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THE IMPLICATIONS OF WiMAX FOR COMPETITION AND REGULATION

English - Or. English

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FOREWORD

This report was presented to the Working Party on Telecommunication and Information Services Policies in June 2005 and was declassified by the Committee for Information, Computer and Communications Policy in October 2005.

The report was prepared by Taylor Reynolds of the OECD's Directorate for Science, Technology and Industry. It is published under the responsibility of the Secretary-General of the OECD.

TABLE OF CONTENTS

Boxes

KEY FINDINGS

A set of emerging wireless technologies is posed to greatly increase the range of high-speed wireless broadband. The technologies behind WiMAX should allow for wireless data speeds of up to 40 Mbit/s over a distance of 10 kilometres using relatively inexpensive equipment. These same technologies could also offer faster data transfers to mobile devices than is possible over current third-generation mobile networks under certain conditions. WiMAX-certified equipment should become available in late 2005 and should significantly increase the speed and reach of wireless data networks.

The development and rollout of WiMAX introduces several regulatory and policy issues highlighted in this paper. The paper begins with a brief overview of the technologies behind WiMAX and its market positioning relative to broadband and 3G mobile networks. Next, the paper examines the potentially significant policy and regulatory issues for governments and regulators. Finally, the appendix presents country experiences and details the status of WiMAX across the OECD. The key findings of the paper include:

1. The success of WiMAX partially will depend on the availability of spectrum in OECD markets. Initial equipment will work in one of three main frequency ranges, 2.5, 3.5 and 5 GHz. Existing allocations of spectrum should be examined to see where space could be available for new broadband wireless technologies. Spectrum allocations should be technologically neutral.

2. The success of WiMAX could be hindered by mobility restrictions applied to certain spectrum bands. While the relationship between 3G, WLAN and WiMAX is likely complementary, competition and crossover among the technologies will be greatest when connectivity is not limited to pedestrian speeds.

3. Port blocking and traffic structuring on new WiMAX networks could harm stand-alone voice and video operators who might compete with services provided by the WiMAX operator. The role (if any) of the regulator is not yet clear but will likely become important if anti-competitive complaints arise.

4. WiMAX equipment could play a key role in providing long-range fixed-wireless connectivity in rural and remote areas as well as mobile connectivity over shorter distances.

5. Regulators should ensure that WiMAX operators can interconnect to both Internet exchanges and the PSTN subject to the national laws and regulations governing interconnection to public telecommunications networks. Interconnection should be available on the same terms offered to existing operators.

6. WiMAX equipment could raise privacy and security concerns by enabling wireless surveillance over long distances without consent. Other safety concerns include the use of streaming video content in vehicles that could distract drivers and the safe use of radio transmitting devices near children.

7. Long-range WiMAX may expand the reach of current broadband networks to remote areas and decrease the need for wire-line subsidies. Regulators may need to re-examine how universal service funds are allocated and what role wireless broadband technologies will play.

WiMAX may prove to be a disruptive technology for the telecommunication sector but careful policy can ensure that the disruption creates the maximum benefit possible in the market.

INTRODUCTION TO WIMAX

In telecommunications, one key factor in the success of given technology is timing. Skype's Voice over Internet Protocol (VoIP) service has proven extremely popular but a similar VoIP client (CoolTalk) that was bundled with early Netscape browsers in 1996 never caught on in great numbers. Much of the technology behind VoIP remains the same but the public is much more willing to embrace the technology now, nearly 10 years after it first appeared as a consumer Internet application.

Wireless broadband may be on the verge of a similar shift of acceptance with the emergence of WiMAX (Worldwide Interoperability for Microwave Access) and its supporting technologies. Wireless technologies have been available for years to establish long-distance Internet connections but equipment prices were too high for the market to bear, leaving the technologies under-utilised. The tide may again be shifting towards wireless broadband with the promise of low-cost, but powerful WiMAX equipment.

The WiMAX Forum has estimated that new WiMAX equipment will be capable of sending high-speed data over long distances (40 Mbit/s over 10 kilometres in a line-of-sight fixed environment). At these distances, WiMAX equipment could play a key role in helping bridge the digital divide as long-distance wireless links could help deliver higher-speed access to areas traditionally out of reach of fixed-line networks. WiMAX has also been attracting particular interest as a disruptive technology that could impact fixed and mobile markets, in both their voice and data segments. Finally, WiMAX has also been tapped as a potential key component of next-generation converged or ubiquitous networks.

Earlier fixed-wireless access technologies such as Local Multipoint Distribution Service (LMDS) and Multichannel Multipoint Distribution Service (MMDS) were, at one point, touted as the solutions to many of the same market gaps that WiMAX is now expected to fill. However, LMDS and MMDS never gained widespread market adoption due to problems with interoperability and a lack of economies of scale. The WiMAX Forum is working to change these shortcomings.

By performing independent interoperability and conformity verification, the WiMAX Forum hopes to encourage the widespread adoption of broadband wireless technologies under the "WiMAX" seal. A certified piece of equipment from one manufacturer would then work with a certified base station produced by another – resulting in more competition and lower prices.

The WiMAX Forum is an industry association modelled after the Wi-Fi Alliance, the group which successfully promoted Wi-Fi certification and the adoption of the IEEE 802.11 set of standards. The WiMAX Alliance is hoping to replicate Wi-Fi's success by promoting and certifying the interoperability of broadband wireless products using the IEEE 802.16 and ETSI HiperMAN network specifications. Equipment manufacturers will be able to have their products certified as WiMAX compliant after completing a testing process[1] The objective of the process is ensuring that equipment purchased from different manufacturers will work with each other — thus enabling robust competition in the hardware market, lowering prices and increasing WiMAX penetration.

The WiMAX Forum has a good deal of momentum and backing behind the certification process with 230 companies as members. A sample of influential members includes Intel, Samsung, Cisco, Nokia and Motorola. However, the technologies behind WiMAX are not the only new and evolving wireless technologies so there is no guarantee of WiMAX success. The backers of rival technologies such as IEEE

802.20 (Mobile-Fi), Flash OFDM and third generation mobile (3G)/(IMT-2000) are vying for similar positioning in the market.

Box 1. Confusion around the term "WiMAX"

WiMAX is not a technology, but rather a certification mark, or "stamp of approval" given to equipment that meets certain conformity and interoperability tests for the IEEE 802.16 family of standards. A similar confusion surrounds the term Wi-Fi (Wireless Fidelity), which like WiMAX, is a certification mark for equipment based on a different set of IEEE standards from the 802.11 working group for wireless local area networks (WLAN). Neither WiMAX, nor Wi-Fi is a technology but their names have been adopted in popular usage to denote the technologies behind them. This is likely due to the difficulty of using terms like "IEEE 802.16" in common speech and writing.

Using the terms "WiMAX" and "IEEE 802.16" interchangeably poses problems since it is feasible that equipment manufacturers could build products based on IEEE 802.16 standards that would not be labelled as WiMAX certified.

For the purpose of this paper, the term "WiMAX" refers to WiMAX-certified equipment that is based on the IEEE 802.16 set of standards. Any reference to WiMAX technologies implies the IEEE 802.16 set of standards that are the foundation of WiMAX certification.

WiMAX FORUM

Source: OECD (text), WiMAX Forum (graphic).

WiMAX and IEEE 802.16

The technologies and standards behind WiMAX are those developed by the IEEE 802.16 Working Group dealing with broadband wireless access. The group began developing technologies for wireless metropolitan networks in 2000, publishing its first standard in April 2002 for equipment operating in the 10-66 GHz frequency band.[2] This initial range of frequencies requires line-of-sight connectivity and large towers, making it more suitable for high bandwidth backhaul. The group then extended the standard (IEEE 802.16a) for use in the lower frequency range of 2-11 GHz. This new frequency range allows for non-line-of-sight connectivity and should be popular given certain license-exempt bands in that range.

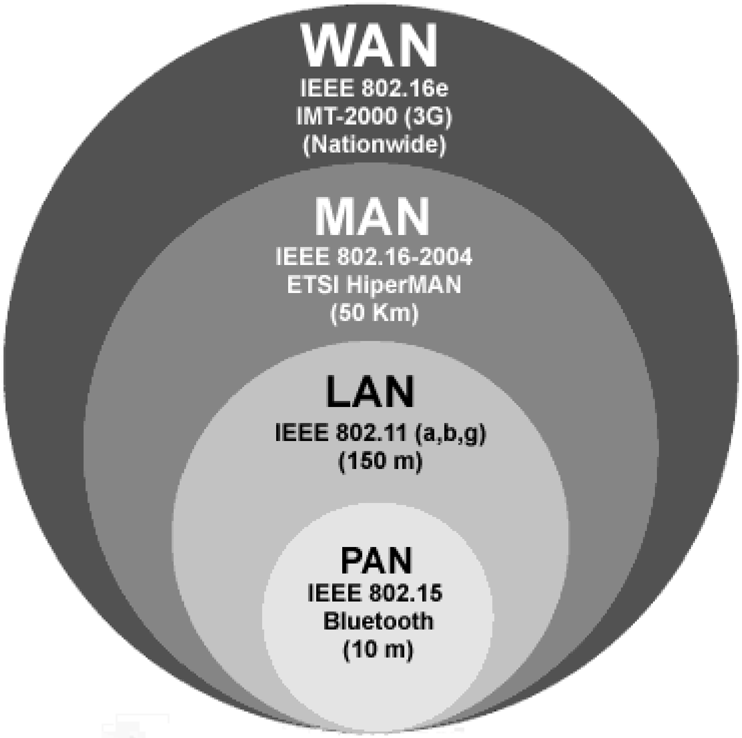
The group's current standard IEEE 802.16-2004[3] (previously IEEE 802.16d) deals specifically with wireless connectivity between fixed devices. In addition, a new mobile standard (IEEE 802.16e) is currently under development that would allow access via portable devices such as laptops, personal digital assistants (PDA) and mobile phones. The fixed and mobile standards have evolved separately due to the complexity of mobile handoffs from one cell to another. Finally, one of the new task groups (IEEE 802.16f) is working on incorporating mesh networking capabilities into the standard. If it succeeds this could extend the range of networks by allowing each cell in the network to backhaul traffic from other cells, effectively routing around obstacles such as mountains.[4]

Reach and speeds

The technologies behind WiMAX are better suited for larger geographic networks than Wi-Fi. Figure 1 shows a breakdown of common network sizes, with the technologies behind WiMAX covering the two largest geographic areas – wide area networks (WAN) and metropolitan area networks (MAN). WANs have traditionally been covered by two wireless technologies, national mobile networks and satellite providers. In contrast, wireless technologies have not found widespread adoption in the MAN coverage area of 50 kilometres. WLAN technologies, such as those underlying Wi-Fi, have been very successful at delivering data over a range of 150 metres and Bluetooth's technologies provide access within 10 metres.

Figure 1. Typical network ranges

IEEE 802.16 technologies are best suited for longer-range wireless communications



Notes:
WAN: Wide area network
MAN: Metropolitan area network
LAN: Local area network
PAN: Personal area network

Source: OECD based on:
http://www.qoscom.de/documentation/51_WiMAX%20Summit%20paris%20-%20may04.pdf

Any claims of WiMAX reach and speed can only be estimations as actual WiMAX-certified products have yet to reach the market. Many predictions and comments in the press about WiMAX may be overly optimistic and tend to rely on theoretical maximums rather than what users may be able to typically expect. The WiMAX Forum has information on what they consider a "typical" mobile installation that is probably a more realistic estimation of the capacity of WiMAX networks and the speeds end users may experience.

The WiMAX Forum predicts that a typical base station will service an area between three to ten kilometres without the need for line-of-sight. In this environment, the base station should be able to deliver 40 Mbit/s per channel for fixed and portable access applications. The actual maximum throughput will depend on a host of factors including the size of the radio channel, spectral density, transmission power limits and geography. However, one cell could theoretically allow hundreds of business connections at 1.5 Mbit/s and thousands of residential connections at 256 kbit/s.[5]

"Pre-WiMAX" equipment supplier Wi-LAN advertises a base station that is capable of operating in the 3.4-3.6 GHz range and supplying a total of 288 Mbit/s of connectivity over a cell coverage area. The cell could be broken into six sectors, each capable of a theoretical maximum of 48 Mbit/s. Each sector could then service a maximum of 2048 fixed connections.[6]

Proponents claim that mobile WiMAX deployments could provide up to 15 Mbit/s of capacity within a cell radius of roughly 3 kilometres. This capacity would be shared by all subscribers in the cell. The throughput is lower for mobile subscribers but access will be possible from moving vehicles. Korea's new WiBro (Wireless Broadband) technology is based on a preliminary version of 802.16e and should offer 1 Mbit/s downloads to individual users in vehicles moving at 60 km/h.[7]

Other research claims that most WiMAX claims are overly optimistic. In a paper developed for the CDMA Development Group, Signals Research Group reports that 802.16-2004 should be able to achieve throughput of 11Mbit/s, assuming the use of an outdoor antenna and a 3.5 MHz channel allocation in the 3.5 GHz spectrum band. They cite claims by WiMAX proponents than in non-line-of-sight implementations the average throughput decreases to 8 Mbps with a cell radius of 100 metres in a dense urban area and a few kilometres in a rural deployment.[8]

Costs

The high cost of previous long-distance wireless equipment such as LMDS and MMDS led to its relegation as a niche technology. LMDS equipment ran roughly USD 4 000 per unit with a base station costing USD 100 000.[9] As a result, the WiMAX Forum is keen to keep prices low through standardization in order to push adoption of the technology. It is difficult to estimate costs for equipment before the technology is available but some information is available. Currently, pre-WiMAX equipment is considerably cheaper, with Motorola's subscriber equipment costing less than USD 300. Some estimates of rollout costs are available as well. In-Stat estimates that it would cost USD 3 billion in equipment, towers, sites, labour and set-up costs to build a national WiMAX network in the United States.[10]

Spectrum costs may or may not play a large role in the overall cost of the network. Certain operators are likely to use equipment in license-exempt bands, especially in rural and remote areas. For others who decide to focus on licensed spectrum, costs could be an issue. Policy makers are keen to avoid a situation where the high costs of spectrum acquisition limit the ability of a new entrant to fund physical infrastructure rollout.

In some countries the price for national licenses has been quite low. In Austria for example, WiMAX Telecom paid USD 208 000 (EUR 160 000) for a national 3.5 GHz license within a competitive award process.[11] In many countries operators are looking to make use of spectrum they acquired for other fixed wireless licenses or earlier mobile radio technologies. Flexibility in national spectrum policies may be important in keeping costs down.

WiMAX overlap with other technologies

One of the most interesting elements of WiMAX, and the technologies behind it, is how they overlap with many existing communication networks it terms of coverage and speed. First, WiMAX is seen as a competitor to fixed broadband connections such as digital subscriber lines (DSL), cable modem, and fibre optic technologies. WiMAX equipment will likely be able to provide fixed wireless access comparable to lower-speed DSL connections (*e.g.* 256 kbit/s) over a wide area. DSL, cable and fibre will be able to provide much faster connections when wired infrastructure is already in place but WiMAX equipment may still be competitive with lower-speed wired connections. The lower per-user speeds of WiMAX equipment will likely rule out WiMAX connections for high-bandwidth consumer applications such as High Definition Television (HDTV) transmission.

WiMAX may also encroach on the mobile telephony and data markets that are currently serviced by mobile operators. WiMAX cells may be able to provide faster data connections to users than current 3G networks such as Wideband Code Division Multiple Access (WCDMA) and Code Division Multiple

Access 2000 – Evolution, data optimised (CDMA2000 1xEV-DO) that are capable of data rates of 2-2.4 Mbit/s shared among all users in the cell. Carriers are looking forward to future 3G enhancements such as High Speed Downlink Packet Access (HSDPA) and further revisions to CDMA2000 that may offer speeds closer to predicted speeds for WiMAX. While 3G networks will likely remain the most spectrally efficient for voice, mobile carriers may still see some voice traffic moving off traditional mobile networks and on to VoIP services over WiMAX networks.

Finally, WiMAX will also be partially substitutable for Wi-Fi connections. Wi-Fi can support faster speeds to individual users on the network but users are limited to a typical range of 100 metres. The development of a mobile WiMAX will likely have implications on Wi-Fi hotspot providers. If a city has ubiquitous WiMAX connectivity, Wi-Fi operators may move towards a more specialised role of offering higher-speed data connections in small geographic areas. However, the fixed version of WiMAX will be a good candidate technology for Wi-Fi backhaul.

