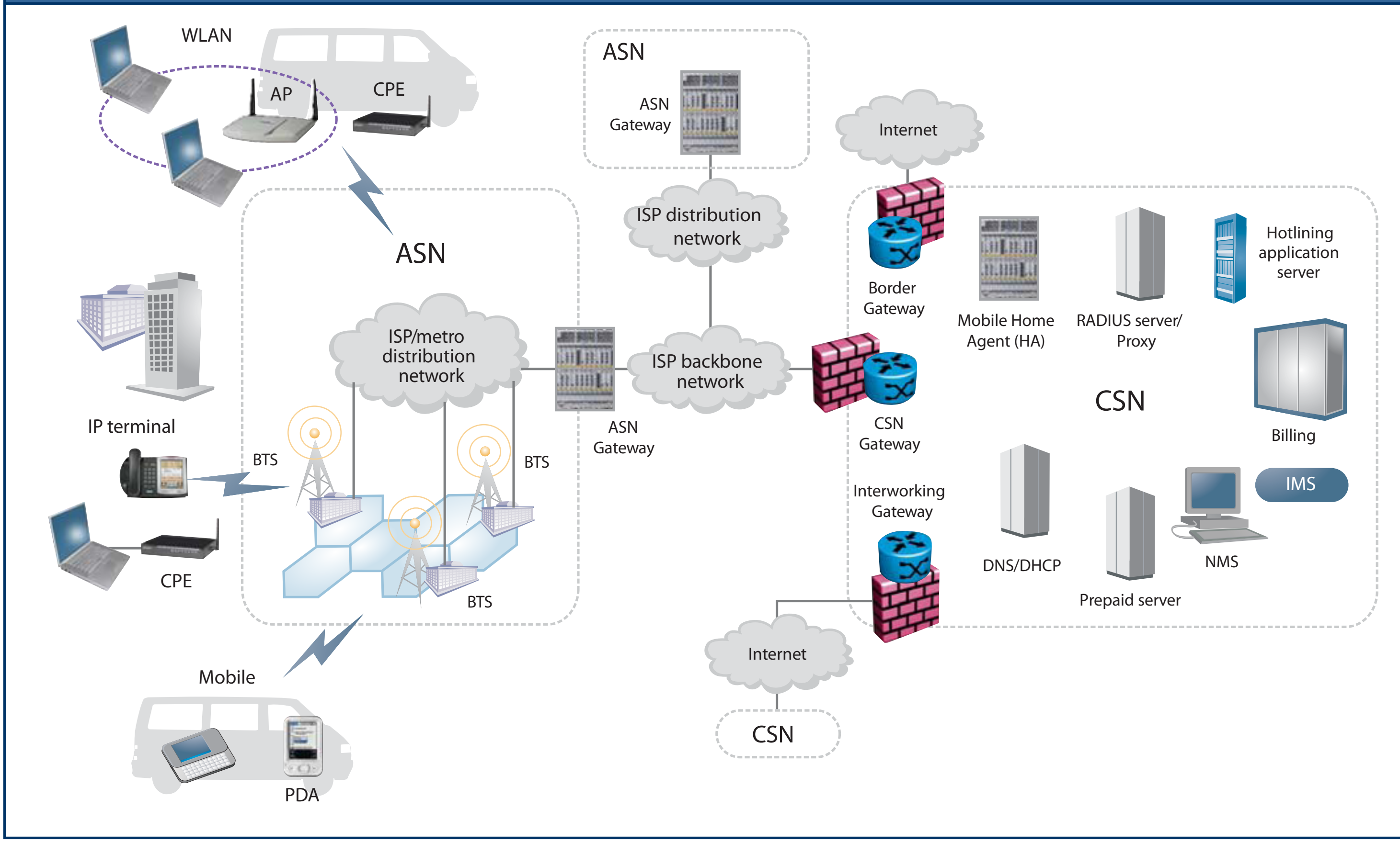
What is AAS?

