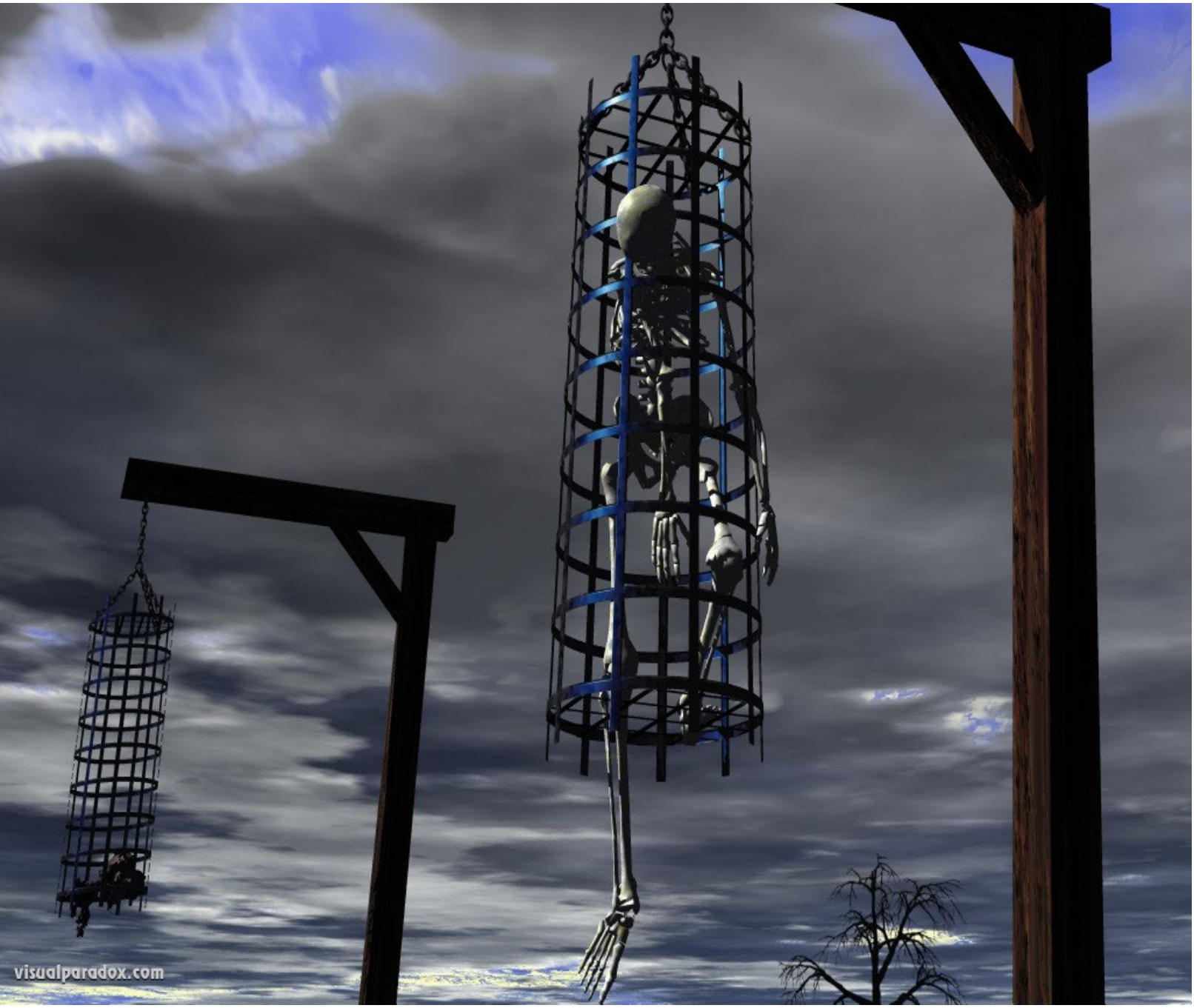
The development of WiFi and WiMAX

The 3G Death march?