Complementary and competitive technologies

WiMAX-certified equipment will not be the only choice for businesses, consumers and operators who need longer-range wireless connections. A host of other companies are developing wireless technologies and products that will compete directly with WiMAX in the market. Some of these technologies will likely be favoured by mobile operators over WiMAX since they can be installed via upgrades rather than through the rollout of new networks. The success of WiMAX will be intrinsically linked to the success of some of these competing technologies.

The evolution of 3G networks could pose a threat to the success of WiMAX. Many 3G operators have shown less interest in mobile WiMAX and are more interested in technological upgrades to their own networks that would enable them to compete with WiMAX. Third-generation mobile operators have incurred great expense to roll out new networks and the prospect of starting again with a new WiMAX network is not appealing. Operators will likely favour faster network upgrades of existing networks rather than the rollout of a parallel WiMAX network. Operators are hoping the transformation to high-speed wireless broadband on their networks can mimic the successful upgrades of CDMA2000 1x operators to higher-speed EV-DO technologies.

Third generation networks are currently delivering some higher-speed data in areas where they have been rolled out. However, the bandwidth available in a cell is shared by all users connecting via the cell. WCMDA and CDMA-2000 1x networks currently cannot offer the bandwidth predicted for WiMAX. However, upgrades to and evolutions of both these technologies are promising higher speeds, comparable to WiMAX, in roughly the predicted time frame for the rollout of mobile WiMAX equipment. The development of 3G networks and their evolution is discussed in much greater detail in the OECD report, *The Development of Third-Generation Mobile Services in the OECD.*[12] This section provides a brief introduction to just a few of these technologies.

Evolution of WCDMA: HSDPA, HSUPA, Super 3G

WCDMA operators have shown particular interest in a network upgrade called high-speed downlink packet access (HSDPA). HSDPA should be able to deliver 10 Mbit/s in a 5 MHz channel, which will be shared among users in the cell.[13] This is a considerable improvement over standard WCDMA networks capable of delivering 2 Mbit/s of connectivity to be shared within a cell[14] since network upgrades could provide the same amount of connectivity now to individual users.[15]

Another development that could increase the speed of mobile data is High Speed Uplink Packet Access (HSUPA) which would provide more symmetry between the uplink and downlink by increasing the capacity on the uplink side.

Japan's largest mobile carrier, NTT DoCoMo, has also been pushing a new standard called Super 3G that should be a lower-cost upgrade to existing WCDMA networks. The goal for the planned network is to offer 100 Mbit/s of downstream bandwidth with 50 Mbit/s of uplink capability. While the Super 3G predictions are impressive, their development and implementation are likely many years away. For example, DoCoMo has targeted the range of 2007-2010 as the timeframe for potential rollouts.[16]

The 3rd Generation Partnership Project (3GPP) Radio Access Network (RAN) working group has initiated a study item on long term evolution of the radio interface towards even higher data rates and capacity, including Super 3G. These technologies would be designed to coexist with 3G networks and would be deployable in bandwidths from 1.25 to 20 MHz, making it possible to introduce them gradually into existing GSM or 3G spectrum.

A key enabler for the increased performance is expected to be the use of multiple antennas at both base station and terminal. This is often referred to as "multiple-in, multiple out" or MIMO. At the same time, 3GPP's Services and System's Aspects Working Group 2 is already considering the evolution of the 3GPP network architecture with flexibility to accommodate multiple air interface standards.

HSDPA will offer faster connections to mobile phones but mobile operators are also very interested in leveraging their 3G networks for business data services. 3G data cards, typically built for a laptop's PCMCIA slot, are becoming more popular with business users who want outdoor or mobile access to the Internet at any given time. These dedicated data services will likely compete directly with mobile WiMAX.

Evolution of CDMA2000

CDMA2000 operators are also looking into ways to increase data speeds on their networks. The total data speed available on a CDMA20001x EV-DO network cell is roughly 3.1 Mbit/s in 1.25 MHz of spectrum. One potential upgrade could be a multi-carrier version of CDMA called CDMA2000 3x that would increase the size of the radio channels by a factor of three to increase speeds. Operators can also deploy up to 15 EV-DO carriers in a 20 MHz bandwidth and achieve data rates of up to 46.5 Mbps.

Mobile-Fi (IEEE 802.20)

Finally, one technology gaining a significant amount of attention is from another IEEE working group, 802.20, which is developing Mobile Broadband Wireless Access. The goal of the 802.20 working group is to develop a fully mobile, high-speed wireless standard from the ground up without having to work with legacy standards that were originally designed for fixed wireless connections (*e.g.* IEEE 802.16). The group has developed a set of technical requirements for a standard but is not yet considering any specific technical proposals. Backers of the technology include Flarion and ArrayComm. ArrayComm's iBurst technology has been commercially deployed in countries such as Australia and South Africa but some analysts have said the momentum behind WiMAX and the time required to develop the 802.20 standard will make it difficult for such technologies to gain significant market share.[17]

A list of mobile wireless technologies is given below in Table 1. WiMAX is represented by Korea's WiBro technology, even though details of how WiBro and 802.16e will be linked are still very vague. The table highlights the difficulties WiMAX proponents will face in promoting their technology over others. There is no "sure bet" for mobile data connectivity but WiMAX seems to have a good deal of momentum and interest from large telecommunication and computer industry backers. In addition, a successful rollout of Korea's WiBro network in 2006 should help increase the prospects for WiMAX worldwide.

Table 1. WiBro in Korea – A preview of mobile WiMAX

	WiBro	3G			WLAN
		TD-CDMA	HSDPA	EV-DO	802.11
Peak data rate					
Download (Mbit/s)	18.4	3.1	14	3.1	54
Upload (Mbit/s)	6.1	0.9	2	1.2	..
Bandwidth (MHz)	9	5 (10)	5	1.25	20
Multiple Access	OFDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CSMA/CA
Duplex	TDD	TDD	FDD	FDD	TDD
Mobility	Middle	High	High	High	Low
Coverage	Middle	Middle	High	High	Low
Standardization	TTA & 802.16e	3GPP	3GPP	3GPP2	IEEE 802.11x

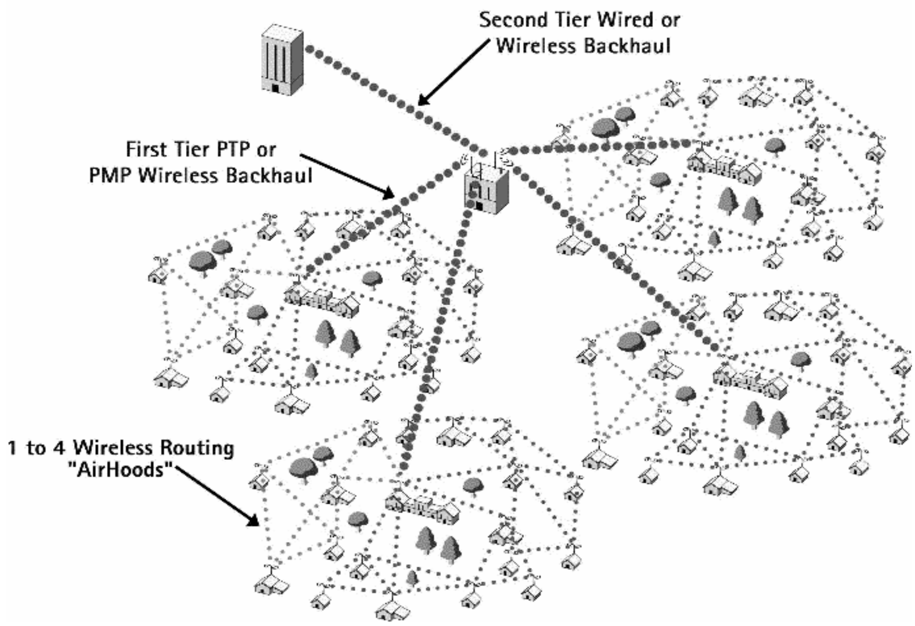
Source: Samsung Electronics - http://www.itu.int/ITU-D/imt-2000/documents/Busan/Session3_Yoon.pdf.

Interactions with Wi-Fi

WiMAX may enjoy a complementary relationship with Wi-Fi due to differences in the reach of each of the networks. WiMAX connections can be used to provide backhaul connections to Wi-Fi hotspots over longer distances. WiMAX could also play a key role in connecting Wi-Fi hotspots in a mesh-type network to quickly increase coverage and capacity (see Figure 2). Pre-WiMAX equipment is already being used to provide backhaul connectivity to moving trains in the United Kingdom and similar services have been announced in other OECD countries as well (see Box 2).

Figure 2. WiMAX as the backbone of meshed networks

Darker lines represent WiMAX backhaul lines to neighbourhoods. The lighter lines represent Wi-Fi connections between households.



Source: Nokia Networks – http://www.ieee.li/pdf/viewgraphs_wireless_802.pdf.

Box 2. Internet access on trains via WiMAX

Commuters in the United Kingdom taking trains on the 60 mile journey between London and Brighton will be able to access the Internet via a Wi-Fi connection on the train at 100 mph. Pre-WiMAX technologies will provide a backhaul connection to the train that will be distributed via Wi-Fi to passengers. The trains provide transportation to 8 000 commuters each day that could subscribe to T-Mobile's service as early as summer 2005. T-Mobile will charge GBP 5 per hour or GBP 13 per day for access.

In instances when the WiMAX connection is unreachable, the system automatically switches to General Packet Radio Service (GPRS) without interruption. The T-Mobile service provides an example of how mobile networks, Wi-Fi and WiMAX technologies can be complementary.

Sources:
http://www.t-mobilepressoffice.co.uk/press/uk/2005/worlds-first-broadband-Wi-Fi.htm
http://wifinetnews.com/archives/005134.html.

Typical Wi-Fi installations can accommodate 54 Mbit/s of bandwidth within a 100 metre radius and among 32 users. WiMAX implementations will likely provide a similar amount of total bandwidth spread over a much larger area to many more users. Therefore, users will have access to faster connections via Wi-Fi when it is available and will likely move to WiMAX or competing mobile technologies when out of range of a Wi-Fi signal.

In addition to offering higher bandwidth to individual users, Wi-Fi may also be the connection of choice, when available, for users of portable devices because of reduced battery drain. Wi-Fi cards and equipment communicate over short distances and thus require less power to transmit a signal than a WiMAX card which would need to connect to a distant tower.

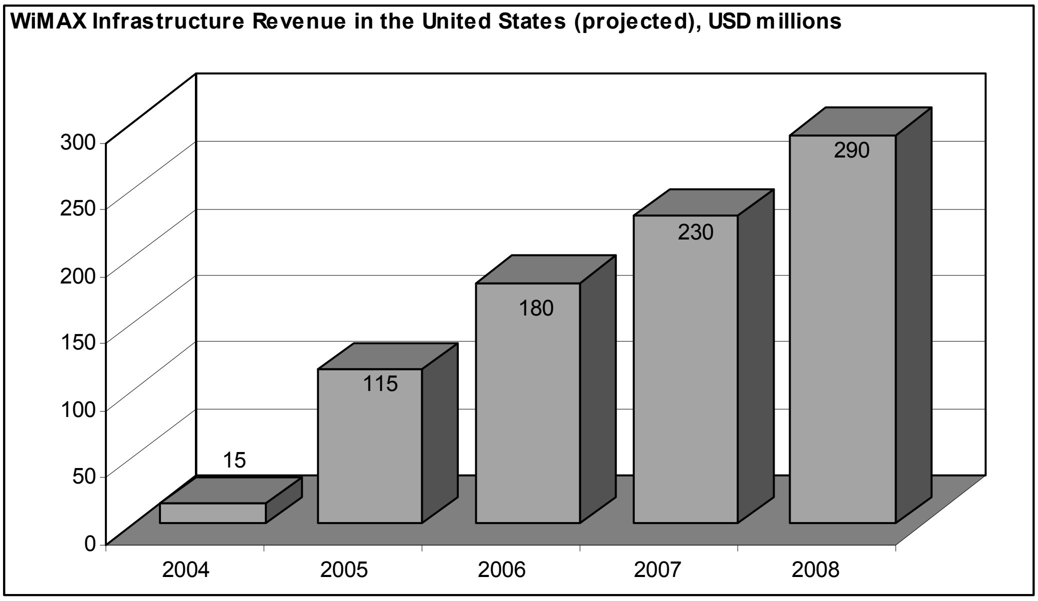
The interaction of WiMAX and Wi-Fi will most likely take place in the larger context of a converged network. Devices will connect to the fastest and most efficient networks available at any given time. When a device moves out of range of a current connection, it will search for the next most-effective connection for a handoff. Under a scenario such as this, WiMAX, Wi-Fi and 3G networks will be complementary technologies that simply serve different mobility demands.

The role of WiMAX

Despite all the excitement over WiMAX, the ultimate role of WiMAX in the wireless market is debatable. Large supporters such as Intel have a vision that WiMAX will change the way we all access the Internet in a matter of years.[18] The Telecommunications Industry Association (TIA) in the United States seems to support a positive view with their recent projections on the market size for WiMAX in the United States (see Figure 3).

Detractors claim that the economics of large-scale WiMAX networks are simply not justified.[19] Some point to a recent decision by Hanaro (Korea's second largest fixed-line broadband provider) to drop the WiBro license they recently won as an example of the market coming to terms with the difficulties.[20]

Figure 3. WiMAX infrastructure estimates for the United States



Source: TIA's 2005 Telecommunications Market Review and Forecast:
http://www.tiaonline.org/media/press_releases/index.cfm?parelease=05-24

One key area where WiMAX is likely to be successful is in providing higher-speed data connections to rural areas. The fixed-version of 802.16 should help rural communities obtain higher broadband speeds with lower infrastructure costs, a role very similar to that envisioned earlier for LMDS and MMDS[21], although the bandwidth and data rates are different. What will make the WiMAX rollout different is the level of support from vendors and the strong effort to standardise equipment.

Areas where the likelihood of WiMAX success is debatable will be the provision of DSL and cable modem-type broadband connectivity to households in previously wired areas as well as the delivery of highly mobile data services. DSL and cable modem networks are expanding quickly in OECD countries and offer higher speeds per user than WiMAX will be able to accommodate. Mobile WiMAX will also face stiff competition from mobile phone networks as higher-speed 3G data technologies evolve.

The uncertain road ahead

WiMAX technologies have undergone several transformations from their conception as fixed-wireless access technologies to nomadic/mobile technology. The standard has had to adapt to fit the changing demand of consumers and the working group has accommodated the demand for mobile connectivity through the founding of the IEEE 802.16e working group.

Some analysts believe that the largest market for WiMAX will arguably be nomadic and mobile access, which will be provided by IEEE 802.16e in several years time. This would leave the fixed-wireless WiMAX equipment (on the verge of certification) with a limited market, mainly in rural and less developed areas or as a backhaul connection for carriers. Businesses are thus faced with the difficult task of deciding when to implement IEEE 802.16 technologies. Equipment for the current standard (802.16-2004) began its certification process in July 2005 but there is a lack of clarity on how and if this equipment will be upgradeable to the mobile version of the standard when it is ratified.

Originally the mobile and fixed versions of the standard were to use the same physical layer, allowing most upgrades to be accomplished by means of a software update. However, the 802.16e working group recently allowed the integration of Korea's wireless broadband standard "WiBro" as an element of the standard, and along with it another physical layer (the actual physical method of sending data). This introduces another layer of complexity for the upgrade process from fixed to mobile access.

It looks as if some operators will withhold purchasing and implementing WiMAX equipment until the mobile versions are ready. However, other operators are hoping that by investing in fixed WiMAX equipment now, they can build a subscriber base on a network that could be upgradeable to 802.16e when the standard is ratified. Operators may also be concerned that early "pre-WiMAX" operator and consumer equipment may require substantial set-up costs and effort, which could in turn hinder widespread adoption by consumers.

Another issue that carriers have been concerned with is quality of service (QoS) on 802.16 networks. The initial 802.16-2004 standard includes QoS but does not include definitive instructions on how it should be implemented. The inclusion of QoS will be necessary to guarantee clear streaming of video and audio, including voice. WiMAX does leave open the ability to implement QoS at the media access control (MAC) level[22] (where data packets are encoded and decoded into bits) but this is left up to equipment manufacturers that may or may not adopt QoS solutions that work with equipment from other manufacturers. Any incompatibility between providers will reduce some of the benefits of competition among equipment manufacturers.