AAS stands for Adaptive Antenna Systems, an antenna technology that directs the signal to the end-user device. Using beam steering technology to track devices, this technology focuses the signal on active devices, delivering greater coverage. AAS technology has been available for over 10 years.

How do MIMO and AAS compare?

When put to the test, MIMO prevails. MIMO delivers three times the bandwidth at one third of the cost. In a recent business case using the City of Atlanta in Georgia, USA, as an example, Nortel simulated a 2.5 GHz WiMAX network using real-life data and compared the two technologies. AAS performed well only with minimal subscribers. Once 50,000 subscribers signed on, MIMO thrived by delivering much greater bandwidth and utilizing one third fewer cell sites. Networks designed for success will need MIMO-powered WiMAX.

Figure 5. Nortel WiMAX 802.16e solution



- Macro-cellular architecture
- DSP-based software-defined modem for future evolution and upgrades
- Configurations: Indoor, outdoor and wall-mountable
- Supports over-the-air encryption using AES-128 bit algorithm that is designed to meet FIPS-140-2 security requirements.

The BTS consists of two primary building blocks: a Digital Module (DM) and a Radio Module (RM) or Remote Radio Head (RRH). Both modules can be mounted in the standard 19" indoor rack or supplied outdoor enclosure. The Digital Module provides the following functions for the WiMAX BTS:

- OFDMA baseband processing
- WiMAX MAC processing
- Radio interface
- Network timing and synchronization
- OAM processing and management
- Scheduling traffic and enablers for applications

The Digital Module supports 2X2 MIMO configurations for up to three sectors, and can be connected to a second digital module to create 4X4 MIMO configurations, or up to six-sector configurations.

The Radio Module is an indoor rack-mounted radio that contains six transmitters, six receivers, RF filters and the digital baseband processing.

The Remote Radio Head (RRH) is mounted closer to the Antenna for improving the Link Budget. The RRH is a tower, pole or wall-mounted radio that consists of two transmitters and two receivers housed in an environmentally hardened enclosure. It has a fiber optic interface to the Digital module along with a DC power feed.

Outdoor deployments will utilize an outdoor enclosure to house the Digital and Radio Modules. The outdoor enclosures are common across all the frequency bands. A streamlined Digital Enclosure (DE) optimizes the outdoor deployments for the 3.5 GHz product line.

Capacity Growth

As the network capacity grows, Nortel's BTS can scale accordingly. The Nortel 2X2 MIMO solution can be upgraded to a 4X4 MIMO configuration with ease and maximum investment protection. The 4X4 configuration uses the same RF channel as the 2X2 configuration; therefore no additional bandwidth is required.

Core network

Access Service Network (ASN) Gateway

The key function of Nortel's ASN gateway is to aggregate the base stations and manage handoff of devices from one BTS to another. Nortel's ASN Gateway is built on a carrier-grade, high availability/reliability IP networking platform. This gateway offers a high degree of cost-effectiveness versus performance scalability that is required for WiMAX deployments ranging from township or campus deployments requiring only a few BTSs, all the way up to nationwide deployments involving thousands of BTSs.

> Nortel's WiMAX OAM (Operations, Administration and Maintenance) solution simplifies the complexity of managing the diverse WiMAX network elements and services, while providing the level of OAM functionality for the WiMAX network being deployed.

Connectivity Service Network (CSN)

The Connectivity Service Network (CSN) is at the core of the WiMAX network architecture providing control and management for the ASN and subscribers with services such as DHCP server, AAA, FTP, inter-operator and inter-technology roaming, sendees and other applications.

The CSN also includes the Internet Protocol Multimedia Subsystem (IMS) services support capable of offering VoIP, Video, Gaming, Converged Mobility offering seamless handoffs between WiMAX, Wi-Fi and other cellular technologies and several other consumer and enterprise applications.