1. Summary

This study examines the situation of the wireless broadband access industry. The industry may be undergoing a disruption. The traditional telecommunication vendors and operators are introducing the third generation (3G) of mobile phones and networks. At the same time, IP-based wireless technology such as WiFi and in the future WiMAX grows ubiquitous.

Our findings suggest the following:

The WiMAX standard will represent a great opportunity for emerging markets, rural areas in developed countries as well as populated areas with a demand for "hot-spot" wireless broadband services.

WiMAX can and probably will represent both opportunities and threats for both fixed and mobile operators. The distinction between fixed and mobile telephony will become blurred.

We expect the cellular 2G networks and the WiFi/WiMAX technologies to be symbiotic for the coming years.

The upcoming WiMAX technologies will be disruptive to the 3G technologies. We expect that the 3G vendors and operators either will be forced undertake further significant investments in their technology and networks to upgrade to the future OFDMA standards (802.20) or have to accept writing off a large part of their 3G investments.

2. Introduction and scope

This project report is written as a part of the course 15.365J Disruptive Technologies in the spring of 2005. The course is taught at the Sloan School of Management at Massachusetts Institute of Technology by Professor James Utterback.

The team members have been Trond Jacob Botheim, Matti Kinnunen, Eivind Surdal and Per Morten Torvildsen.

This report explores the broadband wireless access (WBA) industry and its possible influence on the still emerging 3G cellular technology. The two technologies approach the same market of mobile data communication from two different angles. On one hand, there are third generation cellular phone networks, which are based on global standards by the telecommunication industry standardization body 3GPP or similar. On the other hand, coming from the internet and computer industry, there are the WiFi and WiMAX technologies. The two technologies are competing for the same market, which could mean that one could suppress the other.

By 3G technology in this context we mean the radio network technology, more precisely denoted by UTRAN (leaving CDMA 1X EV-DO aside). UTRAN is the radio network standard for UMTS networks and its radio interface component is called UTRAN-FDD (for frequency division duplex). UTRAN uses a radio technology called Wideband Code Division Multiple Access (WCDMA).

WiFi is a denomination of wireless technology complying with the IEEE 802.11 series of standards. WIMAX denotes systems compliant with the IEEE 802.16 standards. These technologies standardizes at the lower ISO levels as radio transmission equivalents to IEEE 802.3 Ethernet LAN and lack higher-level functionality of cellular networks. For the purpose of performance comparison, this is not a concern. Networks built on WiFi technology are called WLANs.

These different technologies differ from each other in terms of performance, cost, and maturity. The two technologies also have different proponents, and their eventual success would be dependent upon different industrial structures. The cellular industry originally is largely self-sufficient with user equipment, network equipment and network operators. The emergence of distributed networking based on WiFi and Wimax is dependant on the growth of fixed broadband infrastructure, the proliferation of laptop computers and smaller devices with wireless facilities and the growth of VoIP (voice over IP) fixed telephony. Distributed networking could also depend on new business models, as uniform payment and access control schemes may arrest the development of the technology – and we may even see the return of wireless infrastructure as a public utility as a consequence.

The scope of this report is the following: We first study the trajectories of factors enabling the emergence of WBA services. We then examine the technological performance of the technologies involved and their evolution. Next, the product and

technology architectures are discussed and the cost structures are compared with the incumbent technologies.

The influence of environmental, social and political trends as well as the regulatory conditions in which the technologies evolve is discussed.
The question whether a dominant design has emerged in the WBA industry is examined from the perspective of standardization and compliance of equipment and from the study of the ecology of market players.

Finally we conjecture on the future of the rival technologies.

3. Evaluation of some major trajectories

3.1. Indicative signals for the development of future technologies

Our work concludes that there are several signals in the marketplace for the future technologies and drivers for future services. From our point of view the development patterns discussed below will be the main indicators for future technologies.