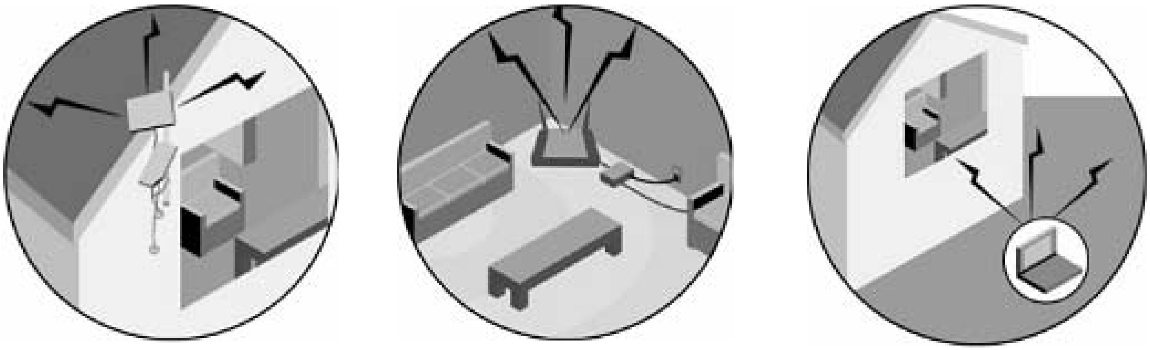
Status of rollout

Despite confusing claims of several manufacturers and operators, in May 2005 there was no WiMAX-certified equipment on the market. Certification testing started in July 2005 with the first WiMAX equipment expected to arrive in the fourth quarter 2005.[23] One of the standards behind WiMAX, IEEE 802.16-2004 has been standardized and some manufacturers such as Alvarion, Airspan, Redline, Towerstream and Radioland are selling "pre-WiMAX" or "WiMAX ready" equipment based on the standard, although as of yet, no equipment has been certified as WiMAX compliant. Eventually this equipment could be brought into compliance via a software or hardware upgrade. For some equipment manufacturers, the rush to put equipment out in the market has been so great that they formed their own groups to do initial interoperability testing and resolve problems before the official testing began in July 2005.[24]

The rollout of WiMAX-certified equipment will arrive in stages (see Figure 4). The first WiMAX-certified equipment will be for fixed wireless systems using the current 802.16-2004 standard. Equipment manufacturers will likely start by offering a combination of tower equipment for operators and outdoor residential equipment that could be mounted on the side of a house or an apartment. This equipment should be available in mid 2005. In the second stage equipment will likely move indoors, but remain "fixed" in one location. Mobility will arrive in the third certification stage. With the development of 802.16e, WiMAX services should finally be available from nomadic/portable devices such as laptops, smart phones, and PDAs as well as car navigation systems and other non-traditional devices that could make use of a mobile Internet connection. Korean operators hope to have this type of mobile network operational in 2006.

There was progress towards the development of WiMAX-certified equipment in April 2005 when Intel and Fujitsu both announced they had completed chips that will be the heart of consumer and business WiMAX equipment. Both companies have produced "systems on a chip" that handle multiple functions in an effort to keep down the cost of end-user equipment. The chips are both based on the 802.16-2004 standard. Intel's chip, "Rosedale" is built for customer premise equipment (*e.g.* devices for homes and businesses to connect to WiMAX networks).[25] Fujitsu's chip, the MB87M3400, targets the same market and level of functionality.[26] Fujitsu and Intel's chips are not the first 802.16-2004 chips to reach the market but their entry as market leaders means prices should stay low as output grows.

Figure 4. The evolution of consumer WiMAX devices



Source: Intel.

REGULATORY ISSUES

The introduction of a new set of technologies, such as those underlying WiMAX, often has regulatory implications requiring the attention of regulators. To some, WiMAX is a complementary wireless technology to existing 3G, WLAN and wired broadband networks. For others, WiMAX is believed to be more of a disruptive technology capable of crossing over into existing markets. Either way, WiMAX and competing wireless technologies could be key components of a future converged network. As such, regulators need to be actively observing developments of the technology and keeping abreast of regulatory changes in other countries. Doing so will help prepare national policy makers for the discussions and debate that will eventually reach all OECD countries.

This section attempts to pull together information from all 30 OECD countries on their challenges and successes with planning for market changes resulting from WiMAX. It will examine several key regulatory issues that will be raised by the evolution of WiMAX and similar technologies. These include spectrum management and allocation, the mobile vs. fixed debate, competition policy, the evolution to next generation networks and the contrasting ideas of technological neutrality and harmonisation.

Spectrum

Many factors will influence the success of wireless networks. Key factors include the availability of spectrum, equipment performance, equipment cost, infrastructure costs and customer penetration and take up. In addition, conditions or restrictions on how spectrum can be used will play a role in the success of new wireless technologies. This section will examine the rules governing the use of spectrum for the equipment behind WiMAX and restrictions on spectrum use that could limit services in some markets.

Allocation

Many credit a nearly globally-unified spectrum band at 2.4 GHz for the success of Wi-Fi. The harmonized spectrum band has allowed equipment manufacturers and consumers to benefit from economies of scale, effectively increasing supply and lowering prices for equipment. This has largely been made possible since the equipment has been largely designed for indoor license-exempt use at low power levels. Spectrum used for WiMAX deployments may prove to be less harmonised.

From the start, the technologies under consideration for the first round of testing by the WiMAX Forum use multiple frequencies to accommodate a wide variety of regulatory regimes. The WiMAX Forum selected three initial spectrum bands for WiMAX-certified equipment which include the 2.5 and 3.5 GHz ranges and license-exempt spectrum at 5 GHz (see Table 2). Other frequencies will likely be included in later testing phases.

Table 2. Key WiMAX Frequencies

Frequency	2.5 GHz	3.5 GHz	5.8 GHz
Allocation	Licensed	Licensed	Unlicensed/Light licensing
Countries	US Mexico Brazil Southeast Asia Korea (2.3 GHz)	Most countries	Most countries
Target	Operators	Operators	"Grass roots" ISPs

Source: WiMAX Forum.

Much of the success of WiMAX hinges on the ability of operators to find appropriate and available spectrum. However, without a globally recognized frequency band, the economies of scale will be reduced.[27] The designers of the 802.16 standards have tried to mitigate some of these issues by reducing the minimum amount of spectrum required for a channel, essentially making it easier to find bands of spectrum among existing allocations. In IEEE 802.16, channel sizes can range from 1.75 MHz to 20 MHz. In contrast, Wi-Fi requires channel sizes of 20-22 MHz and typically operates in the 2.4 and 5 GHz ranges.[28]

The World Radio Conference (WRC) in 2000[29] designated the 2.5 to 2.69 GHz range for IMT-2000 but a few OECD countries have spectrum in that range that could be used for wireless broadband technologies such as WiMAX. In the case of the 3.5 GHz bands, operators can usually choose a technology to implement on the given frequencies. Many of these initial frequencies were set aside for earlier wireless broadband technologies that found little success. However, now the development of 802.16 has led to a renewed interest in their development.

While many countries have specifically licensed systems for fixed wireless access (FWA) in the 3.5 GHz band, others such as the United States and Mexico have allocated the spectrum lower at 2.5 GHz for fixed and mobile broadband services. For example, Mexico has allocated the 2.5 – 2.69 GHz band for MMDS and MDS (restricted TV and Wireless Internet Access) services.[30] Korea's new WiBro technology will work in the 2.3 GHz band that should be encompassed by the first round of testing for the 2.5 GHz band.[31]

The success of commercial fixed and wireless technologies in the 3.4 - 3.7 GHz and 5.8 GHz bands, could be limited by continued worldwide operations of high powered radars in these bands. Successful implementation of mitigation techniques, low power levels and other operational restrictions may prove advantageous to commercial viability of these systems when sharing with radars. In July 2005, the European Commission agreed that the 5.150 – 5.350 GHz and 5.470 – 5.725 GHz bands could be used license free under the condition that equipment must use mitigation techniques such as Transmitter Power Control (TPC) and Dynamic Frequency Selection (DFS) to prevent equipment from interfering with other uses such as military radar systems.[32]

Finally, some operators are rolling out pre-WiMAX equipment in the license-exempt 5 GHz range, specifically 5.8 GHz. This may be an inexpensive solution for rural areas with low population densities and little competing uses for the spectrum. However, the use of the license-exempt bands for paid services is not without risk. Typically, services in license-exempt bands must tolerate interference from other non-licensed usage which can slow down or otherwise disrupt transmissions. Services offered to businesses and consumers may slow down considerably, or even fail to work, in the presence of new systems deployed by new entrants using the same frequencies.

For example, if a rural wireless provider chooses to offer wireless services in the 5.8 GHz range, a competitor would be allowed to set up identical equipment using the same band and likely cause interference. In some markets, the first provider in the area makes use of the license-exempt spectrum under the assumption that competitive entrants will be discouraged at the prospect of interference to their own services from having to share spectrum with the first mover. While competitive operators may be free to use the license-exempt spectrum, its use by the original operator creates a barrier to entry and disincentive to invest in competitive infrastructure.

This will be important for regulators who must struggle with conflicting goals of providing initial connectivity and fostering competition. Allowing the use of unlicensed spectrum for rural network operators serves the purpose of expanding connectivity to areas that were previously unserved. This essentially lowers the barriers of entry for the first entrant in the market because there are no costs to spectrum use.

The trade off is that once the spectrum is occupied by a provider, the entry of additional operators becomes more expensive. Either they choose to operate in the same spectrum, with potentially large reductions in service quality for both operators, or they must obtain licensed spectrum. In urban areas, competition for broadband connectivity often comes from both wired (DSL, cable) and wireless operators. However, in rural operators, often the only choice is a wireless provider.

Another consideration for the use of unlicensed spectrum is that government regulators typically limit the amount of transmission power permitted in such bands. This limitation is especially important at 5.8 GHz, where the higher power could offset the propagation loss associated with spectrum in higher frequencies.[33]

Finally, some have argued that lower frequencies are better suited for rural areas than the 5.8 GHz band because of their propagation factors. This has stirred interest in adapting lower, unused television frequencies for wireless broadband use. Some broadcasting licensees have asked governments to carefully consider any proposals so as not to inadvertently cause interference to adjacent television broadcasts.

Spectrum and mobility

When people talk of WiMAX as a disruptive technology, often they are referring to the impacts WiMAX is likely to have on traditional fixed and mobile telecommunication networks. WiMAX may very well prove disruptive to traditionally telephony if it is able to provide fixed and mobile voice services to data subscribers via VoIP.

Some fixed line operators without their own mobile networks have shown interest in the technology as a way to enter into the mobile voice market which has been slowly eroding their customer base. Mobile operators, on the other hand, are cautious with any new technology that does not provide interoperability with their existing network and that could threaten to erode the value of their large investments in 3G networks. Indeed, much of the success of WiMAX – particularly the mobile variant – may depend on the implementation of voice services over WiMAX.

While the forthcoming IEEE 802.16e standard promises high-speed mobile data access there are still limitations in many OECD countries on how the technology could be used in a given spectrum band. The 5 GHz band is open for license-exempt use in some countries but the high frequency ranges make it more suited to fixed broadband access than mobile services. Therefore the 5 GHz ISM band (5.725 – 5.850) will be better suited for grass-roots wireless ISPs which offer point to multipoint fixed access.

The second frequency range that will be covered by the initial WiMAX certifications is the 3.5 GHz band. International Radio Regulations allocate the 3.4 – 3.6 GHz band to several services on a primary basis and high-powered radars operate throughout the world in this band. In many OECD countries the 3.5 GHz band has been allocated for fixed-wireless uses which make it optimal for licensed WiMAX use.

However, the 3.5 GHz band is limited to fixed implementations in many OECD countries and thus may not be exploited to offer services that are perfectly substitutable with mobile telephony without regulatory changes. In Sweden for example, the 3.4 GHz to 3.6 GHz range has been opened for technologically-neutral fixed wireless access but mobility is allowed only within the same cell. Seamless handovers between base stations are not permitted. The United Kingdom has similar restrictions where the 3.5 GHz and 5.8 GHz bands are limited to fixed operations, although the regulator, Ofcom, is working to ease these restrictions. Ofcom has stated,

> "... [it] should in general be willing to remove licence restrictions as soon as practicable that prevent the use of spectrum for mobile services other than 3G services, where it is possible to do so under law and subject to interference constraints and international obligations. Other considerations may also be relevant in some cases, including the terms on which certain licences were recently auctioned.[34]"

Technologies operating in frequency bands where mobility restrictions are in place will serve as competition more to DSL and cable modem services than mobile.

Box 3. Nomadic connectivity via pre-WiMAX equipment

Equipment manufacturers have recently introduced pre-WiMAX PCMCIA cards for laptops that could be used for nomadic access, but not for full mobility.[35] Navini networks recently introduced a wireless PCMCIA card that works in the 3.5 GHz range. This card, and those offered by competitors, will be the first step towards nomadic access within range of a WiMAX signal.

Source: Navini.com, http://www.navini.com/pages/press/2005/pr04.06.05.htm.

Finally, the 2.5 GHz bands (and 2.3 GHz in Korea) offer an opportunity for voice over WiMAX in countries that have not set aside the band, or large portions of it for other services. The Korean technology WiBro will offer speeds fast enough to support VoIP to users on mobile devices at 2.3 GHz. Countries such as the United States and Mexico have licensed spectrum to operators in the 2.5 GHz band that could potentially be used to offer voice. In the United States, the 2.5 GHz band was licensed for use by MMDS technologies and is now also available for mobile services. Licenses in this band have been acquired by companies such as Clearwire to build future WiMAX networks. Under US rules these operators could provide voice or data, mobile or fixed services.

The three initial spectrum ranges that will be tested for WiMAX equipment and the regulatory situations in many countries may not lend themselves well to the provision of mobile Voice over WiMAX (Vo-WiMAX). WiMAX technologies may not be used in many OECD countries in the 2.5 GHz range unless WiMAX eventually is accepted under the IMT-2000 umbrella. However, members of the WiMAX forum such as Intel are pushing regulators to make more spectrum available, particularly in the sub 2 GHz range.[36] Of particular interest is spectrum beneath the 1 GHz range that could be made available for wireless broadband with the move from analogue to digital terrestrial television.[37]

WiMAX and 3G

The technologies behind WiMAX will be capable of providing VoIP services to mobile and nomadic devices. 3G technologies will remain much more efficient in the use of bandwidth for voice transport, but WiMAX subscribers may still choose to use voice services over their data connections. The extent to which services such as Vo-WiMAX appear in the market will depend largely on regulations governing how the spectrum can be used and whether WiMAX providers have the ability and are allowed to offer services at high levels of mobility.

Some regulators have borrowed various definitions of mobility from the ITU-R Recommendation M.1034-1 as a way to clarify which types of mobility are allowed in certain spectrum bands. The Recommendation differentiates between different degrees of mobility including: stationary (0 km/hr), pedestrian (up to 10km/hr), vehicular (up to 100 km/hr) and high-speed vehicular speeds (up to 500 km/hr).[38] Regulations in several countries restrict wireless broadband technologies such as WiMAX to stationary and pedestrian speeds, making the networks unreachable in public transport or other moving vehicles. These restrictions effectively limit the ability of WiMAX providers to offer voice services at high speeds, similar to those possible from 3G networks.

These restrictions seem to run contrary to the ultimate competitive goals of regulatory agencies in the OECD that have shown a keen interest in fostering innovation of services such as VoIP. In the European Union (EU) for example, the European Regulators Group wrote on the subject of VoIP:

> *"The regulatory approach to VoIP in Europe under the European regulatory framework for the benefit of consumers should enable the greatest possible level of innovation and competitive entry in the market, whilst ensuring that consumers are adequately protected.*[39].

The European Regulators Group statement highlights the goal of fostering innovation and competitive entry into telecommunication markets by VoIP providers. At the same time, the statement points out that the regulatory framework must protect consumers, typically through access to emergency services and standard levels of quality of service. The effect of VoIP, in many markets, has been to reduce prices of both Public Switched Telephone Network (PSTN) and VoIP calls. However, the regulatory situation becomes more complex as VoIP services start to encroach on markets typically served by mobile operators.

