Empowering mobile broadband

The role of regulation in bringing mobile broadband to the mass market

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Executive Summary

Mass adoption of mobile broadband will profoundly change the way we access the Internet and change what we do with it. It will extend the user experience of fixed broadband connectivity beyond the home and the office, and give subscribers wide-area coverage and access to their favorite applications on a multitude of devices.

Subscribers have become more accustomed to wireless broadband data access and, after experiencing Wi-Fi wireless connectivity, increasingly expect to have the same broadband experience regardless of location using multiple mobile devices. Demand for mobile broadband is growing quickly and cannot be met by cellular technologies like Third Generation (3G) alone. High prices and limited throughput have kept adoption of 3G data services limited to business users. The popularity of Wi-Fi, the aggressive growth in the penetration of mobile and nomadic devices, and more generally the growth in fixed broadband and cellular subscriptions, indicate that the market is now ready for mass adoption of mobile broadband service. To make this possible, however, they have to be affordable and support both high-bandwidth and low-latency applications.

Mobile WiMAX™ technology is the technology that best meets the requirements for affordable, high-performance mobile broadband services. The wide industry support for the technology is a reflection of its potential to bring mobile broadband services to the mass market. The strength of WiMAX™ technology stems from a powerful combination of:

- Advanced performance,
- A wide variety of devices,
- Cutting-edge technology,
- Cost effectiveness,
- Support for mobility,
- Early commercial availability,
- Worldwide availability.

New technologies like WiMAX are available and needed to meet the demand for mobile broadband. Regulation plays an essential role in creating an environment that facilitates the commercialization of mobile broadband networks and the subsequent adoption of the service by subscribers. The rapid pace of technological innovation has created a highly dynamic environment which requires a new, forward-looking approach to regulation. Toward this end, the WiMAX Forum® recommends that regulators take four actions:

- Adopt a light and flexible regulatory framework that enables market forces to drive technological innovation.
- Choose a technology-neutral approach to spectrum management and licensing that allows operators to deploy the technologies and services that best meet their market requirements.
- Ensure that network operators have access to the appropriate spectrum and to the flexible spectrum arrangements they need for a viable business model, including domestic and international roaming.
- Act in a timely fashion to make the regulatory changes that will enable operators to meet the pent-up demand for mobile broadband services that exists in the market today.

1 Introduction

Recent technological innovations offer great promise for mobile broadband users. New technologies such as WiMAX have shown that it is possible to bridge the gap between fixed and mobile access and to offer the same subscriber experience whether on a fixed or a mobile network. We refer to this new type of service that combines the performance of a fixed broadband connection with the convenience and ubiquity of wireless technologies as mobile broadband.

Demand for mobile broadband services and applications is growing rapidly. Subscribers want to enjoy the freedom to be online wherever they are, choosing from a variety of device types and form factors, at a reasonable price. Subscribers are becoming more sophisticated and want to do more than just surf the web: they expect to access services and applications that have until recently only been available in home or office settings. Although we do not yet know which applications will dominate, subscribers require increasing amounts of bandwidth and are likely to spend more time online, using a variety of mobile and nomadic devices. In particular, the widely expected rapid growth in subscriber-generated content will drive demand for uplink capacity. More users and more traffic per user translate into a greater demand on the wireless infrastructure and on the spectrum that enables these new services.

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Policymakers can ensure their citizens enjoy the benefits of mobile broadband by implementing a regulatory framework that reflects four main directions:

- **Regulatory approach:** The rapid pace of technological innovation requires an increasingly flexible regulatory approach that provides network operators the ability to deploy new technologies offering better performance at a lower cost.

- **Technology neutrality:** The most effective way to make mobile broadband services available within a short timeframe is to let the market decide which technologies should be deployed. Network operators need to have the flexibility to choose the technology that best meets their requirements.

- **Spectrum availability:** The success of mobile broadband depends on the availability of sufficient and appropriate spectrum to support planned services at the traffic levels expected and with the flexibility to use the available spectrum for mobile, nomadic and fixed services.

- **Timing:** Demand for mobile broadband is unmet in many markets as with current technologies performance is limited or service plans are too expensive. Technologies that can meet this demand are available today and operators should have the opportunity to deploy them to meet the pent-up demand.

This paper explores these topics and develops recommendations for regulators as to how they can empower mobile broadband by allowing network operators to deploy new technologies like WiMAX. It starts with a brief overview of how WiMAX enables network operators to deploy high-performance, cost-effective networks that will bring mobile broadband to the mass market in the near future. The next sections present an assessment of the current availability and adoption of mobile broadband services, of the rapidly growing demand for mobile broadband services and of the benefits that mobile broadband brings to individual subscribers and the overall market. Finally, the paper discusses the role that regulation plays in fostering the availability and adoption of mobile broadband services.

The Annex presents an overview of the advanced technological features that make WiMAX the strongest technology to bring mobile broadband to the market today.

2 WiMAX™ Technology: bringing mobile broadband to the mass market

Mobile broadband offers many potential benefits to subscribers, but to fully take advantage of them it needs to meet several requirements. Mobile broadband has to provide robust support for applications that require high throughput (e.g. video and audio streaming, video calls, large downloads or heavy Virtual Private Network [VPN] use), or low latency (e.g. Voice over Internet Protocol [VoIP], online gaming and streaming). It also has to be affordable to promote mass adoption, which in turn is necessary to offset infrastructure costs.

WiMAX was designed from the ground up to meet these requirements. It is a next-generation technology that makes it possible to capitalize on the currently unmet demand for mobile broadband services by widening their market beyond business users, and by including more price-sensitive consumer users. The next-generation starts now: the first Mobile WiMAX™ products will be certified by the WiMAX Forum in mid-2007 and commercial deployments will start soon after.

A remarkably broad industry support has been instrumental in the development of the technology and of a robust certification program that tests for standards conformance and interoperability. The WiMAX Forum is the industry association that has led the efforts for worldwide adoption of WiMAX technology and that manages the WiMAX Forum Certified™ program. It has attracted 414 members from 51 countries representing the entire value chain, from component suppliers (70 members), to system vendors (91), service providers (137), and content providers and ecosystem players (116).

A combination of factors explains why WiMAX technology is the best candidate for successful rollouts of mobile broadband services:

- **Advanced performance:** WiMAX high-capacity base stations offer high per-user throughput and low latency, and support all those applications supported by a wired broadband connection, including real-time and bandwidth-intensive applications.

- **A wide variety of devices:** Laptop add-in cards and modules will be the first WiMAX subscriber devices to be introduced in the market. A wide variety of form factors will soon follow including PDAs, phones, game consoles, ultra-mobile PCs, MP3 players, and custom devices for vertical market applications. Internet Protocol (IP) architecture offered through WiMAX technology makes it easier to integrate and support these new devices.