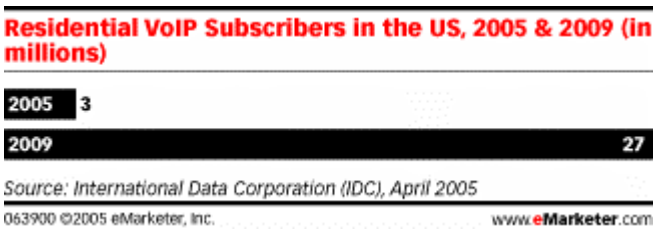
3.1.1. Development of VoIP

In the western world there is a rapid movement from the traditional circuit switched voice services to packet switched voice services in the fixed networks. The growth of packet switched voice is taking place along two paths. One trend is voice over IP (VoIP) using traditional analogue or ISDN telephones with a modem/interface to an xDSL or CATV broadband network.

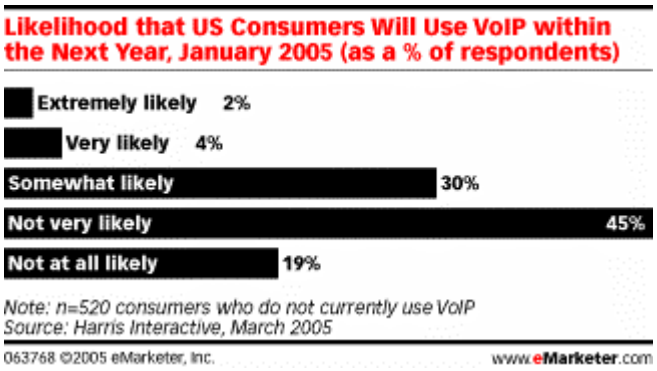
The other trend is voice over Internet, using PCs and PDAs as handsets and transmitting voice through an Internet based application. Examples of such applications or services are Skype, Vonage and MSN. These types of applications need a network connection, which may be fixed or wireless (i.e.WiFi). Today most portable PCs are sold with integrated WiFi chipsets/interfaces. The use of Voice over Internet applications is growing rapidly.

These trends are in our opinion important enablers for growth in the future WBA market. The market potential for the coming WiMAX technologies will be strengthened if a growing share of the consumers and businesses are used to and comfortable with voice being an important data application.

The growth of VoIP may be fuelled by increasing availability of the services: WiFi may facilitate nomadic use and Wimax may make them ubiquitous. Presently there are only 3 million residential VoIP users in the US, and only 27 million projected by 2009. Only 6% consider themselves very or extremely likely to start using VoIP within the next year[1].

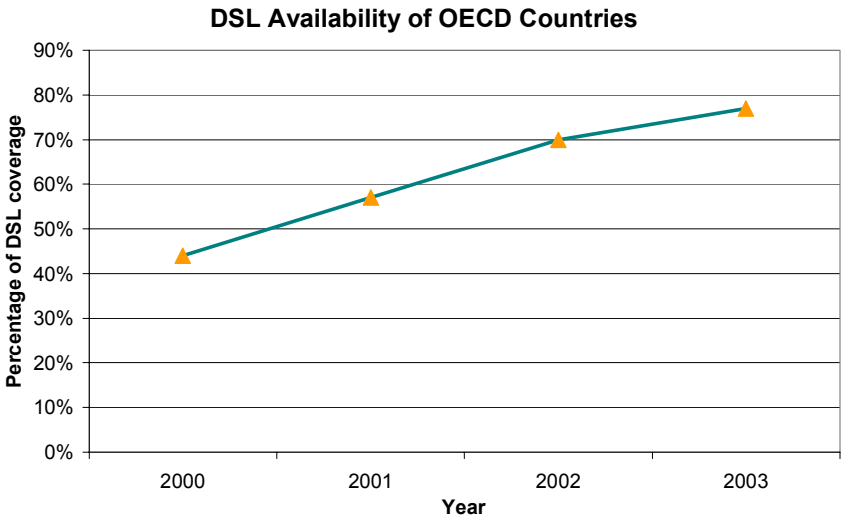


[1] VoIP Still Has a Long Distance to Travel, April 05, 2005 IDC; Harris Interactive



3.1.2. Broadband development

All over the western world the fixed broadband market is growing rapidly. The service is deployed using a variety of technologies. Incumbent traditional Telcos typically use copper access cables for xDSL access. This is often the case for the OECD countries, as shown in the figure to the right.