Mobile operators in many markets paid for 3G spectrum on the assumption of a certain number of competitors in the market equal to the number of licenses offered. Under this system, governments also benefited from the licensing fees they received. Third generation networks are in operation in many OECD countries but operators in some countries are just starting to introduce services. Mobile operators point out that the introduction of a lower-cost competitor to 3G data-type services could severely limit the abilities of mobile network operators to pay for planned investments. This dilemma puts regulators in a difficult position of balancing innovation in the market and also helping ensure the successful rollout of 3G networks.

The evolution of mobile or nomadic VoIP can be seen with the move towards its use on Wi-Fi enabled PDAs. Popular VoIP providers such as Skype and Vonage have applications that run on PDA platforms. This allows users to place and receive calls anytime they are near an accessible Wi-Fi access point. Usage has been fairly limited due to lack of Wi-Fi coverage and the short battery life of devices. However, the usage patterns do show a likely evolutionary path for Voice over wireless connections.

Current licenses in Europe in the 3.5 GHz range will be available for fixed broadband access but unavailable for mobile services without a change of the restrictions on the band. There may be good reasons why the fixed requirements have been introduced but nevertheless, the results are barriers to entry for innovative wireless providers who may want to provide competitive mobile services.

Technological neutrality

As mentioned above, one of the issues regulators must face is technological neutrality as it pertains to spectrum use. Clearly there is some spectrum that is better suited for certain applications than others, such as lower frequencies for longer range communications. In the past, spectrum authorities have made considerable effort to ensure that assigned spectrum was actually used for the purpose envisioned by the initial license as a way to foster the development of a particular application or technology. Successful examples include GSM, IMT-2000 and TV standards. However, policy makers in some OECD countries have moved away from technology-specific spectrum allocations as a way to anticipate rapid technological change.

The development of WiMAX-type technologies was not clear when 3G spectrum was allocated in many countries. Mobile operators obtained licenses, and in some cases have been unable to roll out networks under the prescribed time schedule or adhere to coverage requirements set out in the license. For some operators, the economics of deploying a new 3G network may not be as firm as they would like.

In can be envisaged that some firms with currently unused 3G licenses may be interested instead in using their frequencies to offer WiMAX coverage that can be built onto existing cellular infrastructure to offer broadband access and VoIP services. The 2 GHz range allocated for most 3G networks is also optimal for WiMAX networks. The same may be true for some fixed wireless spectrum holders that would like to use spectrum for future mobile WiMAX in the 3.5 GHz band for example. At the same time, other telecommunication operators have expressed the preference to deploy harmonised solutions for the benefits of roaming, inter-operability and economies of scale.

For regulators, any significant technological changes to the original licenses may pose problems if operators were required to fulfil certain obligations tied specifically to their networks. This is often the case with third-generation licenses in particular. A decision on whether to allow the transformation of a license will need to be made for each specific circumstance. However, the trend towards more liberalised spectrum use, including spectrum trading, and technologically neutral spectrum allocations may offer the best chance for the market to quickly adapt to the ever-changing and evolving communications market, even if there is also the potential for reduced harmonisation and economies of scale.

The need for market flexibility is well highlighted by some experiences with wireless local loop licenses in the late 1990s. At the time, wireless local loop (WLL) technology was predicted to be highly disruptive to local access markets. However, due to a range of factors including higher-than-expected operating costs, WLL licensees were unable to establish profitable networks and, in some cases, the allocated spectrum has remained unused since.

Previous OECD work has shown that liberalisation of spectrum use and spectrum trading can have considerable benefits. They enable the market to decide how much spectrum should be allocated to different uses; enable faster flexible access to spectrum, including unused and underused spectrum; help to promote the development of new, spectrum efficient technologies; and boost innovation in the use of the spectrum and spectrum-based products and services.[40] It is worth noting that critics of secondary markets and technological neutrality point to recent successes with harmonised spectrum and the benefits from economies of scale that they may allow.

Secondary markets could provide a mechanism for operators to obtain licenses for use by WiMAX technologies if they were not previously awarded a license. In addition, liberalised spectrum use could allow operators to buy underused spectrum in alternative bands to convert for wireless broadband use. Finally, secondary markets would also ensure that those spectrum bands are not put at risk of non-use if WiMAX technologies do not succeed in the market.

Quality of service

Network quality of service is determined by both physical and market characteristics. On the physical side, connection quality will be related to the distance of the terminals from the transmitter and the amount of interference in the frequency band. On the market side, increased competition among telecommunication providers typically leads to increased quality of service as operators struggle to attract and maintain customers. Most quality of service issues are typically resolved quickly and efficiently in well-functioning markets. Problems can arise in cases where products offered are significantly differentiated or consumers are locked into contracts for extended periods of time. Several aspects of quality of service will be very important for regulators as WiMAX technologies begin to appear on the market.

Port blocking and traffic structuring

Several non-OECD countries, such as Panama and Egypt have experimented with port blocking as a way to protect the legal national fixed-line monopoly from customer migration to voice over IP technologies.[41] These efforts have largely failed with VoIP users finding ways around the blockages and a strong negative reaction from the public. Port blocking has recently emerged in the OECD as an anti-competitive tool by ISPs to prevent consumer access to competing services. Typically claims of port blocking are tied to the provision of VoIP or video services that compete with those offered by the operator.

VoIP blocking has recently become an issue in the OECD. Recent cases include Madison River Communications LLC in the United States which was accused of blocking ports commonly used for VoIP by a stand-alone VoIP provider. The FCC examined the complaint and the company agreed to settle the case for USD 15 000. The case provided an initial glimpse into challenges that await regulators throughout the OECD. The FCC quickly resolved the port-blocking complaint in the United States but there are more complicated questions that will surely need to be addressed with both port blocking and "traffic structuring."

Box 4. Blocking ports

The most common Internet protocol used to initiate connections between different computers on the Internet is Transmission Control Protocol (TCP). A TCP connection between two computers is made by way of an Internet protocol (IP) address and a destination port on the computers. The IP address is comparable to a physical address of a post office while a port would be a post office box inside the building. Internet applications make use of predictable ports to initiate communications. For example, Web servers such as www.oecd.org allow for incoming requests on port 80. Web browsers attempt to display a web page by contacting the Web server's IP address with a specific request to port 80. Major Internet applications use different ports which are managed by the Internet Assigned Numbers Authority (IANA) (http://www.iana.org/assignments/port-numbers). Operators can often effectively *disable* an Internet application by disallowing traffic requests to certain ports on their networks that are required to be used by the application.

Traffic structuring is less overt than port blocking because it can take advantage of the underlying structure of the Internet protocols. Traffic flowing across the Internet is typically handled on a "best effort" basis.[42] This is a feature of the Internet's routing architecture that essentially tries to send data from one computer to another over the most efficient route. Typically all Internet traffic receives equal priority on a first-come-first-served basis with no guarantee of delivery. As a result, applications need to use error checking and request any packets that may not have arrived. The architecture was designed, and works best for less time-sensitive applications such as e-mail and file transfer protocol. This is because packets are not sent over a dedicated channel and may arrive out of sequence or with a slight delay. A delay of a few seconds makes little difference to e-mail users but can completely disrupt a phone conversation using VoIP or a data stream of a live event.

As Internet applications have evolved so has the need for data streams that offer a higher level of quality than simply "best effort". Certain data such as digitized voice requires near-instantaneous transmission while e-mail can encounter short delays with negligible effects for the consumer. As a result, network engineers have struggled to improve the reliability of voice and data services on the Internet by using protocols such as User Datagram Protocol (UDP) or developing solutions to create dedicated "channels" on the existing infrastructure such as Multi-protocol label switching (MPLS). The end result is a network where certain transmissions can be given priority over others.

Network operators are able to attach "flags" to data packets that are then read by routers and given priority on the network. The router can essentially give first transit priority to data packets that have the appropriate tag while temporarily holding back packets that arrive without the tag until all flagged packets are sent. The packets are queued according to a multilevel priority structure called class of service (CoS). Voice and video packets are given higher priority than simple file transfers or e-mail. Traffic from other users on the same network can also be given a priority ranking over traffic coming from an outside source.

The result is network operators could give priority to traffic from their network services over the traffic of other services not originating on their network. Network operators have argued that such techniques simply introduce higher levels of quality of service for video and voice services on their network without affecting the quality of "best effort" transmissions. They also emphasize that the vast bandwidth of high-speed fibre and newer broadband technologies means there should be no slowing of non-flagged packets.

Critics counter that "speeding up" the traffic for the operators' services will necessarily slow down the traffic of competitors.[43] Competitive providers have complained that as the volume of flagged traffic and the percentage of bandwidth dedicated to same-network services increases, the quality of service for best-effort transmissions on the remaining open bandwidth will decidedly fall. Introducing quality of service for voice, video and other time-sensitive services will be important to the development of these services. At the same time, techniques to improve the quality of one service could have a detrimental effect on competing services, raising anti-competitive concerns.

Experts claim that traffic management techniques will be used on all types of networks, fixed and wireless as a way to offer users differentiated levels of service.[44] However, their implementation will have particular importance to regulators on wireless networks where spectrum is limited. Typically, a well-functioning, competitive market should reward firms that maintain good services all around and "punish" those where certain services aren't available to consumers. The effectiveness of this market will be largely determined by the number of WiMAX operators who have the ability to provide services. Without competition between WiMAX operators, traffic management strategies could curtail competition for certain time-sensitive applications.

Regulators in the OECD are likely to encounter port blocking and traffic slowing of VoIP services first, as the VoIP industry is quickly maturing. However, the same questions will be even more pronounced on wireless networks with the development of video services provided over WiMAX. As bandwidth is constrained on wireless networks, operators have a strong incentive to ensure that video traverses the network in the most cost-effective way possible. Bandwidth-intensive content from competitive providers may be a much bigger issue for WiMAX operators than VoIP, where bandwidth usage is minimal. Certainly buffering techniques which could not be used for voice can help mitigate some of the best-effort traffic problem for video.

The trend to give differing levels of priority to local content is not new in the OECD. In Australia, subscribers to Telstra's BigPond Asymmetric Digital Subscriber Line (ADSL) service typically have usage bit caps between 200 MB and 20 000 MB per month[45] but traffic to and from certain sites is not included in this cap. BigPond maintains an "Unmetered Sitelist[46]" that includes Telstra internal Web sites, BigPond Web channels and links to the sites for the Australian Football League. Telstra's business plan is to offer incentives for users to stay on the network for multimedia but still allows competitive video traffic to traverse the network.

The questions facing regulators are complex. Operators point out that their services are part of a package and consumers are free to choose among competing broadband operators based on the "package" of services they can receive. Critics claim that stand-alone VoIP and video providers are effectively discriminated against if they do not have their own networks.

Box 5. Port blocking and VoIP

The terms of service agreements offered by wireless ISPs have recently drawn the attention of authors who are afraid they can be used to block competing services on their networks. Articles in the WiMAX press have recently looked at how wireless broadband providers have retained the right to block usage of high-bandwidth applications on their networks.[47] These statements have been used in the past to limit access to excessive bandwidth users, particularly large-scale peer-to-peer users. Recently however, some have questioned whether outside VoIP connections could be interpreted as high bandwidth and blocked on the network.

The classification of VoIP and video streaming as high-bandwidth uses could limit competition for these services on WiMAX networks in the future. In a market with effective competition, market forces create a situation where ISPs could attract users by allowing high-bandwidth uses. However, WiMAX networks in rural areas may be the only broadband choice for consumers and blocked and video or voice services from competitors would severely limit competition.

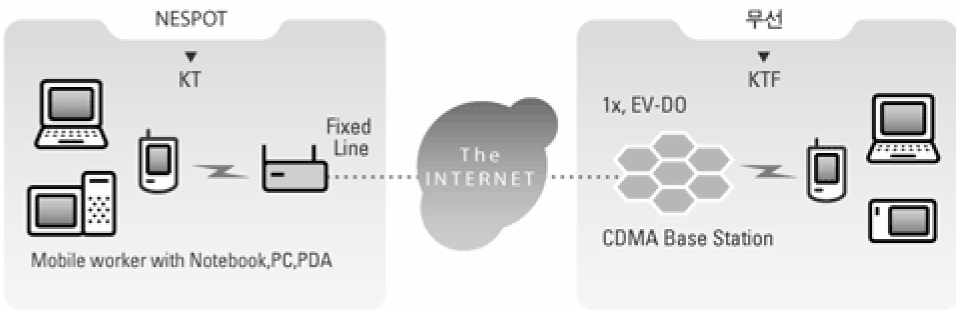
Next-generation networks

WiMAX technologies may be an important component of future converged or ubiquitous networks due to their reach and relatively high-speed wireless connectivity. WiMAX and competing longer-range technologies could certainly be one component of a multi-platform network that allowed users to have access to a seamless, always-on Internet connection. The implementation of WiMAX in a converged environment may be several years away but elements of converged networks have started to appear in OECD countries. Proponents claim the trend is likely to continue when mobile WiMAX devices appear on the market while sceptics are unsure of the impact of WiMAX in the future market.

The line between different types of broadband access networks is blurring with the introduction of services that work seamlessly across platforms. In Korea, KT's Nespot Swing service provides continuous data coverage as a subscriber moves between KT's Wi-Fi network "Nespot" and the CDMA 2000 1x EV-DO network of KT's sister mobile network, KTF (see Figure 5). Users are automatically shifted to the most efficient network via a process where devices first attempt to connect via Wi-Fi (at home or from a public hotspot), and if a signal is not available connect via 3G. Figure 5 shows how the same mobile devices will maintain connectivity either via Wi-Fi from KT or the CDMA 3G network from KTF.

Figure 5. Converged Wi-Fi and 3G data networks in Korea

The network can offer continuous connectivity when moving between Wi-Fi and 3G networks



Source: http://www.nespot.com/web/swing/swing_intro.html

In the United Kingdom, BT's Project Bluephone has plans to offer a phone that works as a cordless handset on a fixed line at home (via Bluetooth) and as a Global System for Mobile Communication (GSM) phone when out of range of the home connection. Operators have been working on developing seamless handoff technologies that work between disparate networks in order to make these kinds of services possible.

While network operators are working to seamlessly bridge together their fixed and wireless networks, application providers have already announced streamlined services that are platform independent. Skype, the IP telephony provider, currently builds client applications for use on a wide range of PC operating systems and portable devices. Skype users can currently make phone calls via desktops, laptops and pocket PCs. However, Skype also plans to release a version of their software for Embedded Linux, Symbian or Windows Mobile devices later in 2005[48]. These versions could then be made available on mobile phones over a GPRS, 3G or Wi-Fi data connection. An example of this trend was the announcement by equipment manufacturer Motorola of an alliance with Skype in February 2005 to work towards integrating Skype functionality into Motorola products.[49]

Both fixed and mobile WiMAX technologies may be important components of any converged network, although each will play a different role in the infrastructure of the network (see Figure 6). Fixed WiMAX technologies will provide similar connectivity to DSL and cable modem technologies, although DSL and cable will provide faster speeds in urban areas. In an economic sense, DSL and cable modem networks will likely be more cost effective per Mbit/s of connectivity where they are already in place. Some claim that rural and remote areas stand to benefit the most from fixed WiMAX deployments and that holds true in a converged setting.

Operators will maximise the efficiency and profitability of the next-generation network (NGN) by moving users to the most cost-effective network that will support their current demands at any given moment. As Figure 6 shows, operators will likely attempt to connect users via wired connections when possible, given their better cost effectiveness per bit of data transferred. When users require mobility, some believe that WiMAX will offer higher speeds and cost efficiencies per bit than 3G at all but the highest levels of mobility, while others believe that 3G will be able to accommodate those needs.