- **Cutting-edge technology:** WiMAX is a technology developed and optimized for packet-based data applications and offers some of the most advanced functionality and spectral efficiency among commercially available wireless data technologies. Its native IP core network and support of IP Multimedia Subsystem (IMS) and MultiMedia Domain (MMD) will make it easier and cheaper to roll out new data applications and to interwork with other IP-based technologies. The use of Orthogonal Frequency Division Multiple Access (OFDMA), the multiplexing mechanism that is at the core of most next-generation technologies, including Third Generation Partnership Project's (3GPP) Long Term Evolution (LTE), brings higher throughput and improved indoor coverage. Quality of Service (QoS) functionality enables mobile operators to offer advanced services and to prioritize traffic from different applications. Finally, advanced antenna techniques like Multiple Input Multiple Output (MIMO) and beamforming bring further enhancements in throughput and range.

- **Support for mobility:** WiMAX technology supports seamless handoffs at vehicular speeds that enable subscribers to maintain their connection as they move across areas covered by different base stations.

- **Cost effectiveness:** WiMAX technology features spectral efficiency that enables network operators to carry more traffic and to deploy a cost-effective infrastructure. Manufacturing economies of scale are expected to drive down product production costs and promote wide product availability. Operator cost savings can be passed on to subscribers, thus widening the appeal and adoption of mobile broadband services to the mass market.

- **Commercial availability:** Mobile WiMAX technology is based on the Institute of Electrical and Electronics Engineers (IEEE) 802.16e-2005 standard, approved in December 2005, and on European Telecommunications Standards Institute (ETSI) High Performance Radio Metropolitan Area Network (HiperMAN). WiMAX Forum certification of Mobile WiMAX products will begin in mid-2007. Mobile WiMAX enjoys a two-to-four-year time advantage compared to cellular technologies like LTE and Evolution Data Optimized (EV-DO) Rev C at a time when the availability of affordable mobile broadband is not sufficient to meet demand for the service.

- **Worldwide availability:** Mobile WiMAX operates in three spectrum bands (2.3-2.4 GHz, 2.496-2.69 GHz, and 3.4-3.6 GHz) which have common allocations in most countries. It is a global technology that subscribers can use worldwide with a single device. The WiMAX Forum certification program tests equipment from different vendors for interoperability and standards conformance thus facilitating the use of the same equipment across markets. WiMAX fully supports roaming capabilities and the WiMAX Forum is already working towards a worldwide roaming framework.

For those readers who would like to learn more about WiMAX, Annex A contains a more detailed description of WiMAX technology, applications, devices and economics.

3 Market demand for mobile broadband

Two technologies currently dominate the market for mobile broadband services: International Mobile Telecommunications (IMT) 2000 3G technologies and Wi-Fi[1].

1. While Wi-Fi does not offer true mobility (i.e. the ability to handoff connections from one access point to the next while the subscriber travels at vehicular speed), it does support nomadic use (i.e. the ability to get connected at multiple locations), which is the access mode most common among laptop users, who are by far the largest and heaviest group of mobile data users today. In addition, Wi-Fi is often used in public transportation environments, where Wi-Fi connection mediates mobile data access.

The business strategies and adoption dynamics for 3G and Wi-Fi have been remarkably different. A comparison between the two offers a valuable learning experience.

3.1 The 3G experience

3G technologies were rolled out to provide an increase in capacity over Second Generation (2G) mobile networks, both for data and voice services. Global System for Mobile communications (GSM) and Code Division Multiple Access (CDMA), the two main 2G technologies, have been extremely successful at expanding the use of cellular voice services and basic narrowband data services like Short Message Service (SMS). To carry the rapidly increasing cellular traffic, mobile operators needed additional spectrum allocations and technologies with higher spectral efficiency. As voice accounts for the largest share of overall traffic, and in almost all markets for over 80% of service revenues, an increase in voice capacity was the highest priority.

3G technologies were developed to address these requirements, at a time when the Internet and broadband connectivity were still in their early days. As a result, 3G technologies like Wideband CDMA (WCDMA) and CDMA 1xRTT were initially optimized to carry switched voice traffic. Although 3G data capacity is higher than in 2G networks, 3G was not designed primarily as a data technology to support heavy subscriber use of packet-based data applications, like VoIP or streaming, that require low latency, or high throughput in a cost-effective way. Despite expected improvements in performance, technologies like High Speed Packet Access (HSPA) and EV-DO Rev A and B are severely limited by the lack of a native IP core and by the use of CDMA multiplexing. Wireless data technologies are migrating to OFDMA: 3GPP and 3GPP2 have recognized the need to change direction and are developing a new generation of OFDMA and IP-based technologies that are optimized to carry packet data traffic.

Building on the strong performance of its predecessors, GSM and CDMA, the initial market expectations for 3G were very high, especially because 3G was the first mobile technology to support broadband applications like video calls, content streaming and mobile TV, in addition to high-speed Internet access. The market reception of 3G data services, however, has been disappointing:

- The uptake among 3G laptop users has been very limited, as subscribers complain of high service prices and limited bandwidth. Vodafone Germany, one of the operators that has most aggressively targeted the laptop market, had only 140,000 laptop subscribers at the beginning of 2006. Verizon in the US had an estimated 650,000 EV-DO data-only subscribers in mid 2006, out of 55 million cellular subscribers.

- The limited capacity of 3G networks has forced operators to be cautious in the services they promote and to tightly control the network resources to avoid congestion. Most operators do not allow certain applications, including VoIP and video streaming. Even when they charge a flat fee, they frequently add “fair usage limitations” which determine the amount of monthly traffic allowed, often set to 1 GB which can easily be reached by subscribers.

- To further control traffic, mobile operators have developed applications they deliver exclusively through their portals, but these have only met with limited success. For instance, Multimedia Messaging Service (MMS) has never taken off and there are indications of decline in its use in countries like the UK, according to that country's regulator, Ofcom[2].

2. Ofcom, “The Communications Market”, January 2005.

Less bandwidth-intensive applications like SMS and instant messaging still generate more than half of data revenues in many markets. The increasing use of off-portal access, where allowed, suggests that subscribers want to have more choice in the applications available to them.

- Capacity limitations in 3G networks also impede the operators' ability to provide affordable broadband data services that are attractive to a large consumer market. The cost of supporting high levels of broadband data traffic in 3G networks is high and results in expensive data plans that only a small niche of business users can afford. This in turn makes it difficult for the operator to recoup the infrastructure costs met to roll out the service.

3.2 The Wi-Fi experience

The initial data from 3G data services incorrectly suggests that the demand for mobile broadband is low and limited to business users. The rapid growth of Wi-Fi suggests otherwise.