Network management

Nortel s WiMAX OAM (Operations, Administration and Maintenance) solution simplifies the complexity of managing the diverse WiMAX network elements and services, while providing the level of OAM functionality for the WiMAX network being deployed. The WiMAX OAM solution leverages the platform used across all Nortel solutions.

WiMAX Device Ecosystem

In order to have a truly successful WiMAX solution, it is critical to have timely availability of end-user devices that have achieved quality and interoperability standards. Nortel Device Ecosystem includes LG Electronics — a global leader in consumer devices and a number of Original Design Manufacturing (ODM) vendors that are the world's most innovative and skilled wireless broadband device/CPE manufacturers, enabling Nortel to deliver a comprehensive end-to-end solution to its customers. Nortel's Device Ecosystem delivers:

- **Flexibility and innovation** — The ability to adapt and deliver on a timely basis given the fast-evolving WiMAX CPE/terminal requirements
- **Quality** — Deliver durable and reliable devices while offering efficient, global customer support and service/warranty capability
- **Cost-effectiveness** — A competitive price offering to network operators in terms of price-to-performance ratio and volume of purchase

A cornerstone of Nortel's Device strategy is the Nortel Device R&D Center of Excellence in Taiwan, which will support and manage technical relationships with our partners while performing interoperability and acceptance testing of the devices for the Nortel WiMAX Ecosystem. The types of Device solutions vary in range from simple PCMCIA cards, to USB adaptors, all the way to ultra-mobile PCs and smart phones with VoIP capability.

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Appendix

Methodology and Demographics

The Webtorials subscriber base was asked to participate in a 23-question online survey about their experiences with and plans for deploying mobile WiMAX. All questions were in a multiple-choice format and included a "Don't Know," "Not Applicable" or "Other (please specify)" option.

Whenever appropriate, the order of the multiple choices rotated randomly so as not to bias the survey respondent by the order in which the options were presented.

The Webtorials survey was conducted in January 2007. A total of more than 275 respondents participated. The survey base was divided roughly between networking personnel in businesses and in service provider organizations.

Geographically, Webtorials subscribers in the U.S. and Canada responded in the greatest numbers, representing 43% of the survey base. They were followed by 24% in Western Europe, including the U.K., 14% in the Asia-Pacific region, and 9% in the Caribbean and Latin America. The remaining 10% described themselves as being located elsewhere. (See Figure A6.)

Figure A1: What is your role in your Company's WiMAX implementation?