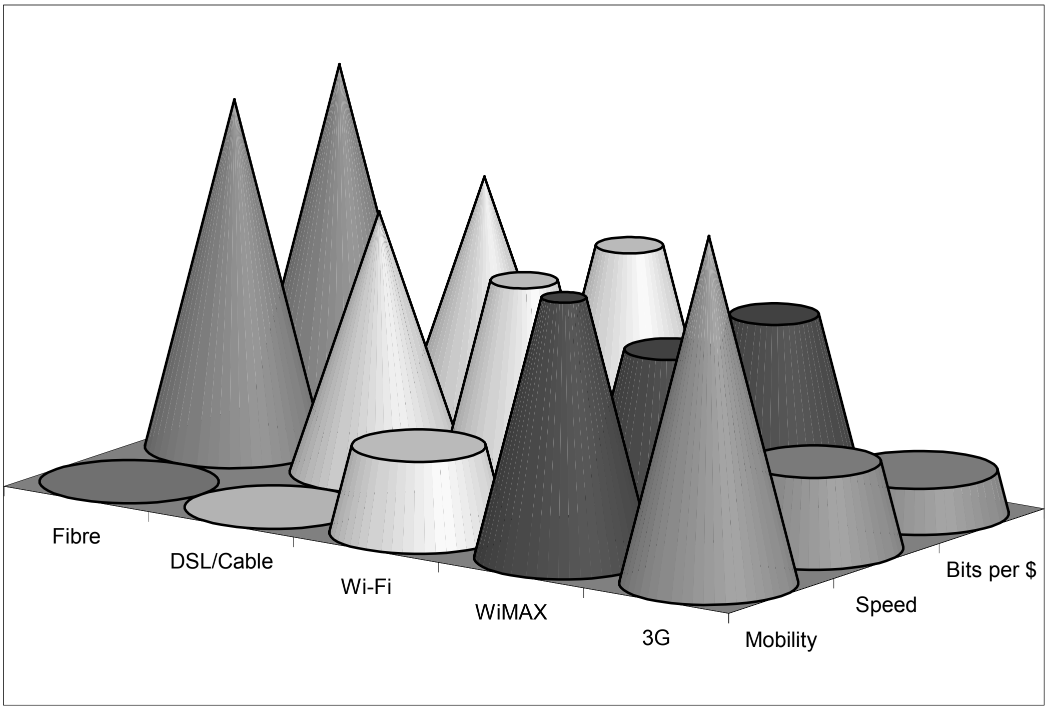
Converged networks will likely connect users via the least-cost bandwidth path that service their usage demands. In rural areas without other broadband options, WiMAX-to-the-home connectivity will likely play the major role in providing "multi-play" services including voice, data and video. In urban environments the role of fixed-WiMAX will likely be more as backhaul for Wi-Fi and other WLAN technologies.

The role of mobile WiMAX technologies may be the most profound in urban areas because they could fill a connectivity void between 3G data networks and Wi-Fi. 3G networks offer very high mobility but at low data speeds. Wi-Fi offers much higher speeds but in a nomadic setting within a range of 150 metres.

In a converged network, the mobile version of WiMAX may be the most efficient data connection for many users outdoors. 3G's more limited bandwidth will likely make it the network of choice for users who, at any given moment, require high mobility. For example, users in trains or moving vehicles may only have access to data provided over traditional mobile networks. However, users moving at pedestrian speeds may be best served by mobile WiMAX connectivity.

Figure 6. The role of WiMAX among other broadband technologies

Higher cones represent better performance in a given category.



If WiMAX indeed proves to be an essential component of NGNs, regulatory authorities will face challenges ensuring there are enough licenses to foster competition among NGNs. Operators with NGN ambitions could be severely hampered without a spectrum license for WiMAX or a similar technology to fill the demand for broadband mobility. Therefore, the allocation of spectrum that can be used for WiMAX-type technologies will likely have a profound effect on the evolution of next-generation networks in OECD countries.

The move towards converged networks that include WiMAX will also likely raise concerns on the level of competition in the market for converged services. The allocation of spectrum that can be used for WiMAX could be a significant determinant of the number of converged network operators in the market. Some predict that converged network operators relying solely on mobile networks for connectivity may be at a disadvantage in terms of cost-per-bit in comparison with operators with the ability to offer WiMAX-type services.

Interconnection

ISPs offering WiMAX connections will need the ability to interconnect to Internet exchanges, and likely to the PSTN if they are providing VoIP services. Governments have a role to play to ensure that new ISPs are allowed to interconnect to existing networks on similar terms and conditions as other operators. Any fixed-line and mobile operators that built WiMAX networks would already have interconnection arrangements in place. However, new entrants to the market would need to be able to pass on Internet traffic and route calls into the PSTN at competitive rates.

Security, privacy and safety

The security risks facing potential WiMAX users should be comparable to users on other wireless data networks. As with other wireless technologies, users with sensitive data will likely require multiple layers of security and encryption to keep data private. The security of the developing WiMAX standards has been under intense scrutiny since the discovery of a flaw in the implementation of Wi-Fi's encryption, Wired Equivalent Privacy (WEP). WEP's flawed 128-bit encryption can be broken within roughly three minutes using new techniques.[50] While certain security elements will be built into the 802.16 protocols, vendors may also offer additional protections as a way to differentiate their products.[51] Currently the technologies behind WiMAX use Data Encryption Standard (DES) or Triple DES (3DES), but a stronger encryption called Advanced Encryption Standard (AES) will be incorporated by the time full-scale commercialisation begins.[52]

One area where WiMAX may pose more security risks than Wi-Fi is the reach of the signal. The short range of Wi-Fi connections meant those wishing to eavesdrop on a signal, in most cases, had to be physically close to the structure. The market has responded with the development of special wall coverings for buildings that help block the leakage of Wi-Fi signals out of buildings.[53] However, the security risks to WiMAX users will be larger than Wi-Fi users due to the outdoor nature and long range transmission of the signals.

Surveillance

WiMAX and other wireless broadband technologies will likely be a key component in new surveillance networks and, as such, will require some oversight from government agencies to ensure privacy. Shorter-range Wi-Fi networks have been available to consumers and businesses wanting to keep an eye remotely on a given location. Commercial Wi-Fi cameras have been sold to consumers as a way to watch a child's room at home from an Internet connection anywhere in the world. Many even include security motion detectors that will record video and e-mail the file when the camera detects movement.[54]

A similar WiMAX-enabled video camera could raise additional concerns because it could be located within a 2 km radius of a base station, or anywhere within a city with blanket WiMAX coverage. The ability to conceal a camera somewhere in a city and receive a constant video stream over the Internet would raise privacy and security concerns that will need to be addressed.

There are also legitimate and valuable uses for a city-wide camera system. For example, WiMAX networks could link traffic cameras across a city to help route traffic around problem areas. WiMAX-enabled cameras could also be located in remote parking areas to provide extra security for late-night commuters.

Law enforcement

Law enforcement agencies in the OECD will likely need access to WiMAX networks as a way to deal with criminal activity. The issues of what data can be collected and how it is treated should be topics of discussions in governments. A simple wiretap into a WiMAX connection may also not provide the kind of information law enforcement need. VoIP providers are starting to provide end-to-end voice encryption that would make any interception (both legal and illegal) much more difficult. The issues become even more complex when the companies providing services are international and beyond the jurisdiction of national law enforcement agencies.

Safety

The introduction of mobile WiMAX may also bring with it additional safety concerns. For example, mobile WiMAX devices should be able to receive streaming video in moving vehicles at slower speeds. This would make possible the installation of WiMAX equipment in cars that would be capable of displaying video signals. Similar television systems for cars already exist today but the ability to stream data over WiMAX from personal video recorders could help increase their penetration. Many of these systems are located on the dashboard of the car and could be a serious distraction to drivers.

Another safety issue that regulators may need to address is radio frequency (RF) exposure to higher-power WiMAX equipment. Mobile WiMAX will likely require transmission power levels similar to mobile phone networks, although the longer distances they cover may require somewhat stronger signals. However, fixed WiMAX will likely operate at higher power levels and their placement in homes may be of concern to regulators. There may be no definitive conclusion to the effects of RF exposure from portable devices, such as mobile phones, but the issue is likely to be important to consumers of WiMAX equipment and communities where towers would be placed.

Universal service

The development of WiMAX and other wireless broadband technologies could have important implications for the future of universal service obligations in the OECD. The development of a lower-cost wireless solution to reach remote areas and households may eventually decrease the reliance on existing programmes.

Fixed WiMAX technologies should be able to effectively transport voice connectivity to areas previously out of range of existing networks. For example, wireless technologies could carry signals to remote areas with relatively few homes, areas where wired networks could prove too costly for operators under existing market conditions. Individual homes in areas with very low building density would have receiver equipment in order to receive voice and data connectivity. WiMAX could be used more as backbone infrastructure in areas where there are several dwelling units in closer proximity to each other with existing copper networks then used to distribute the WiMAX signal from the village centre.

Voice services could be delivered either as VoIP to end users via WiMAX or via traditionally circuit-switched means, with WiMAX simply providing backhaul transport deeper in the networks. However, one key question for regulators in the longer term is deciding when voice offerings using VoIP could be considered viable substitutes for traditional telephony in regard to universal service requirements. The rapid spread of broadband in the OECD has led to an increasing level of substitution from traditional PSTN connections to VoIP networks. However, consumer-level VoIP products are still in their early development stages and often can not offer the same levels of reliability as PSTN connections. Since conversations travel over a broadband connection, any disruption of broadband service, including power interruptions, will make VoIP unusable.

Another concern for regulators considering WiMAX as a tool for universal service provision will be the interconnection of VoIP calls to emergency service providers carried over WiMAX networks. The FCC in the United States has been examining ways for VoIP operators to interconnect to emergency call services (*e.g.* 911 services in the United States). Connecting these calls has posed significant challenges since telephone numbers are no longer necessarily geographically based. There has added a level of complexity for operators who must figure out how to connect calls to the appropriate emergency response department closest to the user. Typically, VoIP operators have relied on a "self-reporting" system where the user initially selects a location that is considered the "home base" to which emergency response crews can be sent. The difficulty of routing emergency calls is not new as regulators have examined how to facilitate effective routing of emergency calls from mobile phones to the appropriate local agencies. The development of VoIP over WiMAX networks will add an even deeper layer of complexity.

One area where the effects of WiMAX and traditional mobile networks will differ in terms of universal service is the provision of broadband. Work done by the OECD in 2003 on broadband and universal service found that broadband was in too early a developmental stage for regulators to require its inclusion in universal service.[55] That advice has proven well-founded as the expansion of broadband wired networks in the OECD has beaten almost all expectations in terms of reach and speed. Now, WiMAX has been talked about as a potential technology to offer both voice and broadband connectivity, which could erode the justification for traditional fixed-line subsidisation in remote areas via universal service funds. However, just as 2003 was too early to mandate broadband as a component of universal service, it would also appear to be too early in 2005 to reduce universal service requirements based on the potential of WiMAX equipment and similar wireless technologies.

As discussed earlier in this paper, the highest-speed broadband will almost certainly require fixed line connections, with wireless technologies providing specialised access in mobile situations. Wireless will still play a key role in providing initial access to outlying areas. However, the limited bandwidth of WiMAX and other wireless technologies could make them only a temporary solution for high-speed access until faster wire line solutions can be installed. If current obligations to roll out wire line infrastructure to outlying areas were reduced, there may be less incentive for operators to put in the types of infrastructure conducive to very-high-speed Internet access in the future. WiMAX networks may provide initial broadband connectivity in outlying areas but may also contribute to the increased stratification between rural and urban areas as fibre networks evolve and urban/rural speed differences exacerbate. Essentially, the future iterations of the digital divide may centre on those with access to fibre or very-high-speed copper connectivity and those without.

Another area where WiMAX could make a contribution towards universal access is connecting payphones in remote areas. The supply and maintenance of public payphones is still mandated by regulators in some OECD countries, even as the number of total payphones in the OECD is in decline. GSM payphones can already provide public phone access in areas covered by a GSM signal. These have been particularly successful in developing economies with large mobile networks but relatively under-developed fixed-line infrastructure.[56] WiMAX could greatly extend the reach of payphone networks, allowing operators a way to install and connect public payphones in very remote locations at a fraction of the cost of rolling out a wire line. Higher-speed WiMAX connections could also allow the payphones to be used for paid Wi-Fi connectivity from the phone, helping providers recoup some of the costs of providing the service.

WiMAX rollouts could also qualify for government subsidies in some OECD countries. In Canada, rural broadband development has been technologically neutral but nearly 50% of the business plans that received funding used a wireless access medium. These were typically Wi-Fi or a mix of Wi-Fi and satellite. Some of these networks will likely be upgraded from Wi-Fi to WiMAX after the certification process starts.[57]

COUNTRY EXAMPLES

Australia

The Australian wireless broadband market is characterised by growing competition between pre-WiMAX and competitive technology providers. Unwired Australia Pty Limited operates a pre-WiMAX network in Sydney that the company claims has 70 sites, 1 200 square miles and covers a population of 3.5 million inhabitants[58]. The service is advertised to reach 10 km from base stations. Broadband plans for 256 kbit/s mobile data cost USD 23.27/month (AUD 29.95) while the fastest service at 1 Mbit/s costs USD 93.20/month (AUD 119.95).[59]

Sydney is also the home to another wireless broadband network that uses the technology behind IEEE 802.20 (MobileFi). Personal Broadband Australia uses iBurst technology and allows users to also connect at speeds of up to 1 Mbit/s for AUD 99 per month within Sydney.[60] The network is said to reach 1 million inhabitants in Sydney as well as users in Melbourne, Brisbane, Canberra and the Gold Coast. There are plans to expand across the country.[61]

Austria

Austria auctioned wireless local loop licences in October 2004 and several companies won licences to provide services in the 3.5 GHz frequency range. The licences do not stipulate the use of a specific air interface but WiMAX is the technology planned for at least one of the networks. WiMAX Telecom paid USD 208 000 (EUR 160 000) for a nationwide 3.5 GHz licence in Austria to provide future WiMAX services.[62] Other licenses were awarded to Telekom Austria, Telekabel and Teleport. WLL frequencies have also been made available between 24-26 GHz.[63]

Belgium

Wireless broadband provider MAC Telecom holds 3.5 GHz and 10.5 GHz licences and has an LMDS network that covers Brussels and surrounding areas. Fixed wireless connections are available to subscribers at speeds up to 155 Mbit/s.[64]

The other fixed-wireless broadband license is held by ClearWire, which is operating a pre-WiMAX network in the 3.5 GHz range. Currently ClearWire has coverage of 50% of Brussels and plans to have 100% coverage by summer 2005. The company has also rolled out a network in Mont-Saint Guibert, a village of roughly 6 000 inhabitants, roughly 30 km from Brussels. Current subscriptions start at EUR 28.99/month for 1 Mbit/s connectivity and EUR 78.99 for 3 Mbit/s.

Canada

Canada has issued a large number of fixed wireless licences in the 2.3, 2.5 and 3.5 GHz bands. Spectrum was auctioned in the 2.3 and 3.5 GHz bands in 2004 and 2005, resulting in a total of 32 companies receiving 841 licenses.[65] A sample of the current license holders includes Inukshuk, SaskTel and the Manitoba School Board. Other licence holders in the band include Look TV, Image Wireless and Skycable who are authorised to provide multi-point distribution services and limited Internet access facilities.

Some networks building on pre-WiMAX equipment have had relative success. For example, the city of Summerside, Prince Edward Island has co-ordinated a private-public partnership to provide pre-WiMAX wireless Internet access to households and businesses in the western half of the province. The project has been funded largely through an award given by Industry Canada under the Broadband Pilot Program.

Denmark

In December 2000 Denmark issued a number of nationwide fixed wireless licences in the 3.5 GHz and 26 GHz bands. Additional licences have been issued in the 10 GHz band. The availability of FWA is very high in Denmark. SONOFON, who was assigned two FWA licenses in 2000, has since 2002 covered more than 90% of the country.

The FWA licence holders Danske Telecom and butlerNetworks both launched pre-WIMAX services in the beginning of 2005, primarily with a focus on the business segment. butlerNetworks has started up a nationwide offering of pre-WIMAX services with minimum speeds of 4 Mbit/s. The pre-WIMAX services are promoted and sold through partnerships with service providers on a wholesale basis, based on butlerNetworks' existing FWA-network.

Danske Telecom has made a rollout of pre-WIMAX services in some parts of Copenhagen. The company has announced a further rollout of pre-WIMAX services in other cities in 2005. Services are sold with speeds from 512 kbit/s up to 2 Mbit/s with a setup fee of USD 350. Monthly prices are USD 47 for 512/128 kbit/s services and USD 111 for 2048/512 kbit/s services.

Finland

Many of the wireless broadband projects in Finland have been undertaken by municipalities and power companies. Typically an area is blanketed with Wi-Fi hotspots operating in license-exempt spectrum that can then be connected together via pre-WiMAX WLL technologies in licensed frequency ranges.