The success of Wi-Fi has taken the industry by surprise and was initially met with suspicion or rejection from mobile operators. The Wi-Fi model differs in significant ways from that of 3G:

- Wi-Fi adoption was driven by end-users, who typically purchase the connection devices. Service providers do not need to subsidize the subscriber unit and economies of scale have led to a much faster reduction in prices than typically seen in the cellular industry. The cost of adding Wi-Fi to a laptop is currently around US $20.

- Wi-Fi can be used in virtually every country worldwide. Despite being deployed in unlicensed bands that are shared by many technologies, a combination of market forces and superior performance has made Wi-Fi a truly global technology. Direct regulatory intervention (other than allowing the use of the technology in the 2.4 GHz band and in some cases relaxing previously defined constraints) was not needed. Increasingly, domestic and international roaming allows subscribers to use their service plan more extensively, in a way similar to that afforded by GSM.

- Few restrictions are placed on the subscriber's ability to access content or applications, as capacity rarely becomes an issue.

- Coverage areas are much more restricted than for cellular networks: Wi-Fi is well suited to high-bandwidth services in limited hotspot areas and cannot compete with 3G or 2G technologies in providing wide-area coverage. However, laptop users are often willing to travel to the closest hotspot where they can download or send their email, or do some work at higher data rates.

- Despite its more limited coverage, and the fragmentation of Wi-Fi service providers, Wi-Fi access through laptops is more widely used for public access than 3G in most markets.

3.3 Learned lessons

The experience with initial mobile broadband services points to a few instructive learning points:

- 3G performs an essential role in providing wide mobile broadband coverage, but by itself it cannot meet the demand for affordable data plans that support extensive use of bandwidth-intensive (content streaming) or real-time (VoIP, gaming) applications.

- 3G is rapidly evolving to improve its performance, but its switched, voice-centric approach limits its ability to meet the demand of an increasingly sophisticated subscriber base. New technologies like WiMAX and plans for technologies like LTE point towards alternative technologies that are optimized for IP data traffic and are better suited to provide the high-throughput, affordable data services that the market requires.

- The global success of Wi-Fi shows that market forces can be more effective than regulation in prompting the market to adopt the same technology worldwide. Although several different technologies competed against Wi-Fi including High Performance Radio Local Area Network (HiperLAN) and Home Radio Frequency (HomeRF), the market quickly settled on Wi-Fi as the technology of choice.

- Wi-Fi has become a widely adopted technology, now installed by default in most new laptops, without the need of hefty subsidies from the operators or without the need of backward compatibility with the existing cellular infrastructure. In fact, the lack of legacy ties to deployed technologies has promoted the emergence of new business models (e.g. the Wireless Internet Service Provider [WISP]), new product offerings (unlimited data access; 3G and Wi-Fi combined data plans) and new marketing channels (hotels or train operators selling broadband access).

3.4 Addressing the pent-up demand for mobile broadband

The growth in demand for mobile broadband is accelerating, but in most markets this demand is not met by the available services, either because service plans are not attractive or because of limitations in coverage or throughput.

In this context, basing estimates of future demand for mobile broadband on historical data from 3G adoption is likely to lead to underestimation. New technologies such as WiMAX will offer services that are substantially different from today's 3G services and will bring a fundamental paradigm shift in usage models, rather than only a gradual increase in performance. Growth in demand will be driven by several factors:

- Increasingly competitive infrastructure costs,
- Affordable service plans,
- High per-user bandwidth,
- Increased freedom to access any content or application available on the Internet,
- Wider choice of devices, from laptops to PDA's and phones, to consumer electronic devices,
- Ability to connect through different wireless interfaces (e.g. 3G, Wi-Fi and WiMAX), optimizing the quality of the data connection as a function of location and ensuring improved coverage.

The market for mobile broadband is maturing quickly. Growth in adoption of mobile data devices is driven by lower prices and the increased functionality that is packed in smaller form factors. Laptop ownership, for instance, is growing at a much faster pace than desktop PC ownership. Devices like laptops have become communication devices in which wireless connectivity is a prerequisite, increasingly taken for granted by business and consumer users alike.

Mobile broadband can count on a huge addressable market (Figure 1). Broadband subscribers are eager to have access to their favorite data applications when they are outside their home or office. Internet users that do not yet have a broadband subscription will look at mobile broadband as a complement or alternative to fixed broadband.

Cellular subscribers have become avid users of basic data services like SMS and messaging and they are ready to move to more advanced data services when they are available and affordable.

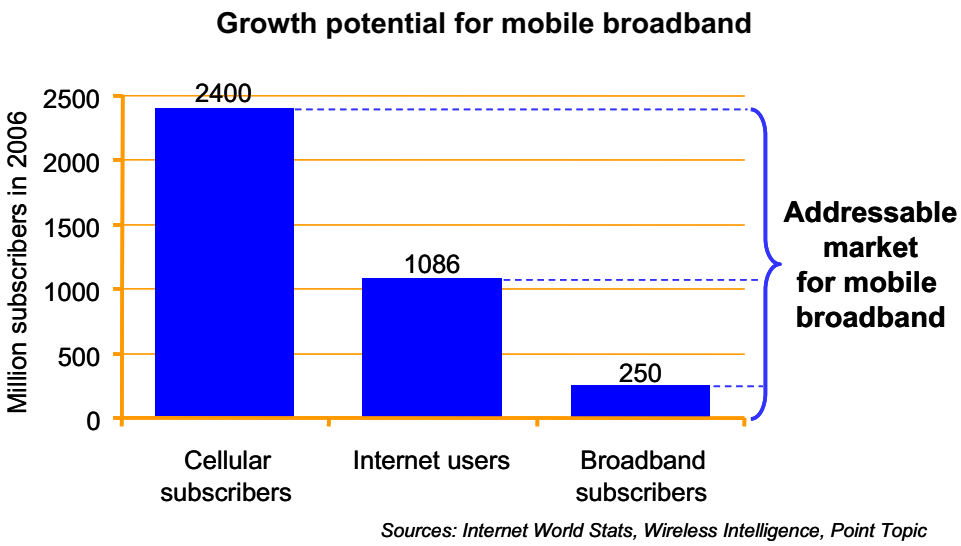

Figure 1. The addressable market for mobile broadband

4 Benefits of mobile broadband

Mobile broadband brings about an entirely new approach to data access that will profoundly alter current usage models. The main drivers are:

- **Ubiquity and mobility**. An affordable broadband connection, available beyond the confines of the office or the home, will substantially change the usage models for both fixed and mobile access. No longer will subscribers have to wait to get home to check the latest news or to check the price of a product they just saw in a store. Directions to an office or opening hours can be checked on the way there.