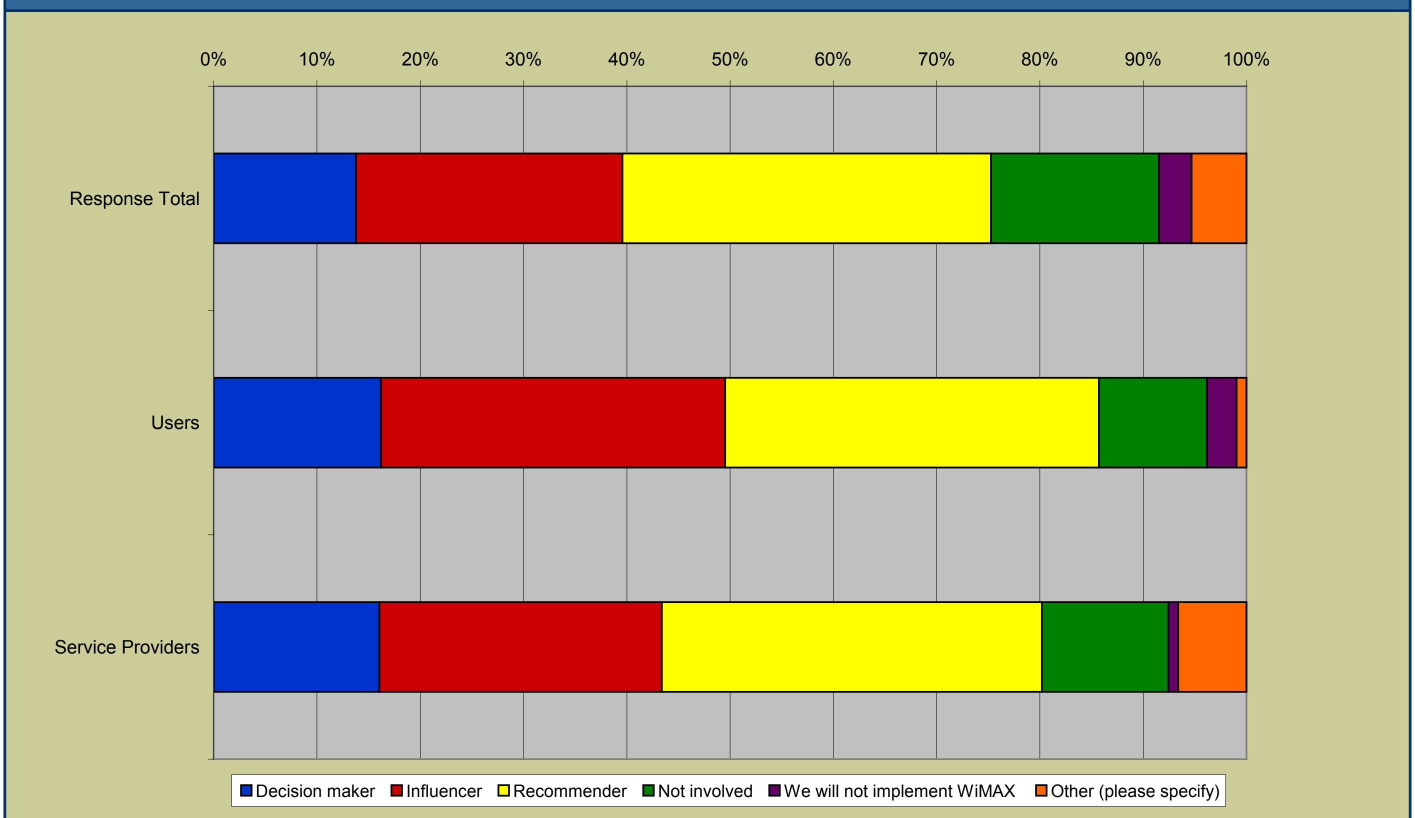

Figure A2: How many employees are there in your organization?