One example is a MAN being built by Vantaan Energia (an energy company) in Vantaa and surrounding cities. The network is currently accessible by 40 000 residents who have access via Wi-Fi. The company plans to reach 80% of households by the end of 2005.[66]

Another energy company, Mäntsälän Sähkö is rolling out a pre-WiMAX network in the mid-Uusimaa region. The network is expected to cover a population of 60 000 over an area of 800 square kilometres. This will be owned and operated by the local energy company Mäntsälän Sähkö, and will cover an area of over 800 square kilometres. Upon its completion in early June the new network, MSoynet X, will cover a population of over 60 000 people.[67]

France

In July 2005, the regulator, ARCEP, adopted two decisions proposing to the Minister of Industry a procedure for the delivery of wireless local loop authorisations. This proposition would allow for the delivery of two new authorisations in the 3.4-3.6 GHz band that would be held independently in each region. In regions where the demand does not exceed the available frequencies, ARCEP would issue authorisations on a “first come first served” basis. In areas with more demand for licences a “beauty contest” selection would be held to allocate the authorisations. Frequencies would also be made available in the 3.6-3.8 GHz band and allocated if needed. Finally, some projects could use the 5.4-5.7 GHz band which should be opened to wireless access systems by the end of 2005 for wireless equipment respecting the version of the ETSI standard including DFS (Dynamic Frequency Selection). The Minister of Industry should publish the procedure proposed by ARCEP, that indicates the rules and the timetable of the whole procedure, in the *Journal Officiel*.

Altitude Telecom operates an LMDS network in the 26 GHz range but has recently acquired a licence in at 3.5 GHz which will be used for pre-WiMAX equipment.[68] The network will service small and medium sized enterprises. The WiMAX network will also be leveraged to deliver voice services using Voice over WiMAX.[69] France Telecom has deployed “pre-WiMAX” trials based on the 802.16-2004 standard in the towns of Amilly, Lehon and La Salvetat. WiMAX backhaul connections were used for one part of the trial to deliver connectivity to Wi-Fi hotspots.[70] The France Telecom trials were allowed to take place in the 3.5 GHz range in the trial areas. Other companies such as Hub Telecom (formerly ADP Telecom) have also announced their intentions to run WiMAX trials.[71]but Altitude Telecom is the only operator that currently has a 3.5 GHz license.

While Altitude and France Telecom are using or trialling pre-WiMAX equipment, the mobile operator Orange is currently trialling an HSDPA network in Lille that is considered a competitor to WiMAX.[72]

Germany

The German regulator, RegTP is in the process of recycling WLL frequencies to be used by newer technologies such as WiMAX. RegTP has proposed a simplified licensing process, named “licensing light” that would make it easier for WiMAX providers to start offering services. Frequencies for WiMAX are available in the 3.5 GHz range and will be available for use in 2006.[73]

Deutsche Telekom will deploy pre-WiMAX technologies in a pilot project. The German national regulatory authority has assigned limited test frequencies for trials scheduled to begin in the region of Bonn in mid-2005.

Ireland

Ireland has several operators with pre-WiMAX plans or trials underway. Irish Broadband has 3.5 GHz licenses in 16 cities including the larger cities of Dublin, Galway, Cork, Limerick and Waterford.[74] It also will implement pre-WiMAX equipment in the 5.7 GHz range[75]. Irish Broadband currently has just under 10 000 subscribers.[76]

The mobile operator O2 has also been trialling WiMAX services in Gleann Cholm Cille, Donegal, in the northwest of Ireland. The service connected residences, businesses and schools for a four month trial beginning in early 2005.[77] DigiWeb has also announced the development of a WiMAX network and hopes to cover 50% of the country by mid-year 2005.[78]

Japan

The Japanese government is currently in the process of deciding how to allocate spectrum for wireless broadband providers. No decision has been taken yet some companies have announced their ambitions to offer city-wide WiMAX networks in Tokyo. The communication operator Yozan would like to start WiMAX trials in Tokyo by mid-year 2005 and would initially start by building out a fixed WiMAX network. The operator has said it will then upgrade the network to the mobile WiMAX after IEEE finalises the standards and the WiMAX Forum begins certification testing.[79] The network is expected to consist of 600 cells that cover the greater Tokyo metropolitan area and surrounding eight prefectures.[80] Tokyo is already wired for DSL and fibre and broadband prices are among the cheapest in the world so Yozan will try to compete on price and mobility.[81]

Korea

The Korean government allocated three WiBro licenses based on the IEEE 802.16e standard in the 2.3GHz range for wireless/mobile Internet services. Korea's WiBro rollout will likely be the first high-speed mobile broadband service of its kind in the world.

KT is working to provide a WiBro demonstration service in Busan in November 2005 for the APEC summit meeting. Korea's leading operators KT (fixed) and SKT (mobile) will launch WiBro services commercially in 2006. KT is set to offer services in April 2006 with SKT following in June 2006.

Luxembourg

Luxembourg has started a consultation on the situation of wireless networks. Previously Luxembourg's regulator (ILR) assigned licences to WLL-operators in two frequency bands, 3.5 GHz and 26 GHz with specific restrictions meant to avoid interference. The new consultation is also considering the 5.8 GHz band and has been included as part of the discussions within the European Conference of Postal and Telecommunications Administrations (CEPT).[82]

Netherlands

The Dutch operator Enertel's has a pre-WiMAX service available for businesses in the Rotterdam/Rijnmond region using the 3.5 GHz range. The service will be extended to Amsterdam, The Hague, Utrecht and Eindhoven, and is anticipated to have reached national coverage by late 2005.[83] The results of the pilot project have been successful.

New Zealand

New Zealand created the rights for two 3.5 GHz radio licenses for fixed wireless use in 2001. The allocation proposals for the spectrum bands were published in March 2004, with priority given to telecommunication suppliers that are part of the Provincial Broadband Extension Project (PROBE).[84] The use of the 3.5 GHz range means that WiMAX equipment could be easily used by providers once it is certified.

Spain

The Spanish wireless ISP Iberbanda has been operating an LMDS network in Spain since 2001 in the 3.5 GHz range in 72 cities. Recently Iberbanda announced they will be installing pre-WiMAX equipment in two Spanish regions, Andalusia and Catalonia. The LMDS network provides services to businesses but the implementation of pre-WiMAX equipment is meant to lower prices for connections to consumers and small businesses.[85] The upgrade of the Iberbanda network to pre-WiMAX equipment is not surprising given the much higher costs of proprietary LMDS equipment.

Switzerland

Switzerland has opened a public consultation on the licensing of broadband wireless technologies in an effort to determine the demand for licences in the market and the most effective way to allocate them.[86] The results of the consultation should be made public in the summer of 2005. Shortly thereafter, ComCom will decide the number of licences and how they will be awarded. For the moment, BWA technologies would be limited to licensed usage in the 3.4 to 3.6 GHz frequency bands. Licence-exempt use could be possible in the 5.7 GHz frequency bands with restrictions on power levels.

Sweden

The local authority in the rural area of Skelleftea commissioned a WiMAX network to provide Internet access to 71 000 people over an area of 7 200 square kilometres. The network will use pre-WiMAX equipment, will likely operate in the 3.5 GHz band and is the result of a joint effort between TeliaSonera, Mobile City and the local university.[87]

United Kingdom

BT has announced they will deliver 100% wireless broadband coverage in Northern Ireland before the end of 2005 using pre-WiMAX technology. BT initially started four trials which took only 6-8 weeks to put into place. The initial trials linked 120 customers via wireless broadband for a period of 6 months. Customers were able to connect to the Internet at speeds between 512 kbit/s and 1 Mbit/s.

Working from the success of the trial, BT is planning to expand the project and provide 100% coverage in Northern Ireland using licence-exempt spectrum in the 5 GHz band. One of the key benefits of the pre-WiMAX network being put in place by BT is its symmetric data speeds. Unlike ADSL where upload speeds are much slower than download, symmetric services can offer high-speed uploads to businesses and consumers.

United States

Potential WiMAX providers in the United States have focused on the 2.5 GHz and 5 GHz ISM bands. The 3 400 – 3 650 MHz range is allocated for use by the radiolocation service (radars) on a primary basis and does not contain provisions for use of fixed or mobile systems. Clearwire is one of the first providers to offer pre-WiMAX services in this frequency band with its network in Jacksonville, Florida. The service covers 120 000 inhabitants in an area of 100 square miles.[88] Clearwire has acquired a large number of licenses and currently has services in Dayton Beach, Florida; Abilene, Texas, and St. Cloud, Minnesota.[89] Monthly prices are USD 27.99 for 512/128 kbit/s service and USD 47.99 for 1500/256 kbit/s service.[90]

The United States recently opened up new spectrum for wireless broadband in the 3 650 to 3 700 MHz range that uses a hybrid approach of licensed and unlicensed regulatory models. The band will require the use of contention-based protocols that will minimise interference. The goal is to stimulate the expansion of wireless ISPs with limited resources.[91]

NATIONAL WIMAX POLICIES

Table 3. Licence-exempt spectrum

Are operators allowed to use WiMAX technologies in the licence-exempt spectrum bands (*e.g.* 2.4GHz or 5.8GHz)?

Australia	There are a number of providers who are claiming to use technologies that are based on the 802.16 standard. This is primarily in the 5.8 GHz class licensed spectrum band. Within Australia there is no licence exempt spectrum. With respect to wireless access services (WAS), the regulator (the Australian Communications Authority) makes a number of spectrum bands available under different licensing arrangements. With respect to 2.4 GHz and 5.8 GHz, these bands are made available for WAS under a class licence. This provides a 'public park' regulatory environment. Users receive no guarantee of protection from interference from other services and must not cause interference to other services. The devices reduce the likelihood of causing interference by virtue of their design and restricted power. Class licences are not issued to individuals and no licence fees are payable.
Austria	2.4 GHz is available since it is technology neutral. However, it is unknown at this time if WiMAX fulfils air interface or not. 5.8 GHz is currently unavailable.
Belgium	It is foreseen that WiMAX could be allowed in the 5.8 GHz band.
Canada	The 2.4 and 5.8 GHz bands can be used for WiMAX. Industry Canada does not designate spectrum for specific technologies, such as WiMAX, but WiMAX can be used in any band, subject to compliance with the technical limits.
Czech Republic	Equipment can be used in 2.4 GHz band provided it fulfills ERC/REC 70-03E, Annex 3 requirements. The same will apply for 5.47 – 5.725 GHz band after this band is opened in the second half of the year 2005. In the 5.725 – 5.875 GHz band, the traffic is approved only for power up to 25 mW eirp.
Denmark	In principle WiMAX technologies can be used in the mentioned frequency bands. However the current regulations need to be observed.
Finland	The 2.4 GHz band is available if they fulfil general requirements mentioned in the Finnish regulation on the use of licence exempt equipment (transmitters power limits, power spectral densities etc.). WiMAX would be allowed in the 5.8 GHz band (5725-5875 MHz) before relevant studies and regulations are finalised at the ECC level.
France	Theoretically it is possible to use WiMAX technologies in the 2.4 GHz band (the 5.8 GHz band is not open in France). However, it may prove difficult in practice due to power restrictions given by PIRE (*puissance de rayonnement des équipements*) and ETSI standards.
Germany	
Greece	2.4 GHz is available for use in Greece.
Hungary	WiMAX can be used in the licence exempt band 2 400 - 2 483.5 MHz under the provisions given for RLANs. WiMAX usage is not yet allowed in the band 5 725 – 5 875 MHz. Compatibility studies are in progress.
Iceland	The license exempt bands are available, provided operators comply with ERC/ECC requirements (REC's and/or DEC's).
Ireland	The 2.4GHz and 5.8GHz bands are both available on a licence exempt basis in Ireland. WiMAX equipment could be deployed in these bands subject to meeting the appropriate harmonised standards or equivalent.
Italy	
Japan	At present, the MIC has not allocated spectrum to WiMAX but is currently examining WirelessMAN with a research committee.

Table 3. License-exempt spectrum

Are operators allowed to use WiMAX technologies in the license-exempt spectrum bands (*e.g.* 2.4GHz or 5.8GHz)? (Cont'd)

Korea	Korea does not mandate a technical standard for wireless facilities and thus there are no separate rules governing the use of WiMAX in license-exempt bands.
Luxembourg	The 2.4 GHz band is used for wireless networks such as Wi-Fi and the use of WiMAX would not be allowed in the same band. The 5.8 GHz band is part of our public consultation, available at: http://www.ilr.etat.lu/freq/docs/CONSULTATION WiMAX fr.doc. The band is important as well because it is the object of discussions at CEPT.
Mexico	Operators are not allowed to use WiMAX technologies in the licence-exempt spectrum bands. At present, the 2.4 and 5.8 GHz bands are not licence-exempt in Mexico.
Netherlands	The position from the Netherlands is first to solve compatibility problems with radar and then move towards license-exempt use via an EEC decision.
New Zealand	
Norway	Any technologies are allowed to use the 2.4 and 5 GHz bands as long as they adhere to the general authorizations for use. Currently, the general authorisations are out for general consultation. Whatever technology it is possible to implement in line with the general authorisation for use of the 2.4 and 5 GHz bands is allowed. Currently the general authorisations are out for public consultations.
Poland	Polish law does not impose any restrictions with respect to the technology applied in the licence-exempt spectrum bands and thus operators can use WiMAX.
Portugal	NA
Slovak Republic	
Spain	
Sweden	The 2.4 GHz band is open for different kinds of technology and a WiMAX system will be allowed as long as it adheres to ETSI EN 300 328 V1.5.1. The 5470-5725 GHz band is in principle available for WiMAX based systems as long as they fulfil certain requirements. The Swedish Post- and Telecom Agency has also decided to offer the 5.725-5.875 GHz band for BWA use – likely on a non-licence condition.
Switzerland	In Switzerland, we can envisage the installation of WiMAX equipment solely in the frequency bands 5.47-5.725 GHz (which have been available since 01 February 2005). However, equipment would be limited to power levels of 1 Watt eirp maximum.
Turkey	
United Kingdom	Operators could deploy WiMAX in the 5.8 GHz band where it complied with the spectrum access requirements given in: http://www.ofcom.org.uk/radiocomms/ifi/tech/interface_req/uk_interface_2007.pdf.
United States	WiMAX could operate in licence-exempt bands as long as the equipment met the technical and operational requirements under Part 15 rules applicable to the particular band in which it was operating. These rules are accessible at: http://www.access.gpo.gov/nara/cfr/waisidx_04/47cfr15_04.html

Table 4. Licensed spectrum

Have licensed bands been made available for WiMAX (*e.g.* 2.3 GHz or 3.5 GHz)?

Australia	In Australia, there is spectrum set aside for "apparatus-licensed" WAS and ‘spectrum licensed’ WAS. No specific spectrum has been set aside for the Wi-MAX technology. However, spectrum licences allocated by the Australian Communications and Media Authority are technology neutral so WiMAX services could be accommodated in the 2.3 GHz and 3.4 GHz bands. Spectrum in the 2.3 GHz and 3.5 GHz bands is held by a number of operators.
Austria	In Austria, the 3.5 GHz technology is neutral so WiMAX may be used by licensees.
Belgium	Fixed wireless access has been licensed a 3 450-3 500 / 3 550-3 600 MHz.
Canada	The 2.3, 2.5 and 3.5 GHz licensed bands can be used for WiMAX. Industry Canada does not designate spectrum for specific technologies, such as WiMAX, but WiMAX can be used in any band, subject to compliance with the technical limits. Consequently other bands may be available for WiMAX in the future as the technology and standards evolve.
Czech Republic	Authorisation for WiMax cannot be issued in the 2.3 GHz band. In the 3.5 GHz band the Authorisation may be issued for access points.
Denmark	WiMAX technology can be used in all frequency bands available for fixed services. As with other technologies the current radio interface specifications need to be observed. The 2.3 GHz band is not currently available for fixed services in Denmark and this band is not immediately available for WiMAX.
Finland	Operators can use IEEE 802.16 equipment in the 3.5 GHz band only if the technical characteristics are similar to current regulation in force (channel width etc.). Technical characteristics are described in the harmonised standard from ETSI and are also published in the EU Official Journal.
France	The frequency bands for WiMAX in France include 3.4 - 3.8 GHz. Part of this spectrum has been released while the rest is in the process of being released.
Germany	
Greece	The 2.3 and 3.5 GHz frequency bands are not available for WiMAX.
Hungary	The 2.3 GHz frequency band is not available for WiMAX. The licence holders of the bands 3 410 – 3 494 / 3 510 – 3 594 MHz have the possibility to apply WiMAX as an option of FWA.
Iceland	2.3 GHz: No, 3.4-3.6 GHz: yes.
Ireland	The 3.5GHz band has been available for licensing on a local area basis in Ireland since September 2003.
Italy	
Japan	The 4.9 and 5.0 GHz bands are available for wireless access systems including WiMAX.
Korea	The frequency band 2 300 – 2 390 MHz has been allocated for WiBro services that support WiMAX to a certain extent.
Luxembourg	The 2.3 GHz band will not be used for WiMAX. The 3.5 GHz band is an element of the current consultation.
Mexico	Mexico has not licensed bands for WiMAX in 2.3 or 3.5 GHz.
Netherlands	The 2.6 GHz and 3.5 GHz bands are licensed.
New Zealand	
Norway	Since 2003, NPT have allocated and assigned a considerable amount of spectrum in the frequency bands between 2 and 40 GHz. These assigned spectrum licences are technology neutral and offer flexibility. The licensees decide on what technology to implement; WiMAX may be implemented. The allocation / assignment accomplished in 2003-2004 includes the 2.3 and 3.5 GHz bands.
Poland	The 2.3 GHz band is unavailable for fixed services or civilian uses. The 3.5 GHz band has been made available for fixed wireless access but is heavily congested. In licensed bands of 3.5 GHz (3 410 – 3 600 MHz) and 3.7 GHz (3 600 – 3 800 MHz) there are no restrictions as to the applied technology, so WiMAX can be used.