- **Mobile lifestyle.** The availability of broadband everywhere is particularly valuable to subscribers with highly mobile lifestyle, like students. A fixed broadband connection may be of little use to them and not worth the cost. A mobile broadband connection may act as the primary broadband connection, in the same way that the mobile phone has become the main phone line for an increasing number of subscribers.

- **Choice of devices**. Most broadband data connections are mediated by desktop or laptop computers today. The availability of phones, PDAs, and consumer electronic devices will challenge the dominance of the PC and open the way to increased flexibility and freedom in the choice of devices available to subscribers. Subscribers will increasingly have multiple devices that can be used in different situations (a laptop during a business trip, a PDA during a lunch break, a MP3 player during a commute, an online gaming console during the weekend), but likely use a single contract for personal broadband services.

- **Innovative applications**. Mobile broadband brings access to all the applications subscribers are accustomed to at home or at work. Their ubiquity makes them more valuable (e.g. traffic information or directions), or changes their scope (location-based mobile search increases the power of desktop-based search). New applications tied to the location of the subscriber or to specific device functionality (in the way that an MP3 player or a game console supports dedicated applications) are expected to emerge. The availability of affordable service plans that technologies like WiMAX enable will drive usage further, as subscribers are encouraged to try out new applications without worrying about high charges.

The impact of these drivers is far-reaching and goes beyond an improved daily experience of data connectivity. For instance, a mobile broadband connection means additional flexibility in organizing a work schedule and increases the productivity of those who do not work within a traditional office. Employees in real estate, deliveries, sales, safety and health, and whose job often takes them away from their desk, can benefit from a connection that keeps them in touch with colleagues and customers through their work day. Teleworking is further enhanced and does not even require the employee to be at home or at another fixed location. Parents can send off the last email of their workday as they wait to pick up their kids. Bus and rail riders can utilize their commute time to get a head start on the tasks waiting ahead.

Users with special needs also stand to benefit greatly from a mobile broadband connection that provides richer content. For instance, video calls will enable hearing-impaired subscribers to conduct calls in sign language.

Today, high prices for many types of service limit the appeal of a mobile broadband connection to high-end business users. Technologies like WiMAX will lead to increased penetration in the consumer market by allowing mobile operators to offer mobile broadband plans at affordable prices and subscribers to purchase easy-to-use entry-level devices at a lower cost. These factors will play an important role in bringing mobile broadband to the masses in both developed and developing countries and in transforming it into a tool for bridging the digital divide.

There are indications of strong demand for mobile data access in emerging markets. In many emerging countries, subscribers can often afford a mobile data device (their mobile phone) before they can afford a desktop and a broadband connection (or even a dialup connection) from home. Basic phones, however, offer very limited data functionality (in most cases, only SMS) and in these markets there is a widespread need for broadband applications, both for business and personal use, as shown by the huge popularity of Internet cafes. Low-cost mobile broadband devices and service plans may be the first opportunity for many of these users to have their own broadband connection, that can be accessed anywhere, without the need to have a fixed residential phone line or to go to the nearest public Internet cafe.

The mobile broadband infrastructure can also be used to deploy machine-to-machine vertical applications that would be too expensive to deploy on a dedicated network. Safety and security are among the most actively explored vertical applications. Mobile broadband makes it possible to monitor difficult-to-reach environments. Audio-visual information, for instance, the results of a chemical inspection (e.g. to locate explosives) or diagnostic tests (e.g. to identify a malfunctioning part in a train) can all be uploaded and analyzed remotely.

As with other technologies, the benefits of mobile broadband are not limited to those who use it on a daily basis, but will extend to the entire country. The deployment of cutting-edge mobile broadband networks will promote national R&D competitiveness and raise the profile of domestic equipment vendors. Employment opportunities will also result from additional manufacturing production, network deployment and service provisioning.

5 The role of regulation

Regulation played an instrumental role in driving the rapid adoption of cellular telecommunications worldwide and in creating the basis for international roaming. Regulators would like to see the success of GSM and CDMA repeated with mobile broadband. However, the accelerated pace of innovation over the past decade has made a new regulatory approach essential to stimulate the deployment and adoption of mobile broadband.

The impressive success of GSM across European countries has historically been attributed to stringent requirements from national regulators that all mobile operators use the same technology. But it is likely that uniform adoption of GSM within Europe would have occurred even without regulatory constraints. Mobile operators would have been likely to adopt GSM anyway because it was the technology that best met their requirements at the time. With a technology-neutral approach, Europe could have benefited from an earlier introduction of CDMA technologies, which could only be deployed with WCDMA after the allocation of 3G spectrum. An earlier move to CDMA gave a technological advantage to markets like the US, where a technology-neutral, market-driven approach already dominates.

In retrospect, 3G operators could have also benefited from less stringent requirements in some markets. For instance, the Time Division Duplex (TDD) bands, often allocated along with the Frequency Division Duplex (FDD) spectrum, mostly sit unused several years after the spectrum auctions have been concluded. Without a requirement to deploy specific technologies, these bands could now be used to deploy WiMAX or other mobile broadband technologies.

The rest of this section discusses how the specific changes brought by mobile broadband, and the current technological and competitive environment, call for a new, flexible regulatory approach that facilitates the adoption of emerging technologies and enables mobile operators to roll out affordable services.

5.1 A new role for regulation

The introduction of multiple digital transmission systems requires regulators worldwide to adopt a flexible approach and trust market forces to actively drive technological innovation. In the current dynamic environment dominated by a fast-paced technological innovation, the role of the regulator is likely to become more complex and wide-ranging. Rather than defining specific technology-based licensing conditions and spectrum allocations, regulators will increasingly need to define broad spectrum usage rights that allow network operators the freedom to adopt the most advanced and cost-effective technologies as they become available and that enable multiple wireless technologies to be deployed side by side while minimizing interference.

5.2 A technology-neutral approach

Technology developments and shifts in market demand happen in ever-shrinking timeframes, and it has become difficult to anticipate which technology will dominate and which services will be in greatest demand. The pace of change has accelerated in part because of heavier involvement by the computer and consumer electronic industries, which typically have shorter product cycles than the telecommunications industry. Wi-Fi is a clear example of a technology with a quick adoption cycle, mostly driven in a bottom-up fashion from laptop PC users, something few people predicted. WiMAX is expected to follow a similarly compressed timeline.

With increasing frequency, multiple wireless and wired technologies are integrated into a single device. The trend towards subscriber equipment that supports multiple wireless interfaces will enable users to automatically connect to the best network available, depending on location, device, bandwidth required and application used. To make this possible, network operators need to have the flexibility to roll out different technologies when and where appropriate. This will result in more intensive and efficient spectrum usage and a more carefully tailored package of mobile data services made available where most needed.