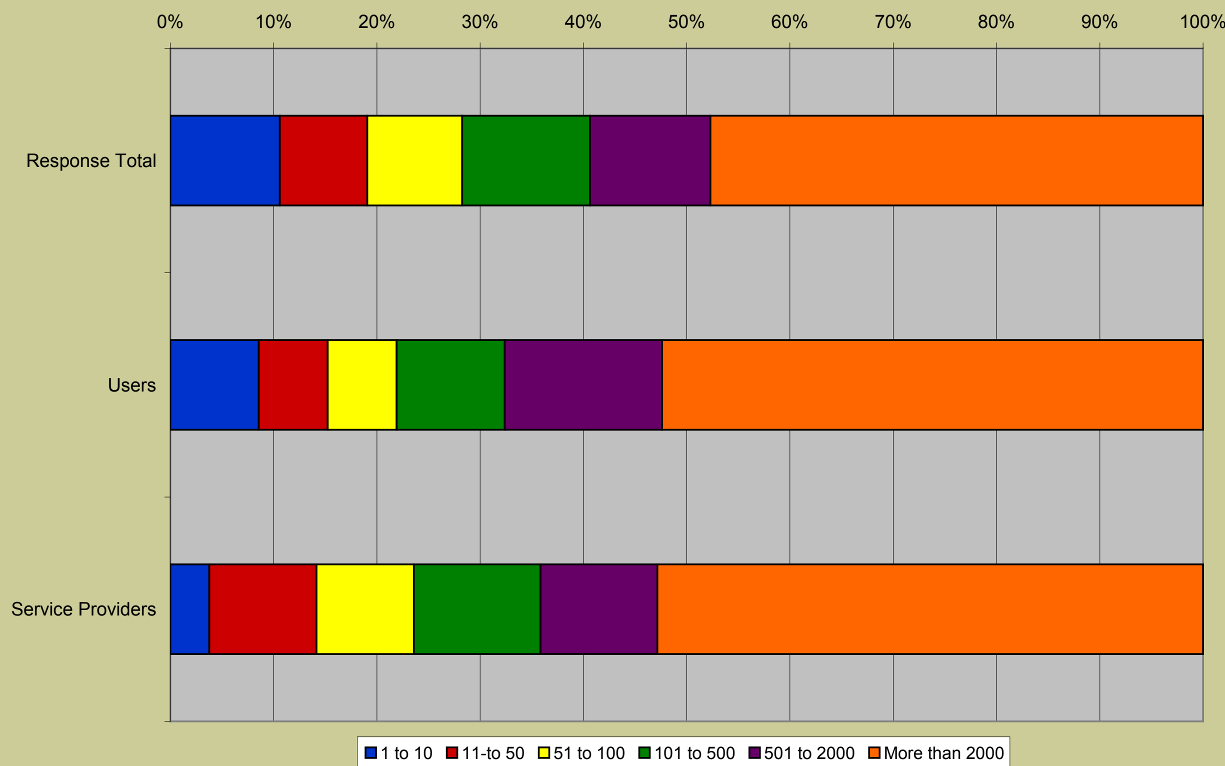

Figure A3: When do you believe mobile WiMAX services will be offered (for commercial providers) or used (for end users) for the following purposes?

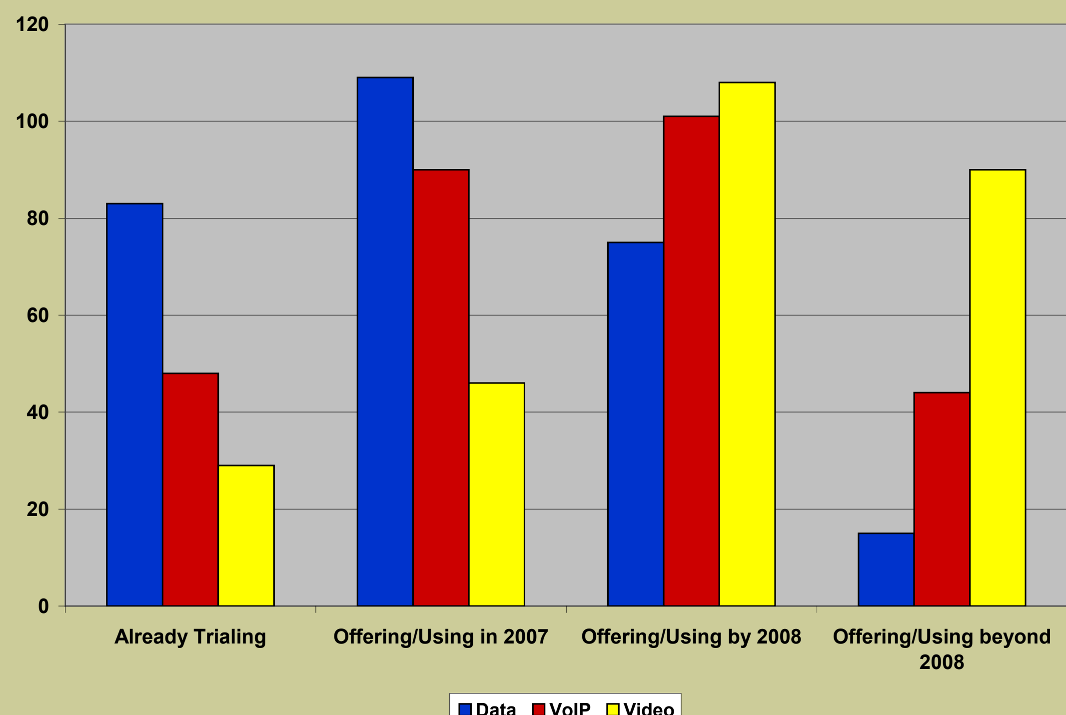

Figure A4: How would you rate your company relative to how rapidly it adopts new technology?