Source: *Organization for Economic Co-operation and Development*
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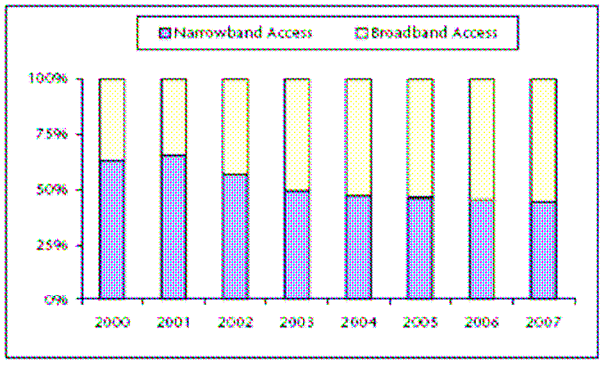
Pyramid Research has estimated that the global market will change from the traditional narrowband technologies (i.e. analog, ISDN) to broadband technologies. The figure to the right shows the projected distribution of capital expenditure between narrowband and broadband access technologies until 2007. These numbers are collected from the 24 largest Telcos. There is a clear trend that investments are changing from narrowband to broadband. These figures only apply to the telecom copper access networks. They do not include investments in Cable TV, fiber-optic cables and wireless access technologies.

EXHIBIT 3 Global Narrowband vs. Broadband CAPEX, 2000-2007



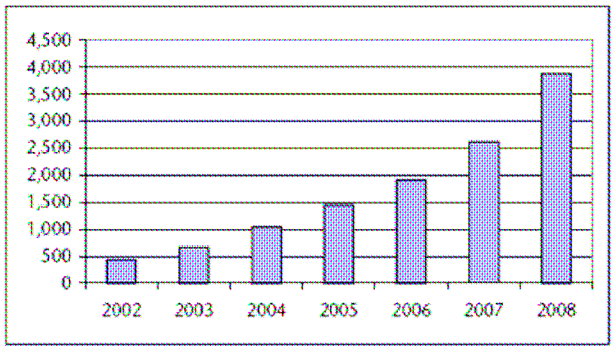
Source: Pyramid Research Report: *Fixed CAPEX: Trends, Opportunities and Profiles of the 24 Largest Telco Spenders.*

The xDSL based technologies use the traditional copper cables originally installed for telephony. In many densely populated areas Cable TV networks (CATV) offer an alternative infrastructure for internet access. These alternative access technologies are developing

rapidly. They are capable of handling bandwidths/data rates up to 100 Mbps. Access through fiber-optic cables offer what for all practical purposes is unlimited bandwidth, but this access technology is primarily used for commercial buildings and not in a consumer household market.

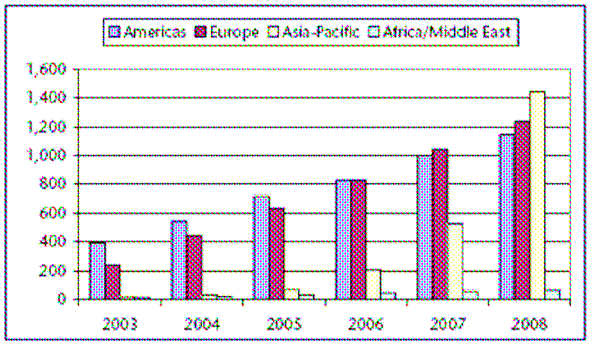
A third trajectory curve is the growth in fixed wireless broadband accesses (FWBA). This is fixed broadband lines using wireless equipment for user access (the last mile). These technologies are well suited for areas were there is no fixed infrastructure (copper cable or CATV) present. The most common technology is point-to-multipoint radio in the frequency bands from 1GHz to 40 GHz. Pyramid Research expects the use of this technology to grow from 20% to 40% annually, serving nearly 4 million subscribers in 2008. FWBA solutions have traditionally served niche markets. These markets were in rural areas in the US and in second- and third world countries where it is expensive to develop a fixed infrastructure. The solutions were historically proprietary technologies that operated in a few limited spectrum bands (i.e. LMDS and MMDS). These solutions were also limited to "line-of-sight" deployments, typically in relatively flat, unobstructed terrain where the home receiver required a direct line-of-sight to the base-station tower. These technologies have got a significant opportunity in the traditional markets and a huge potential in growth areas without fixed infrastructure. Here WBA can be used to develop the communications infrastructure at an affordable cost.