A technology-neutral approach allows operators to decide which technology to adopt and brings the necessary flexibility to the market, facilitating the deployment of cost-effective, advanced technologies. Spectrum allocations typically span 10 to 20 years and it is likely that at some time during this period an operator may decide to move to a different technology that better fits its requirements.

Mandating a specific technology discourages technological innovation, and in many cases it limits the ability for new entrants to compete in the marketplace. Allowing a choice of technology, operators can extend competition to technology. Furthermore, increased competition at the technology level will give users more choice: multiple technologies will increase the variety of services available, their pricing and the applications they support.

It is exciting to see that many regulators globally have rapidly recognized the importance of regulatory flexibility and have embraced a technology-neutral approach to spectrum management. This will ultimately increase overall spectrum availability and pave the way for new technologies like WiMAX.

5.3 Spectrum allocations

A key step to enabling the deployment of mobile broadband services is spectrum availability. 3G spectrum is used mostly for voice services and narrowband data applications. Technology-neutral spectrum allocations are needed to address the new requirements of mobile broadband and enable the deployment of new technologies unencumbered by legacy ties to existing technologies.

The 2.496-2.69 GHz band (also referred to as the 2.5 GHz band in the U.S. or the 2.6 GHz band in Europe) is currently the best candidate for mobile broadband deployments as it has been widely reserved for mobile services, but it has not yet been assigned for these services in many countries. Signal propagation in this band enables the deployment of mobile services in a cost-effective way. Higher frequencies (3.4-3.6 GHz or 5.7-5.8 GHz) are at present well suited for fixed and nomadic services and in many countries are available for deployment. The propagation properties in higher bands are less favorable to mobile access, with the exception of areas with high demand, as they reduce base station range and thus increase the deployment costs. In the 3.4-3.6 GHz band, nomadicity and limited mobility[3] can be supported in areas where demand is high (e.g. in urban areas) and a high density of base stations is required to meet the capacity requirements. Spectrum allocations below 2 GHz offer better propagation characteristics, but spectrum in those bands is typically already allocated and in use, and as yet there is no band that could become available in a majority of geographic regions, with the possible exception of the 700 MHz band, though in most markets this is not available in the short term.

3. In some countries this may not be possible as regulation prohibits roll out of mobile services in the 3.4-3.6 GHz band.

Particular actions to promote mobile broadband include:

- Open IMT-2000 bands to complementary data-optimized technologies like WiMAX. This approach leaves operators free to select the technology that best meets their market requirements. On a global scale this will enable all countries, especially emerging ones, which often do not have a legacy of 3G networks, to benefit from the advantages that new technologies like WiMAX bring.

- Permit mobile broadband services in other bands that have common global allocations. The 2.3-2.4 GHz band is emerging as a band that is widely available. In other markets, additional bands may be or become available for mobile broadband such as the 3.3-3.4 GHz band in India and in other markets, and the 700 MHz band over the next few years. While these bands are not yet available worldwide, their availability is a precious resource to operators, either to expand their mobile broadband services into the new bands for increased capacity or to develop services for specific market segments. For instance, they may reserve spectrum in the 700 MHz band for rural deployments.

- Let operators decide which services to offer within their spectrum holdings. In addition to choosing which technology to deploy, operators should have control over the level of mobility they want to offer. For instance, in many markets operators can only roll out fixed services in the 3.3-3.8 GHz bands. This approach not only limits the overall availability of services in the market and the ability of operators to gain revenues from the infrastructure they have deployed, but increasingly the distinction between fixed and mobile access ceases to be meaningful and difficult to define and enforce.

- Allow spectrum licensees to choose the duplexing scheme whether TDD or FDD. TDD duplexing is expected to dominate as it is best suited for data communications. TDD uses a single channel for the uplink and downlink which provides the necessary flexibility in managing inherently asymmetric data traffic. FDD uses two channels, one for the uplink and one for the downlink, and is well suited for symmetric services like voice, but can result in inefficient spectrum utilization for data services. In addition, advanced antenna technologies like MIMO and beamforming, which bring substantial increases in throughput, can be more easily implemented in TDD solutions.

- Introduce trading in rights of use in the secondary market. This regulatory component keeps technology ecosystems healthy and improves efficient use of spectrum. As business entities compete to provide the best services to end users, enabling shifts in geographic partitioning of spectrum, band disaggregation, ownership and leasing is likely to lead to more targeted services and better coverage for both business and consumer subscribers.

5.4 Timing

Finally, prompt regulatory action will allow citizens to benefit from mobile broadband services thanks to the convergence of three factors:

- A wide selection of mobile data devices with different functionalities, form factors and price points will enter the market over the next two to three years and will drive an increase in demand for connectivity. There is already pent-up demand for mobile broadband in developed and emerging countries, and network operators are keen to deploy new technologies now that support these devices and the services they support.

- Commercial availability of new technologies like WiMAX makes it possible for operators to start deploying the infrastructure in the short term. A flexible regulatory environment will enable them to

deploy these technologies using the spectrum they already have as well as in newly acquired spectrum bands.

- The impending allocations within the 2.496-2.69 GHz band in many countries makes the issue of spectrum assignment for mobile broadband time-critical, as this band offers the best prospect for worldwide availability of mobile broadband.

6 Conclusions

Mobile broadband is the segment with the fastest growth in mobile communications. The 3G infrastructure currently deployed is not sufficient on its own to meet the demand - present and future - for affordable mobile broadband services. Data-optimized technologies like WiMAX can complement 3G and offer high-performance, affordable mobile broadband services targeted to the mass market.

We are at the stage when we need a new, flexible and forward-looking regulatory approach that allows network operators to choose which technology to deploy and which services to offer to their subscribers, to keep up with technological innovation and the growth of demand in the market. This will in turn enable operators to offer the attractive and affordable service plans and applications that will bring mobile broadband to the mass market, in developed and emerging countries alike.

WiMAX technology is the strongest candidate for deployment as it is the first commercially available technology that is optimized for mobile broadband and provides the right cost-performance balance to meet the requirements of network operators and their subscribers.

Encouraging the availability and adoption of mobile broadband requires an innovative regulatory approach. The WiMAX Forum encourages regulators worldwide to take the following actions to facilitate the early adoption of mobile broadband:

- Adopt a light and flexible regulatory framework that enables market forces to drive technological innovation.
- Choose a technology-neutral approach to spectrum management and licensing that allows operators to deploy the technologies and services that best meet their market requirements.
- Ensure that network operators have access to the appropriate spectrum and to the flexible spectrum arrangements they need for a viable business model for mobile broadband access. This includes domestic and international roaming.
- Act in a timely fashion to make the regulatory changes that will enable operators to meet the pent-up demand for mobile broadband services that exists in the market today.