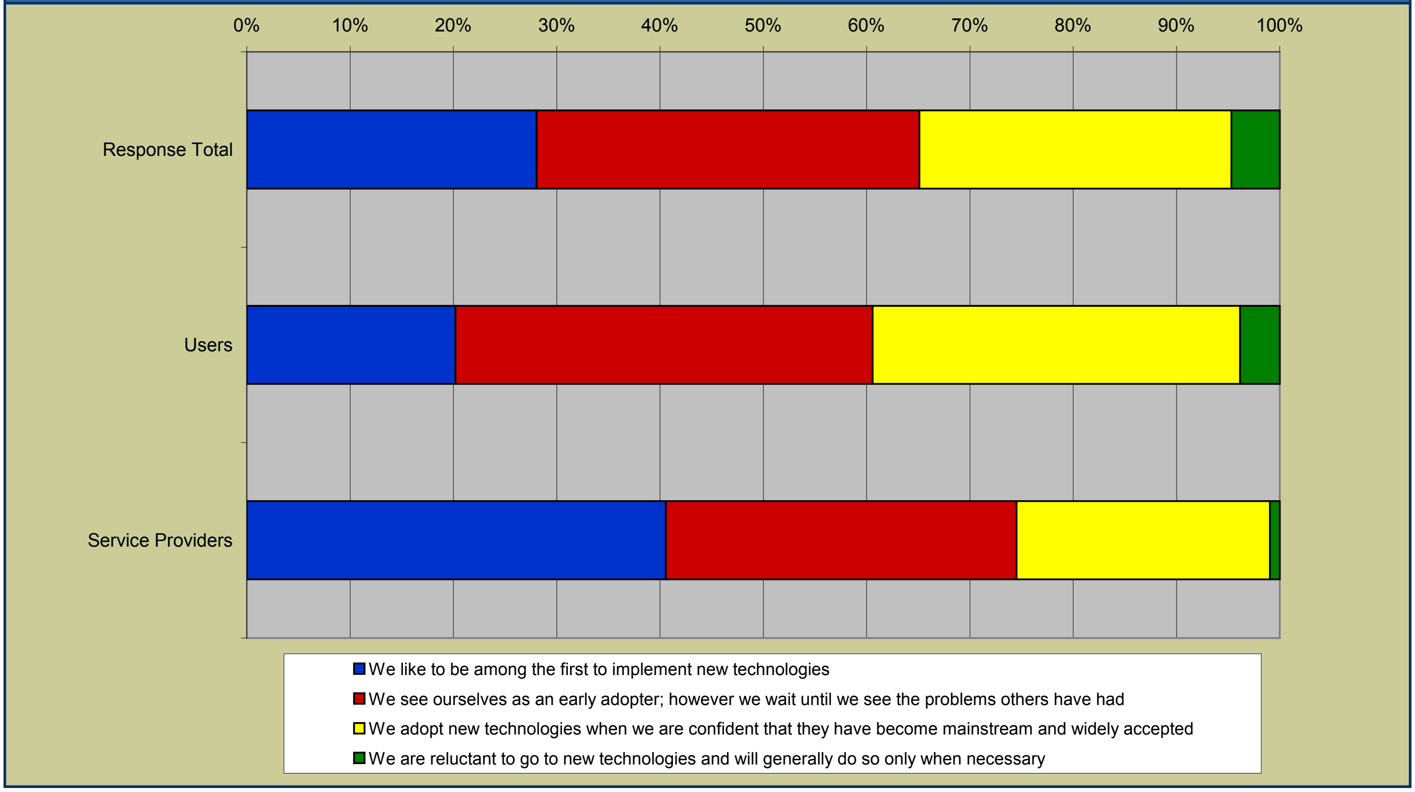

Figure A5: What are the approximate annual revenues of your company?