Table 4. Licensed spectrum

Have licensed bands been made available for WiMAX (*e.g.* 2.3 GHz or 3.5 GHz)?
(Cont'd)

Portugal	Licences have not yet been awarded for WiMAX technologies in Portugal. Licensing regimes for these technologies are still under evaluation. So far, Portugal is of the opinion that a harmonised approach within Europe may result in considerable advantages for all involved parties, taking into account that the introduction of WiMAX is under discussion in European fora, namely in CEPT and EC. Both technical and regulatory aspects are still being analysed. Notwithstanding, it is expected that more information on this issue will be made available by the end of 2005. The public consultation carried out in 2004 in Portugal with respect to the interest in FWA systems operating in different frequency ranges found interest in the implementation of WiMAX.
Slovak Republic	
Spain	
Sweden	The 3.41-3-6GHz band is open on a technologically neutral basis. For the 3.6-3.8 GHz band, a first public consultation has been carried out regarding the possibility of allocating the whole band for multiple licenses on a regional basis (multiple licences per regional area).
Switzerland	A public consultation was launched to know the needs of the market. The only frequency band that can eventually be made available is 3.4 – 3.6 GHz. However, there is still a concession made for WLL in this frequency band.
Turkey	
United Kingdom	Details of spectrum bands that Ofcom will offer to the market are listed in the Spectrum Framework Implementation Plan at: http://www.ofcom.org.uk/consult/condocs/sfrip/. Within the 3.4 - 4.0 GHz range two licensees have access to spectrum; Pipex and UK Broadband and at present neither uses (or is required to use) WiMAX equipment. It should be noted that Ofcom will make spectrum available without (unless necessary from a spectrum management reasons) technology constraints and therefore access to bands will not have to comply with a particular air interface standard (such as WiMAX), so WiMAX "bands" could be used by other air interface standards.
United States	Licenses that have been awarded in the 2.3 GHz and 2.5 GHz bands can be used by WiMax-compatible or other technologies that are using pre-WiMax technologies – installations are currently being made. The 3.4-3.6 GHz band will not be available for WiMax in the United States. However, the 3 650 – 3 700 MHz band has recently been allocated to fixed and mobile services. Also, the FCC plans to auction 90 MHz at 1.7-2.1 GHz, which could conceivably be used by license winners to provide services via WiMAX if the industry standard is modified to allow operation below 2 GHz.

Table 5. Licences received

If licensed, have any licenses been awarded (and to which companies)?

Australia	The major holder of spectrum in the 2.3 GHz band is Austar (2 302–2 400 MHz) which is a Pay TV provider, but is not currently using this spectrum. Telstra and Unwired Australia hold a significant amount of the spectrum across Australia in this band. Unwired holds or has access to spectrum covering the east and southern coasts of Australia which captures 95% of the Australian population. Personal Broadband Australia, holds a spectrum licence in the 1 900 – 1 920 MHz band, although it uses iBurst technology and not IEEE 802.16.
Austria	Information on the recent auction for 3.5 GHz spectrum can be found at: http://www.rtr.at/web.nsf/englisch/Telekommunikation_Frequenzvergabe_Bisherige%20Auktionen_BisherigeAuktionen_WLL-2004?OpenDocument
Belgium	2 licences : Mac Telecom and ClearWire
Canada	Licences have been awarded for wireless access systems in the bands 2.3, 2.5 and 3.5 GHz. Spectrum in the 2.3 and 3.5 GHz bands was auctioned in 2004 and 2005. A total of 32 companies were awarded 841 licences. Information on licence areas and licensees is available at http://strategis.ic.gc.ca/epic/internet/insmt-gst.nsf/vwapj/licencewinners.pdf/$FILE/licencewinners.pdf. Spectrum in the 2.5 GHz band across most of Canada was awarded in 2000 using a comparative review process (see http://strategis.ic.gc.ca/epic/internet/insmt-gst.nsf/en/h_sf01708e.html for more information). Licence holders include Inukshuk, SaskTel and the Manitoba School Board. Other licence holders in the band include: Look TV, Image Wireless and Skycable who are authorized to provide multi-point distribution services and limited Internet access facilities. Licensees have asked for more flexibility and this policy is currently under review.
Czech Republic	3 FWA licences have been issued.
Denmark	Several licences have been issued for both point-to-multipoint services as well as point-to-point services. NITA does not know whether the licensees have used WiMAX technology or not. All licensees can be seen in our frequency register on line at: http://frekvens.itst.dk/servlet/tstsog/tstsog.index (in Danish).
Finland	Currently only one test licence has been granted for WiMAX due to fact that all current equipment is pre-WiMAX. Any current licence holder can change their equipment to WiMAX with an additional application to FICORA (there could be changes in the licence conditions due to changes in technical characteristics).
France	Only one licence has been awarded, to Altitude Telecom. The spectrum was allocated on a first come first served basis.
Germany	
Greece	Some frequencies above 5 GHz have been sold to OTE and other companies. However, these licenses were not necessarily specific for WiMAX technologies.
Hungary	Five operators may use FWA systems including WiMAX on the basis of nationwide licences in the bands 3 410 – 3 494 / 3 510 - 3 594 MHz.
Iceland	The 3.5 GHz band is partly used already but WiMAX technology has not been used yet.
Ireland	In the 3.5 GHz band, 90 local area licences have been issued to 9 different operators.
Italy	
Japan	The number of licences is not limited for the 4.9 / 5.0 GHz bands since these bands have to be shared among operators using a carrier sense function.
Korea	Facilities-based telecommunication services require a government license and KT, STK and Hanaro Telecom were granted license for WiBro services at 2.3 GHz in March 2005.
Luxembourg	The decisions will be made after analysis of the current consultation, likely in June 2005.
Mexico	NA
Netherlands	The 2.6 and 3.5 GHz bands are both licensed, but not specifically for WiMAX.
New Zealand	

Table 5. Licenses received

If licensed, have any licenses been awarded (and to which companies)?
(Cont'd)

Norway	An overview of current assignments in bands between 2 and 40 GHz is available at: http://www.npt.no/pt_internet/eng/resource_management/frequency_management/licences/2_12_GHz.xls and http://www.npt.no/pt_internet/eng/resource_management/frequency_management/licences/13_40_GHz.xls Using the 2.3 and 3.5 GHz bands as an example, both bands are technology neutral and the licenses are flexible. Licensees decide on what technology to implement and whether to offer fixed, mobile or nomadic services. The licences may also be traded. There are 4 licensees in the 2.3 GHz band (expiry date is 2018). As a result of the auction in 2004 there are 8 licensees in the 3.5 GHz band (expiry by 2022).
Poland	Three nation-wide licenses at 3.5 GHz have been given to the following operators: E-internets Sp. z o.o., Naukowa i Akademicka Siec Komputerowa, Polska Telefonia Cyfrowa Sp. z o.o. Work is ongoing to select further nation-wide operators.
Portugal	NA
Slovak Republic	
Spain	
Sweden	Two national licences of 2*28 MHz have been awarded to TeliaSoner AB and Interloop AB. 21 regional licences (1 per geographical area) of 2*28MHz have also been allocated. Of those, 20 are awarded to seven different operators and one is available for application. The seven regional licence holders are: AB Stokab, Gotland Energi AB, HallWan AB, Norrsken AB, Paradigm Communication System Limited, Quadracom Wireless AB and Region Skåne.
Switzerland	At present, there is a wireless local loop licence that could be used for broadband wireless access. Other licences have not yet been allocated. The public consultation period for new licences has ended and the decision of the Communication Commission is pending.
Turkey	
United Kingdom	Within the 3.4 – 4.0 GHz range two licensees have access to spectrum; Pipex and UK Broadband and at present neither uses (or is required to use) WiMAX equipment.
United States	NA

Table 6. Licensing process

If licensed, how were (or will) the licences (be) awarded?

Australia	The Productivity Commission's enquiry report into Radiocommunications (2002) and the Australian Communications and Media Authority publication 'From DC to Daylight – Accounting for use of the spectrum in Australia – A Spectrum Management Strategy' (2004) provides extensive detail of how apparatus and spectrum licensees have and will be awarded. http://www.acma.gov.au/acmainterwr/aca_home/publications/reports/aca_spectrum_strategy_report.pdf.
Austria	Auction
Belgium	Beauty contest
Canada	Spectrum was awarded using a comparative licensing process and more recently, using an auction process. Information on licence areas and licensees is available at http://strategis.ic.gc.ca/epic/internet/insmt-gst.nsf/vwapj/licencewinners.pdf/$FILE/licencewinners.pdf. Spectrum in the 2.5 GHz band across most of Canada was awarded in 2000 using a comparative review process (see http://strategis.ic.gc.ca/epic/internet/insmt-gst.nsf/en/h_sf01708e.html for more information).
Czech Republic	For frequencies up to 3.560 GHz the licences are awarded according to the order of applications. A beauty contest is used for licenses in the 3.560 – 3.580 GHz range.
Denmark	Licences have been issued according on a first come, first served basis as well as through an auction and beauty contest. The decisive mechanism for issuing licenses on a first come, first served basis or auction/beauty contest is whether there is scarcity of frequencies. In case of scarcity, auction/beauty contest is used as the award mechanism. Auction/beauty contests have been used in the 3.5 GHz and 25 GHz frequency bands, while first come/first served has been used in all other frequency bands.
Finland	The 3.5 GHz licences are granted on a first come first-served basis and the process is ongoing. Currently there are 10 regional licences in the 3.5 GHz band (some licences have several regions in the licence). In addition there are more than 10 applications currently in process. In principle there can be three licences in the same geographical area so there could be competition between different operators.
France	Only one licence has been awarded, to Altitude Telecom. The spectrum was allocated on a first come first served basis. Two others will be awarded based on a selection procedure if spectrum scarcity is declared.
Germany	
Greece	NA
Hungary	NA
Iceland	Licences will likely be distributed via a "beauty contest".
Ireland	Licences are awarded for local area service provision on a first come, first served basis with facility to conduct a simple comparative evaluation should ComReg receive 2 or more applications for the same area on the same day.
Italy	
Japan	For the 4.9 / 5.0 GHz bands, only registration is required.
Korea	An applicant for WiBro service is required to submit necessary documentation, including business plans, for government review before a licence is granted. Carriers applied for WiBro licences and a licence review committee was established to process the applications. As a result of the review, the three operators passed the requirements and were duly granted a licence.
Luxembourg	Different methods of issuing licences for frequency bands are actually under consideration but have not yet been defined.
Mexico	NA
Netherlands	Auction
New Zealand	

Table 6. Licensing process

If licensed, how were (or will) the licences (be) awarded?
(Cont'd)

Norway	Anyone, at any point in time, may apply for radio frequency licences if the radio frequencies in question are vacant. Market players simply apply and the licence will be awarded within 6 weeks if no competitive application is received. If a competitive application is received usually an auction is set up and NPT may spend up to 8 months preparing and running the auction.
Poland	Licences in the 3.5 GHz band have been issued according to the order in which applications for issuing a licence were submitted and considered (first come/first served). Licences in the 3.7 GHz band were issued and will be issued in accordance with the tender procedure (beauty competition).
Portugal	
Slovak Republic	
Spain	
Sweden	The 21 regional licences were awarded by beauty contest.
Switzerland	This has not been decided yet. The Communication Commission will take the decision on the subject.
Turkey	
United Kingdom	UK Broadband were awarded spectrum at 3.4 GHz under an auction held in June 2003 and the Pipex use (formally Tele2, Liberty Broadband and FirstNet) pre-dates this by a number of years. The licences at 5.8GHz are non-limited, open to all (no exclusivity).
United States	NA

Table 7. Company restrictions

Are there restrictions on the types of companies that are allowed to offer WiMAX services?

Australia	In broad terms, companies operating infrastructure to deliver telecommunications services are required to hold a carrier licence as specified under the Telecommunications Act 1997.
Austria	The restrictions are given in the document: http://www.rtr.at/web.nsf/englisch/Telekommunikation_Frequenzvergabe_Bisherige%20Auktionen_BisherigeAuktionen_WLL-2004?OpenDocument
Belgium	No.
Canada	No. There are no restrictions that would be specific to WiMAX
Czech Republic	No.
Denmark	No.
Finland	No. Current licence holders are telecom operators, electrical companies, municipal groups etc.
France	There are no particular restrictions.
Germany	
Greece	Operators must have an ISP (or similar) licence. For more information see the National Regulatory Authority for the telecommunications and postal services market Web (http://page www.eett.gr).
Hungary	When the WiMAX services will be licensed in the future, Hungary's Administration does not intend to put any restrictions on the types of companies that can provide services.
Iceland	Companies must comply with the general requirements for telecom service providers.
Ireland	There are no specific restrictions on companies who wish to deploy WiMAX beyond meeting the normal regulatory requirements (*e.g.* compliance with the relevant licence, general authorisation for service provision, etc.)
Italy	
Japan	There are no such restrictions.
Korea	There are no such restrictions.
Luxembourg	There are no restrictions relative to potential operators.
Mexico	At present there are no specific rules on companies offering WiMAX services. In general terms, any telecommunications public service provider must have a government concession.
Netherlands	The only restrictions would be related to technology, *e.g.* power limitations.
New Zealand	
Norway	There are no such restrictions.
Poland	There are no such restrictions.
Portugal	
Slovak Republic	
Spain	
Sweden	There are no restrictions but companies must be a registered operator to offer service.
Switzerland	This has not been decided yet. The Communication Commission will take the decision on the subject.
Turkey	
United Kingdom	There are no specific restrictions outside of spectrum requirements.
United States	No.

Table 8. Power restrictions

What are the power restrictions on WiMAX-type equipment in the operational bands?