Annex A. The WiMAX™ technology advantage

Network operators who are committed to deploying mobile broadband can choose among multiple technologies. The WiMAX Forum believes that Mobile WiMAX[4] is the next-generation technology that is best placed to deliver mobile broadband services in four dimensions:

- Performance and technology,
- Timing,
- Selection of devices and applications,
- Economics.

1. Performance and technology

WiMAX performance is impressive when compared to leading 3G alternatives (Figure 2), both in terms of throughput and spectral efficiency, especially with the addition of MIMO and beamforming. The improved performance stems primarily from a different technology focus. WiMAX is a technology designed from the ground up for IP-based data applications: mobile broadband is the core application for WiMAX. 3G technologies support data access within a framework that was initially devised and optimized for voice applications. Not surprisingly, 3G technologies carry voice traffic more efficiently than does WiMAX.

Multiple performance advantages contribute to making WiMAX the technology that provides the best mobile broadband experience:

- **High capacity** supports a large number of customers per base station sector.
- **High throughput** per customer extends the range of available applications.
- **Low latency and robust QoS** functionality provides support for real-time applications, such as VoIP.
- **Fixed, nomadic and mobile services** are supported, making WiMAX a technology ideally suited to delivering a wide array of broadband services.
- **Worldwide availability** through the use of commonly allocated spectrum bands and a roaming framework.
- **Dynamic bandwidth allocation,** enabling flexible management of spectrum resources and a more efficient use of spectrum.
- **Easy integration within the wider wireless ecosystem**, encompassing technologies like 2G, 3G and Wi-Fi.

4. WiMAX Forum® specifications define two versions of WiMAX technology. Fixed WiMAX™ technology is based on Orthogonal Frequency Division Multiplexing (OFDM) and supports fixed access and currently operates in the 3.4-3.6 GHz band. The first WiMAXForum Certified products for Fixed WiMAX were announced in January 2006. Mobile WiMAX™ technology is based on OFDMA and supports fixed, nomadic, and mobile access. This paper focuses on Mobile WiMAX™ technology and specifications and all references to WiMAX refer to the mobile version, unless otherwise noted.

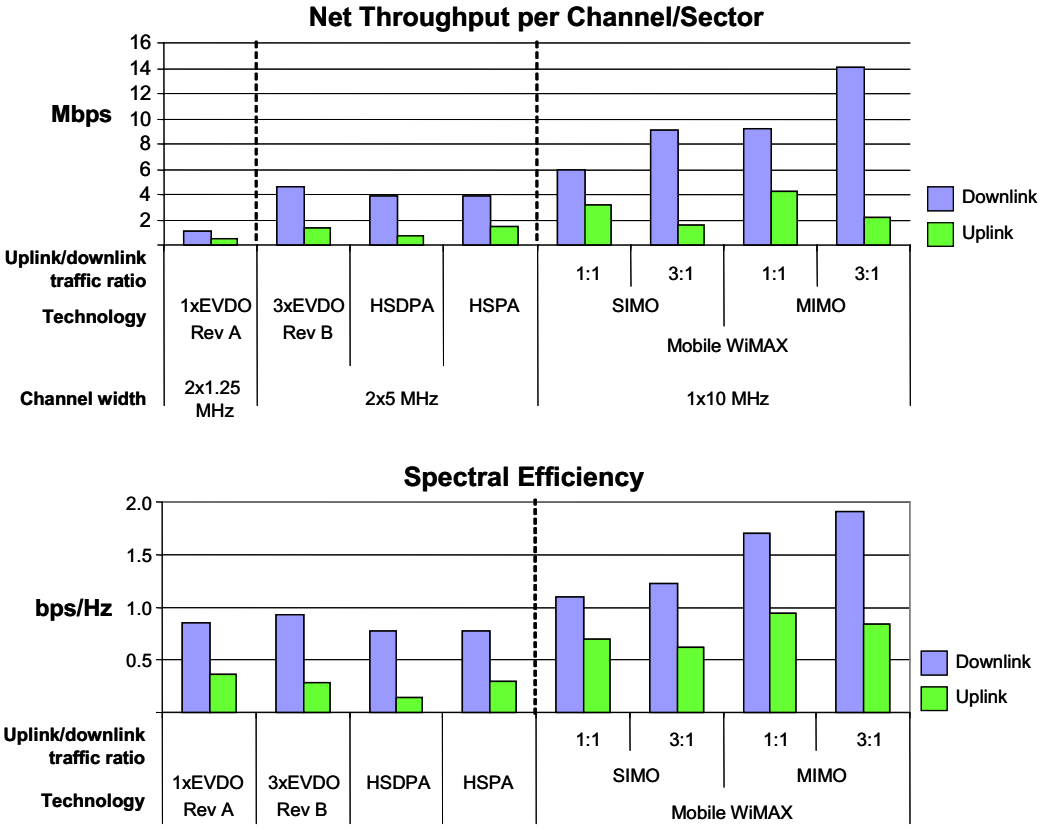

Figure 2. Performance comparison between WiMAX and 3G technologies. Note: 1xEV-DO uses one 1.25 MHz channel for the uplink and one for the downlink, 3xEV-DO uses three 1.25 MHz channels for the uplink and three for the downlink. Single Input, Multiple Output (SIMO) refers to the use of multiple (in this case, two) receiver chains at the mobile unit. No results for beamforming are shown as they are dependent on the base-station implementation and results can vary according to the deployment scenario. Source: WiMAX Forum.

The following technologies are critical to WiMAX advanced performance:

- **Orthogonal Frequency Division Multiple Access (OFDMA):** This is a multiplexing technique well suited to multipath environments that gives network operators higher throughput and capacity, great flexibility in managing spectrum resources, and improved indoor coverage. OFDMA has emerged as the technology of choice for next-generation mobile networks. 3GPP has incorporated OFDMA in its LTE specification and 3GPP2 is moving in the same direction.

- **Time Division Duplex (TDD) and Frequency Division Duplex (FDD)**: The IEEE 802.16e-2005 standard and ETSI HiperMAN support both duplexing mechanisms. However, the initial WiMAX Forum certification profiles for Mobile WiMAX only support TDD as this is the duplexing mode that is best suited for data applications and advanced antenna technologies, and one that most network operators and vendors prefer.

- **Multiple Input Multiple Output (MIMO) and beamforming:** These advanced antenna technologies bring a substantial improvement in throughput and coverage.

- **Multiple handoff mechanisms**: WiMAX implementations support a variety of handoff mechanisms that allow subscriber devices to maintain a connection while traveling at vehicular speeds.

- **IP core network**: The use of a common IP platform simplifies interworking with other wired and wireless technologies.