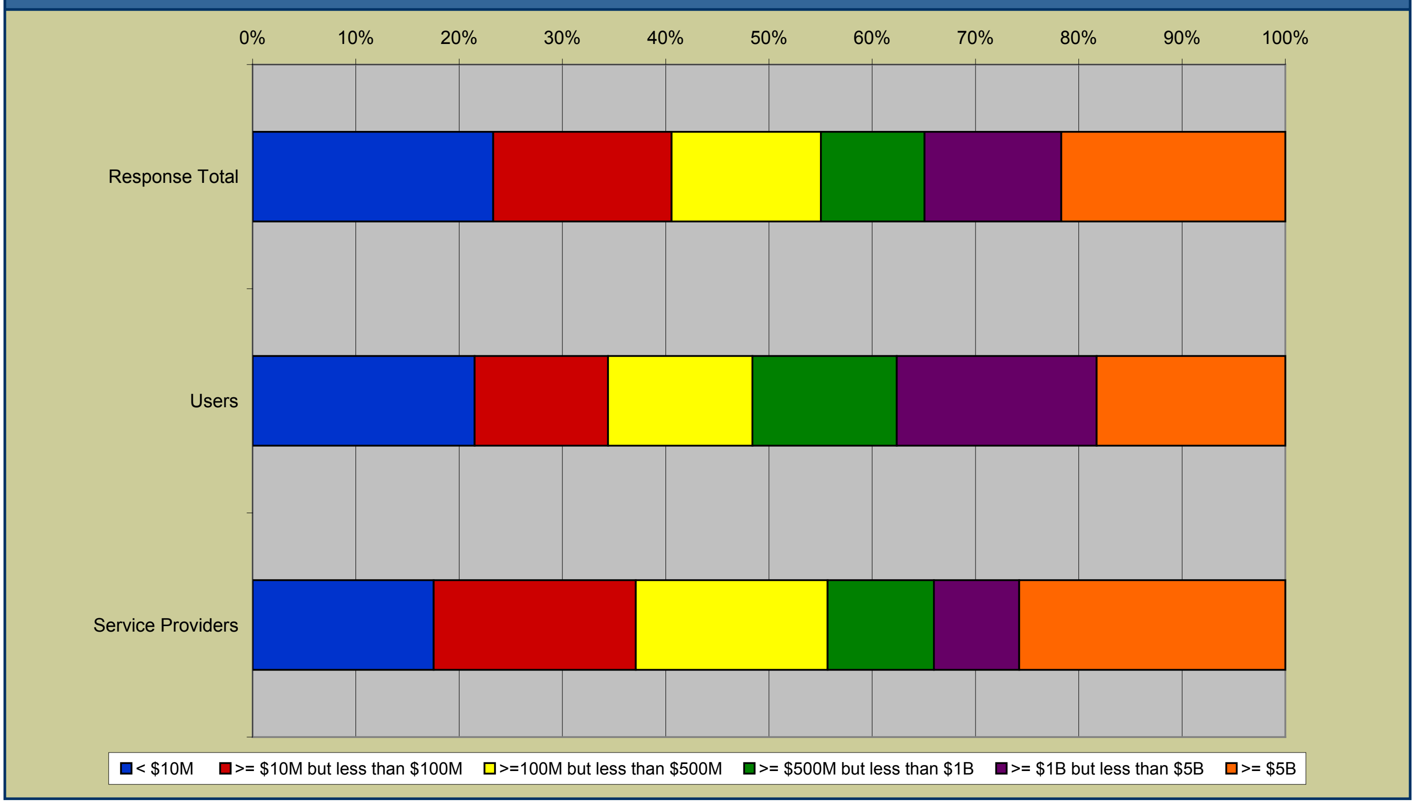

Figure A6: Where is your company headquartered?