Australia	The suite of 802.16 standards upon which WiMAX is based supports operation in both public park spectrum and licensed bands between 2 and 66 GHz using orthogonal frequency division modulation (OFDM). Operation in public park spectrum at 2.4 and 5.8GHz for digital modulation transmitters using OFDM is authorised by the low interference potential devices (LIPD) class licence. The LIPD class licence authorises digital modulation transmitters to operate at 4W in the frequency bands 2 400 to 2 483.5 MHz and 5725 to 5 875 MHz. In Spectrum Licensed bands the equipment deployment needs to comply with the SL conditions specific to that band. Licensed spectrum would need to comply with specific RALI where typically power restrictions for the base stations are not specified but may be for subscriber or remote stations.
Austria	Information on power restrictions can be found at: http://www.rtr.at/web.nsf/englisch/Telekommunikation_Frequenzvergabe_Bisherige%20Auktionen_BisherigeAuktionen_WLL-2004?OpenDocument
Belgium	There are no specific power restrictions, only power flux density limits at the border.
Canada	Any power restrictions vary based on the frequency band. These are the technical restrictions that would apply to any transmitter in the same band. When developing our technical standards, Canada attempts to use commonly used technical standards that are harmonised between as many countries as possible. This is important to try and achieve economies of scale and reduce equipment costs.
Czech Republic	Maximum output power 30 dBm (FWA base-stations).
Denmark	In licensed bands there are no power restrictions, but co-ordination agreements with neighbouring countries shall be observed (power flux density limits apply in border areas)
Finland	In the 3.5 GHz band typical power levels are +28 dBm transmitter power and 16 dBi antenna gain for base station equipment (60° radiation pattern). In the 2.4 GHz band the 100mW EIRP limit applies.
France	There are no specific restrictions concerning the power of WiMAX equipment.
Germany	
Greece	NA
Hungary	Technical parameters, including power restriction, are under study.
Iceland	There will be no national Icelandic requirements but power limits set by the ECC will apply.
Ireland	
Italy	Power restrictions will vary between licensed local areas but an overall maximum power (EIRP) is proposed at 14dBW/MHz. All licensees are required to meet the requirements of the ICNIRP guidelines.
Japan	For the 4.9 / 5.0 GHz bands up to 5W.
Korea	There is no specific restriction regarding WiMAX-type equipment.
Luxembourg	Site clearance must conform to regulations. The power level of equipment must adhere to restrictions defined by the ITM (*l'Inspection du Travail et des Mines*) in Luxembourg. http://www.itm.etat.lu.
Mexico	There has been no decision take on this matter yet in Mexico.
Netherlands	If there are restrictions they are always related to technology, *e.g.* power limitations.
New Zealand	

Table 8. Power restrictions

What are the power restrictions on WiMAX-type equipment in the operational bands?
(Cont'd)

Norway	There is usually no maximum power limit apart from what is implied from the block edge mask and co-channel (geographical) boundary. A spectrum licence is a right of use which is described first and foremost through the specification of the bandwidth, spectral position, geographic coverage and the duration of the licence. NPT defines the block edge mask and co-channel (geographical) boundary. The spectrum is assigned as "management rights" without usage restrictions apart from the defined block edges and co-channel (geographical) boundary. The licensees manage the use of frequencies themselves within the framework provided for in laws, regulations and terms and conditions of the license. There is no external guard band between adjacent frequency blocks.
Poland	In the licensed bands there are no power restrictions. In the licence-exempt bands restrictions as to the radiated power are compliant with the recommendation 70-03 and relevant ECC decisions.
Portugal	
Slovak Republic	
Spain	
Sweden	In the 3.41-3.6 GHz band the restriction is Pout = +35dBm at the output of the active unit (that is into the feeder cable to the antenna).
Switzerland	In the 3.4-3.6 GHz bands the maximum power levels are 35 dBW equivalent isotropically radiated power (EIRP). Broadband wireless access could possibly be used in the 5.470 to 5.725 GHz frequency band but with power limited to 1W EIRP.
Turkey	
United Kingdom	Within 5.8GHz, EIRP 2W or 100mW/MHz. For the frequency bands 3.4/3.6 GHz, up to 14 or 21 dBW/MHz (co-ordination permitting).
United States	The power limits, antenna heights, etc., must comply with the technical and operational requirements applicable to the particular licensed or unlicensed band in which the device is operating.

Table 9. Service restrictions

Are there restrictions on the types of services that can be provided over WiMAX?

Australia	There are no restrictions. WiMAX is a standards-based technology to support broadband wireless access, so the focus is broadband data. Typical services are Internet, VOIP, video etc.
Austria	Details can be found at: http://www.rtr.at/web.nsf/englisch/Telekommunikation_Frequenzvergabe_Bisherige%20Auktionen_BisherigeAuktionen_WLL-2004?OpenDocument
Belgium	There are no restrictions.
Canada	Any types of services may be provided, subject to compliance with the technical rules. Mobile operation is not permitted in the 3.5 GHz band.
Czech Republic	There are no legislative restrictions, however in practise WiMAX should be used as an access point.
Denmark	There are no restrictions.
Finland	There are no restrictions.
France	Operators must propose an offer of access.
Germany	
Greece	NA
Hungary	The Administration of Hungary intends to allow all types of services (voice, video, and data).
Iceland	No such restrictions have been defined.
Ireland	There are no specific restrictions on the services that can be provided by WiMAX platforms.
Italy	
Japan	NA
Korea	There are no restrictions.
Luxembourg	
Mexico	There are no restrictions on the types of services, provided that the service provider has a concession to offer that type of services.
Netherlands	No other limitations than that they must be used for fixed services.
New Zealand	
Norway	There are no restrictions. The licensees decide on what technology to implement and whether to offer fixed, mobile or nomadic services.
Poland	There are no such restrictions.
Portugal	
Slovak Republic	
Spain	
Sweden	The 3.41-3.6 GHz licences are specific for fixed services.
Switzerland	This has not yet been decided. The Communication Commission will make the decision on the subject.
Turkey	
United Kingdom	The 3.5 and 5.8 GHz bands currently have a fixed only requirement for frequency management reasons (*i.e.* mobile operation is not permitted).
United States	There are no restrictions on the types of services that may be provided, as long as the device operates within the applicable regulatory Part 15 limits.

Table 10. Pre-WiMAX trials

Have any operators trialled or rolled out pre-WiMAX services? Which operators and which services?

Australia	We are not aware of any service providers that are using IEEE 802.16 technology. A number of wireless providers have made reference to their capacity to transition to Wi-MAX / 802.16 in the future. For example Access Providers, a wireless broadband service provider based in Melbourne, claim that they are using equipment that is capable (with software upgrades) of operating in compliance with the 802.16d wireless networking standard.
Austria	Unknown
Belgium	Clearwire rolled out an OFDM network
Canada	Industry Canada does not track services specific to WiMAX. Inukshuk Wireless has rolled out service in a number of small Canadian communities in the 2.5 GHz band. RipNet has rolled out services in the 3.5 GHz band and also Chatham Internet Access. There are likely several others.
Czech Republic	N.A.
Denmark	Typically this kind of information is not available. However some operators have made trials with pre-WiMAX services. This includes Danske Telecom.
Finland	Pohjanmaan PPO Oy will start trials during spring 2005 and will provide data, voice and video.
France	Altitude Telecom has already started services. They offer Internet access, private networks and LAN to LAN services.
Germany	
Greece	There have been no rollouts.
Hungary	There have been no rollouts.
Iceland	The PTA has issued two temporary licences for WiMAX tests (no commercial use). There were no particular services mentioned. The two companies with temporary licences are Iceland Telecom and EMAX EHF.
Ireland	ComReg has issued 2 trial licences for pre-WiMAX deployments and some pre-WiMAX equipment has been deployed in the licensed 3.5GHz band.
Italy	
Japan	There have been no trial services offered in Japan. However, some companies have expressed their intention to have trials.
Korea	ETRI conducted a field-test in November 2004 but no operator has trialled or rolled out the service. Preparations are being made for the commercial service scheduled to begin in June 2006
Luxembourg	No. There are no pre-WiMAX offers in Luxembourg. However, two operators in the 3.5 GHz band already have licences for WLL services.
Mexico	Alestra, a telephony operator is trialling pre-WiMAX services
Netherlands	Enertel is carrying out a Wimax pilot in a frequency range that is covered by their WLL-licence (the 3.5 Ghz range). This pilot is reported to be successful.
New Zealand	
Norway	Since the licences contain no roll-out requirements and no “use-it-or-loose-it” provision it is up to market players themselves to decide on when to implement and what to implement. Usually the licensees have no obligation to report to NPT regarding their roll-out, their coverage, their business plans etc. However, licensees have on a voluntary basis provided information which indicates that they are planning network roll outs based on WiMAX specifications. The former incumbent, Telenor, has indicated via the press that they are testing networks and applications based on WiMAX specifications.
Poland	NA
Portugal	Some licensed operators as well as public entities (mostly municipalities) have indeed demonstrated strong interest in developing WiMAX trials. This process is presently under analysis by ANACOM. UMIC is not aware of any on-going trial at the moment.
Slovak Republic	

Table 10. Pre-WiMAX trials

Have any operators trialled or rolled out pre-WiMAX services? Which operators and which services?
(Cont'd)

Spain	
Sweden	In Skellefteå there is a trial run by Mobile city, Intel and Teracom/Quadracom. The trial is addressing Fixed Wireless access in rural areas.
Switzerland	OFCOM has made concessions for WiMAX trials. Swisscom and *Services Industriels de Genève* (SIG), a power company in Geneva, have obtained permission to perform trials. CableCom, a cable company has also received permission to conduct trials. The concession for trials is, in principle, 6 months. This can vary according to the geographic location and the request.
Turkey	
United Kingdom	Spectrum users are not normally required to inform Ofcom of the air interface standard that they are using. Information from the media and stakeholders has shown that Telabria have published their use of pre-WiMAX systems in 5.8 GHz and there are likely to be others. For information, UK Broadband in 3.4 GHz band uses a sub set of the 3GPP UMTS standards which is not a WiMAX standard.
United States	See Clearwire trials as described in the document text.

Table 11. Potential WiMAX services

Which services will likely be offered over WiMAX (*e.g.* voice, video, and data)?

Australia	Given the current developments in the provision of wireless broadband services in Australia, it is anticipated that the full range of broadband enabled services could be provided using Wi-MAX. However, the particular services that companies who adopt this technology choose to offer are likely to vary depending on their plans.
Austria	Unknown, but according to licence: http://www.rtr.at/web.nsf/englisch/Telekommunikation_Frequenzvergabe_Bisherige%20Auktionen_BisherigeAuktionen_WLL-2004?OpenDocument
Belgium	Data
Canada	The services to be offered will be based on market demand and left to the operator. They will likely be wireless broadband capable of a variety of IP services including VoIP, IPTV, Internet access etc.
Czech Republic	NA
Denmark	All
Finland	All IP based services can be offered.
France	Data services will be offered and certainly VoIP. However, video will likely not be offered.
Germany	
Greece	NA
Hungary	Our expectation is that operators will typically offer data connectivity.
Iceland	Services will be decided by the market. No administrative regulations regarding services have been issued.
Ireland	To date, the types of services being actively deployed are broadband Internet access and leased line replacement solutions. VoIP is being deployed in some sectors and Ireland has made a number range available for this purpose.
Italy	
Japan	NA
Korea	WiBro is expected to deliver a variety of services such as interactive services (*e.g.* Web browsing, game interfaces etc.), streaming services (*e.g.* VOD & MPEG) and background services (*e.g.* FTP, e-mail, SMS, multicasting, MMS, Push to Talk etc).
Luxembourg	The results of the consultation will give a better global view of the services that will be offered.
Mexico	Data services will likely be the major component of service offerings.
Netherlands	All services.
New Zealand	
Norway	Whatever services for which there is sufficient demand will likely be offered. Sufficient demand means that market players find it commercially attractive to produce and offer the services. No regulatory constraint regarding the offering of different electronic communications services has been implemented in the licences so it is likely that the decisions will be market based.
Poland	NA
Portugal	Data, voice and video (in this order). Some operators have indicated that they would be willing to use WiMAX in the future as an alternative access network / last mile for offering triple play services.
Slovak Republic	
Spain	
Sweden	We expect data and voice services to be offered in the short term.
Switzerland	This information is likely to be contained in the forthcoming report on the public consultation.
Turkey	
United Kingdom	This is a decision for the operator, although WiMAX will support all types listed.
United States	The FCC does not predict what types of services will be offered in the future. However, the press has mentioned several possible services including low-cost broadband.

Table 12. Government subsidies

Would WiMAX rollouts in rural areas qualify for government subsidies?

Australia	The Australian Government's funding initiative to improve the availability of equitably priced broadband services in rural areas, the Higher Bandwidth Incentive Scheme, is technology neutral. The key issue for a service to be considered suitable is that it can satisfy minimum performance thresholds and maximum price limits that are required under the program.
Austria	It is unknown if there will be subsidies. There are currently no such subsidies from RTR nor TKK.
Belgium	There are no specific subsidies.
Canada	There are indirect subsidies that can be used for WiMAX. There are subsidies from various levels of governments to assist in connecting communities and bridging the digital divide. These are not specific to a technology and operators are free to select the technology that is best suited for the applications and offer a cost effective solution. Some of these programmes include Broadband and Northern Development (BRAND), the Municipal Rural Infrastructure Fund and Canadian Strategic Infrastructure Fund.
Czech Republic	The National Broadband Access Policy (Broadband Strategy of the Czech Republic) is technology neutral, so there are no restrictions in the sense of government subsidies for any technology.
Denmark	There are no subsidies planned from the State.
Finland	The Finnish government does not subsidise or support any broadband technology rollouts (ADSL, FWA, WiMAX, IMT-2000 etc.). However, there are some communities (or groups of communities) which are rolling out broadband networks in the rural areas. Most of these projects are applying for funds from the European Union, while others are using local funds in the community - some of which may come from the local governments. The Finnish government does not directly subsidize these projects.
France	There will certainly be subsidies but they will not be administered by ARCEP, but rather the operators and collective territories.
Germany	
Greece	Yes, there are subsidies available.
Hungary	As a broadband solution, WiMAX deployments can qualify for government subsidies as all subsidies must be technology neutral.
Iceland	There have been no published decisions on government subsidies.
Ireland	ComReg is an independent regulator and as such does not offer financial grants in this manner. However, the Department of Communications in Ireland is running a 'Group Broadband Scheme' which is promoting broadband roll-out in rural areas with financial grants available to interested communities. Further information is available at: www.dcmnr.gov.ie.
Italy	
Japan	
Korea	The government does not plan on offering subsidies. When WiBro service is classified as a nation-wide service, the telecom operators would have to bear the loss compensation cost.
Luxembourg	There are no subsidies planned from the State.
Mexico	The issue of subsidies is not clear but for now, is unlikely.
Netherlands	
New Zealand	
Norway	
Poland	
Portugal	State driven initiatives on broadband infrastructure roll out have been technologically neutral, so WiMAX roll outs would qualify under the same conditions as all other technological alternatives for existing government subsidies. There are also special initiatives (pilot projects) that aim at fostering emerging technologies trials.
Slovak Republic	

Table 12. Government subsidies

Would WiMAX rollouts in rural areas qualify for government subsidies?
(Cont'd)

Spain	
Sweden	They would have previously qualified for subsidies but the continuation of the programme is under evaluation and the payouts have been frozen for the moment.
Switzerland	These discussions have not been on the agenda yet in Switzerland. There have been no requests until now.
Turkey	
United Kingdom	Ofcom does not offer subsidies in the use of spectrum.
United States	In the United States there are no plans to initiate a government subsidy program specifically for WiMAX products. Under the Universal Service program, however, there is a Schools and Libraries support program (also called the E-rate program) which does provide subsidies for certain schools and libraries to purchase "internal connections" which might include wireless communications equipment. Government grants and low cost loans are available for certain rural telecommunication infrastructure projects.

GLOSSARY

3DES	Triple Data Encryption Standard
3G	Third-generation mobile network
3GPP	3rd Generation Partnership Project
ADSL	Asymmetric Digital Subscriber Line
AES	Advanced Encryption Standard
CDMA2000	Code Division Multiple Access 2000
CoS	Class Of Service
CSMA	Carrier Sense Multiple Access
DES	Data Encryption Standard
DFS	Dynamic Frequency Selection
DSL	Digital Subscriber Line
ESTI	European Telecommunications Standards Institute
EV-DO	Evolution, Data Optimized
FWA	Fixed Wireless Access
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HDTV	High Definition Television
HSDPA	High Speed Downlink Packet Access
IANA	Internet Assigned Numbers Authority
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	International Mobile Telcommunications-2000
IP	Internet protocol
ISM	Industrial, Scientific and Medical
ISP	Internet Service Provider
ITU	International Telecommunication Union
LAN	Local Area Network
LMDS	Local Multipoint Distribution Service
MAC	Media Access Control
MAN	Metropolitan Area Network
MDS	Multipoint Distribution System
MIMO	Multiple In, Multiple Out
MMDS	Multichannel Multipoint Distribution Service
MPLS	Multi-Protocol Label Switching
NGN	Next-Generation Network
OFDM	Orthogonal Frequency Division Modulation

GLOSSARY
(Cont'd)

PAN	Personal Area Network
PCMCIA	Personal Computer Memory Card International Association
PDA	Personal Digital Assistant
PSTN	Public Switched Telephone Network
QoS	Quality Of Service
RAN	Radio Access Network
RF	Radio Frequency
TCP	Transmission Control Protocol
TD-CDMA	Time Division, Code Division Multiple Access
TDMA	Time Division Multiple Access
TIA	Telecommunications Industry Association
TPC	Transmitter Power Control
TTA	Telecommunications Technology Association
UDP	User Datagram Protocol
UNII	Unlicensed National Information Infrastructure
VoIP	Voice Over Internet Protocol
VoWiMAX	Voice Over WiMAX
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WEP	Wired Equivalent Privacy
WiBro	Wireless Broadband
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WLL	Wireless Local Loop

NOTES

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