- **IP Multimedia Subsystem (IMS) and Multimedia Messaging Service (MMD):** Support for IMS and MMD further facilitates interworking and removes existing redundancies in the core network (Figure 3). With IMS and MMD, network operators can develop applications independently of the access technology within a flexible, layered architecture in which application modules can easily be modified or reused. To foster integration with other technologies, the WiMAX Forum has established the Networking Working Group which closely collaborates with service providers, the IEEE, ETSI, 3GPP and 3GPP2 to assure a unified network architecture that facilitates interworking, roaming and infrastructure sharing with current and emerging cellular and wired technologies.

- **Global roaming:** It allows subscribers to access different networks using the same device and a single, familiar interface. The WiMAX Forum is working towards a framework that will encourage the establishment of global roaming relationships among service providers.

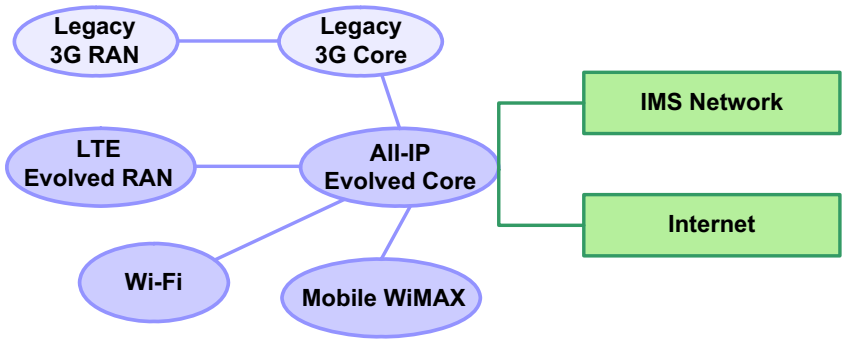

Figure 3. Role of IMS in a network with 3G, Wi-Fi and WiMAX. Source: WiMAX Forum

2. Product availability and evolution timeline

WiMAX is the most promising IP-based, standards-based, mobile broadband technology commercially available. The WiMAX Forum plans to begin certification of mobile WiMAX equipment in mid-2007. All mobile WiMAX products will support handoffs and power-saving mechanisms. More advanced mobile functionality, including support for high-speed handoffs, roaming, MIMO and beamforming, is expected to be available in equipment in the second half of 2007. WiMAX™ products will initially operate in the 2.3-2.4 GHz, 2.496-2.96 GHz and 3.4-3.6 spectrum bands.

WiMAX technology has a two-to four-year time advantage over LTE. Standardization efforts are still ongoing and LTE products are not expected to be available earlier than 2010. Like WiMAX, LTE is an IP-based based technology that is expected to use OFDMA multiplexing and support MIMO.

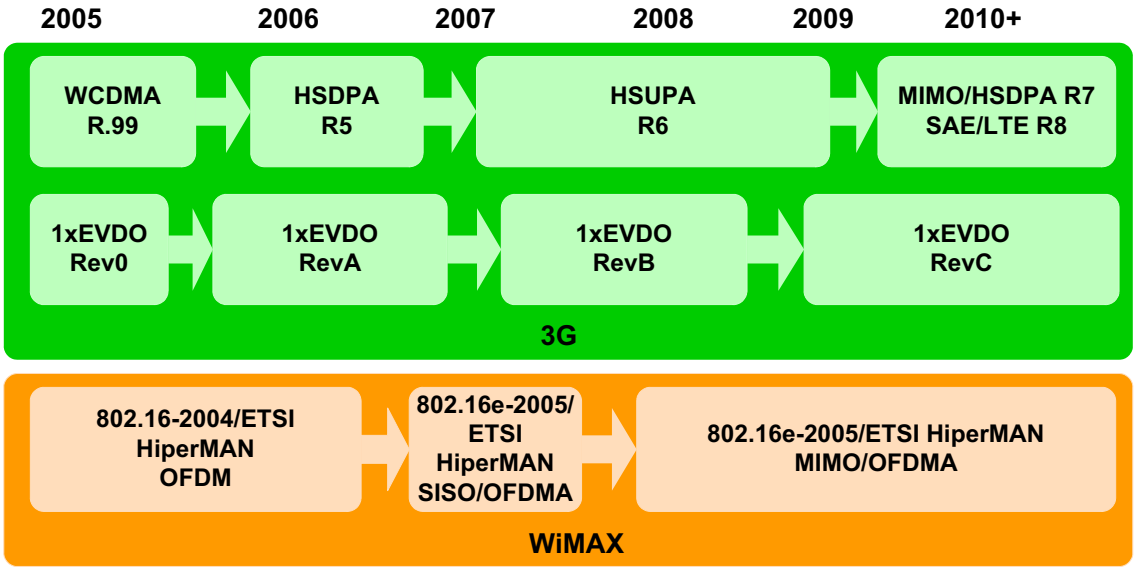

Figure 4. Technology roadmap for 3G and WiMAX. Source: WiMAX Forum

Network operators that want to deploy true mobile broadband services prior to 2010 or 2012 only have one choice since WiMAX is the only technology that offers the next-generation functionality needed to roll out attractive and affordable personal broadband services.

3. Applications and devices

WiMAX technology will promote the adoption of new devices and applications that take advantage of its high-throughput both in the uplink and the downlink, its low latency, QoS functionality and support for mobile access. Among the mobile devices expected to have a WiMAX interface are:

- Data centric devices: laptops, PDAs, ultra-mobile PCs,
- CE devices: game consoles, MP3 players,
- Voice and voice/data devices: cellular phones, smartphones,
- Vertical applications devices: CCTV cameras, in-vehicle devices.

Furthermore, WiMAX will encourage vendors to explore new form factors that current cellular technologies cannot support because of the capacity limitations or because of the cost of traffic transport. In particular, as chipset costs decrease, vendors will be able to develop low-cost devices specifically targeted at emerging countries. For subscribers that have never been able to afford a desktop, these may become their first broadband devices.

WiMAX will complement other wired and wireless interfaces. Most laptops, PDAs and handsets will include an integrated Wi-Fi and WiMAX chipset and allow subscribers to connect to the best available network. Subscribers will no longer face a trade-off between coverage and throughput: with a dual-mode WiMAX and cellular device, for instance, they will be able to connect to the WiMAX network where available, and still retain basic connectivity through 3G or 2G networks in the rest of the country.

When it comes to applications, WiMAX technology means freedom for both subscribers and service providers. Service providers are not forced to develop special applications for WiMAX products because those already existing will work in a WiMAX network just as they do on a wired one without any modification. However WiMAX networks will encourage the early emergence of mobile applications that address the specific needs of mobile Internet users.