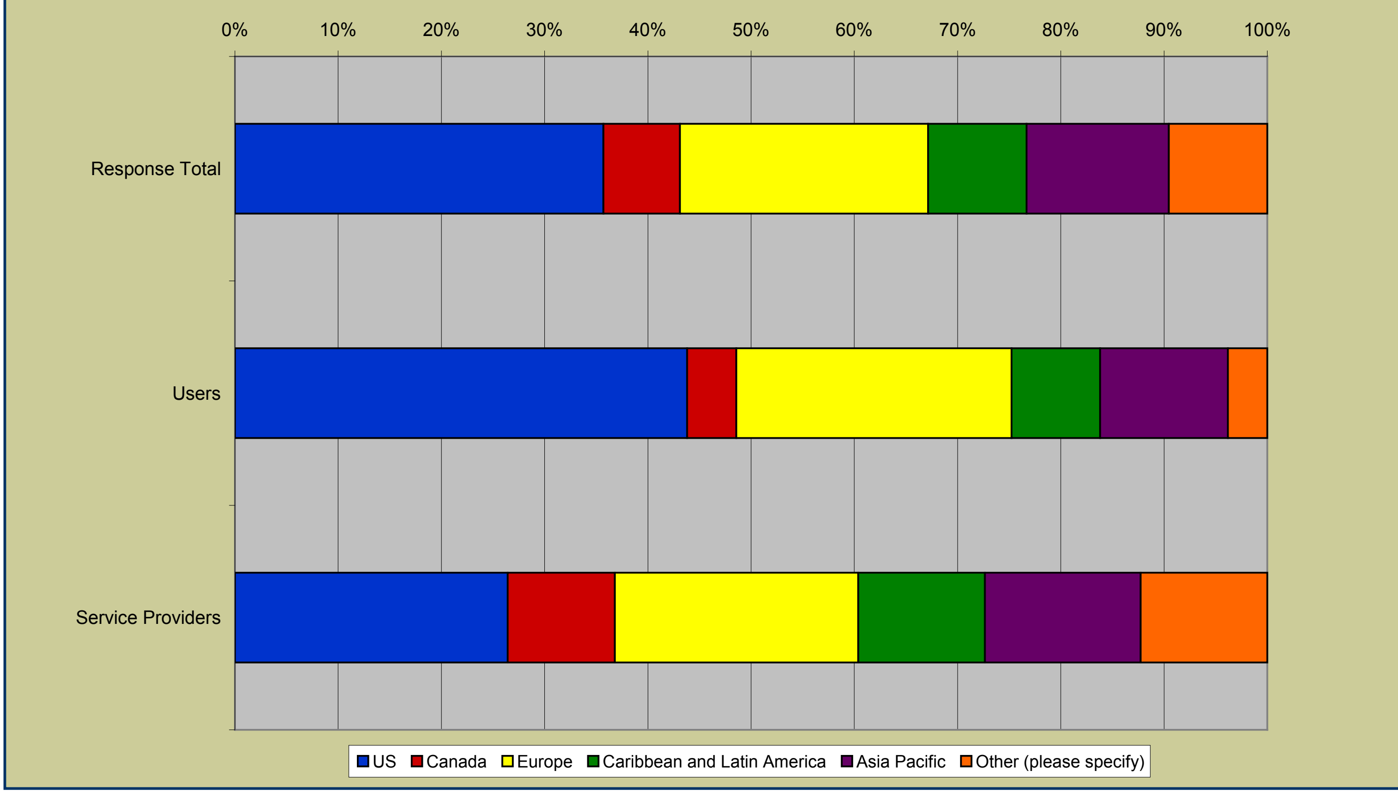

Figure A7: What is your job title?