VoIP is expected to be one of the most popular WiMAX applications. Its value proposition is immediate to most users: with a data connection plan, VoIP calls can be received or placed at a very low or, in some cases, at no additional cost. While WiMAX technology is not designed for switched cellular voice traffic as are cellular technologies like GSM, CDMA and WCDMA, it will provide full support for VoIP traffic thanks to QoS functionality and low latency. WiMAX will not challenge the voice revenues of mobile operators, as cellular networks offer a cost-effective infrastructure for voice communications with an extensive coverage that WiMAX is not designed to replace.

Other real-time applications like mobile video and audio streaming, videoconferencing and gaming, will greatly benefit from the QoS and low latency that WiMAX technology can provide. Virtual presence and virtual collaborations will also benefit from high uplink throughput that WiMAX technology can provide. They will become increasingly important as new devices optimized for these applications are introduced. Broadcast is another potential WiMAX application. Work is currently under way within the WiMAX Forum to further develop the Multicast and Broadcast Services (MBS) protocols within the standard to allow efficient multicasting of content.

Vertical applications like surveillance, public safety, connectivity to remote devices, inventory tracking, fleet management and educational services can also be supported by mobile WiMAX networks with little or no incremental cost to network operators. These applications require robust and reliable connectivity, but in most cases it would be prohibitively expensive to build separate networks to support them. A WiMAX operator is well placed to support these applications and to secure new revenue streams either by providing the service to new market segments, or by establishing wholesale relationships with service providers that focus on specific verticals.

4. The economics for WiMAX

WiMAX technology was designed from the beginning to be an all-IP technology that is optimized for high-throughput, real-time data applications and that is not beholden to a legacy infrastructure. WiMAX technology can be deployed both in greenfield deployments, where network operators rely exclusively on WiMAX networks for the wireless access infrastructure, and in overlay or complementary networks, where operators embed WiMAX technology within their networks to increase capacity and throughput as necessary to deliver true wireless broadband service.

WiMAX technology meets the growing mass-market demand for cost-effective, high-throughput broadband wireless services. The business case for WiMAX deployments is attractive as the cost of the equipment will be kept low through a combination of interoperable components based on open standards, mass adoption of subscriber units, an attractive Intellectual Property Rights (IPR) structure, and high base station capacity. In turn, its contained infrastructure costs and efficient spectrum utilization allow network operators to address demand from the mass market by offering personal broadband services at a price point that both business and consumer users will find attractive.

Mobile WiMAX equipment is based on WiMAX Forum specified implementations of the IEEE 802.16e-2005 and ETSI HiperMAN 1.3.2 standards and is certified by the WiMAX Forum to be interoperable with

other certified equipment in the same spectrum band[5]. Interoperability brings more choices to network operators and increases competition among vendors. Network operators are not dependent on a single vendor to provide both base stations and subscriber units, or to determine the pace and availability of upgrades.

The production costs for equipment based on open standards tends to decrease rapidly as the volumes shipped increase and with the entry of high-volume, low-cost, vendors into the market. The integration of Wi-Fi and WiMAX in a single chipset, and the commitment from device manufacturers to incorporate a WiMAX interface into their new products are expected to contribute to an even deeper cost reduction for subscriber units. The availability of low-cost subscriber units will further encourage adoption from subscribers, and in turn the presence of a large installed base will make deployment of the infrastructure more attractive to network operators. Wide scale deployments of WiMAX and Wi-Fi in laptop computers are expected for 2008.

An attractive IPR structure is another advantage of WiMAX. A fair IPR model can bring down the cost of developing and marketing products and provide for fair treatment for vendors that do not hold patents to essential IPR, which in turn facilitates increased competition in the market and the attractiveness of WiMAX to network operators. The WiMAX Forum is currently exploring solutions to provide a fair and reasonable rate and framework that will benefit both IPR holders and other vendors.

5. While equipment certification verifies interoperability within a single band, most subscriber devices are expected to support multiple bands (and receive certification for each band they support) as is the norm with cellular phones. In this case, the subscriber device can operate within multiple networks domestically and internationally.

Annex B. Further reading

[1] OECD (2005) The implications of WiMAX for competition and regulation
[2] Institute for Prospective Technological Studies, IPTS (2006) Mapping European Wireless Trends and Drivers. Technical Report EUR 2250 EN. Sponsored by the European Commission, Directorate General, Joint Research Center.
[3] Institute for Prospective Technological Studies, IPTS (2004) The Future of Mobile Communications in the EU: Assessing the potential of 4G. Technical Report EUR 21192 EN. Sponsored by the European Commission, Directorate General, Joint Research Center.
[4] WiMAX Forum (2005) Fixed, nomadic, portable ad mobile applications for 802.16-2004 and 802.16e WiMAX networks. Available at www.wimaxforum.org
[5] WiMAX Forum (2006) Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation. Available at www.wimaxforum.org
[6] WiMAX Forum (2006) Mobile WiMAX – Part II: Competitive Analysis. Available at www.wimaxforum.org
[7] WiMAX Forum (2006) Mobile WiMAX: The Best Personal Broadband Experience! Available at www.wimaxforum.org

Annex C. Acronyms

2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project Two
CCTV	Closed Circuit TV
CDMA	Code Division Multiple Access
CE	Consumer Electronics
ETSI	European Telecommunications Standards Institute
EV-DO	[CDMA] EVolution Data Optimized
FDD	Frequency Division Duplex
GSM	Global System for Mobile communications
HiperLAN	High Performance Radio Local Area Network
HiperMAN	High Performance Radio Metropolitan Area Network
HomeRF	Home Radio Frequency
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IMS	IP Multimedia Subsystem
IMT	International Mobile Telecommunications
IP	Internet Protocol
IPR	Intellectual Property Rights
LTE	Long Term Evolution
MAN	Metropolitan Area Network
MBS	Multicast and Broadcast Services
MIMO	Multiple Input, Multiple Output
MMD	MultiMedia Domain
MMS	Multimedia Messaging Service
MP3	MPEG (Moving Pictures Experts Group) Layer 3
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PDA	Personal Digital Assistant
QoS	Quality of Service
RAN	Radio Access Network
SAE	System Architecture Evolution
SIMO	Single Input, Multiple Output
SMS	Short Message Service
TDD	Time Division Duplex
VPN	Virtual Private Network
VoIP	Voice over Internet Protocol
WCDMA	Wideband CDMA
WISP	Wireless Internet Service Provider

About the WiMAX Forum®

The WiMAX Forum is an industry-led, nonprofit corporation formed to help promote and certify the compatibility and interoperability of broadband wireless products using the IEEE 802.16 and ETSI HiperMAN wireless MAN specifications. The WiMAX Forum's goal is to accelerate the introduction of these devices into the marketplace. WiMAX Forum Certified™ products will be interoperable and support metropolitan broadband fixed, portable and mobile applications.

For more information about the WiMAX Forum and its activities, please visit www.wimaxforum.org.

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