EXHIBIT 18 Global Broadband Fixed Wireless Subscriber Lines (000)



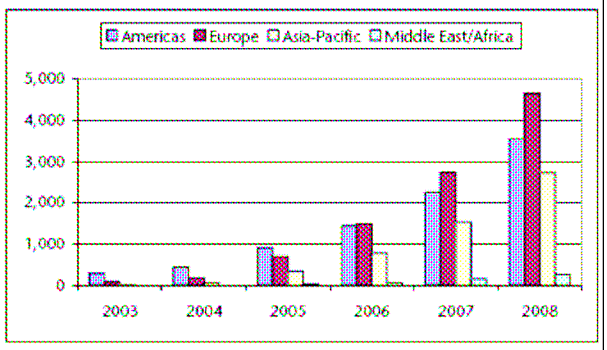
There are different opinions regarding the growth rates for this technology. There are also different opinions on what parts of the world will see the fastest adoption of this technology. Intel and Pyramid Research seem to agree that underdeveloped areas without a historical infrastructure will be the dominant markets. Intel expects the European market, especially the previous Eastern bloc to be the leader in adopting this technology. The total market is expected to grow to 7 million in 2007. Pyramid Research expects the Asian market to be the fastest growing and the total market to reach 2.6 million by 2007. The different estimates are showed in the charts below.

EXHIBIT 38 Pyramid – Broadband Fixed Wireless Subscriber Lines



Source: Pyramid Research.

EXHIBIT 37 Intel – Broadband Fixed Wireless Subscriber Lines



Source: Intel.

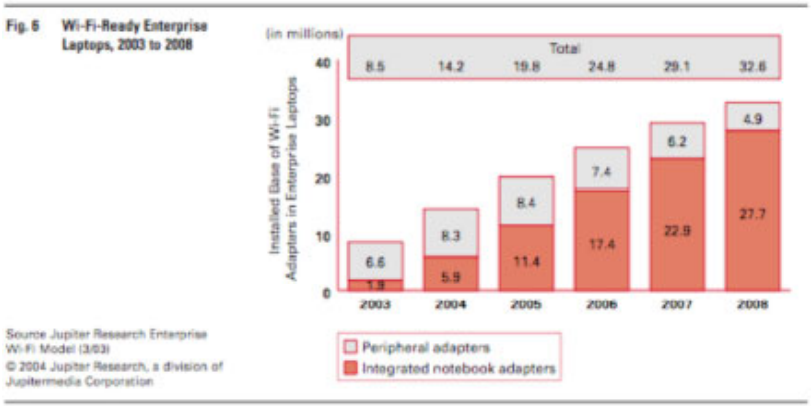
The total market for WBA equipment is forecasted to grow from $558.7 million in 2003 to more than $1.2 billion in 2007[2]. The market for WBA services is forecasted to grow from $650 million in 2004 to $2.4 billion in 2007[3].

3.1.3. Development in CPE/user equipment

In our opinion there are several trends in the user equipment area that are important. One of these trends is the growing number of portable PCs and the features modern portable PCs have.

Portable PCs and/or PC compatible PDAs are becoming a standardized and commoditized tool that is carried around by an increasing number of people. Most of the new portable PCs are sold with standardized wireless network adapters. Today the standard technology is 802.11 WiFi. According to Intel several PC manufacturers plan to integrate chipsets for 802.16 WiMAX in new portable PC models.

Enterprise Laptops with Wi-Fi Capability Will Top 32 Million by 2008



Another important trend can be seen cellular telephone market. The cellular phones are being transformed to multimedia PDAs. Cameras, MP3 players, Web browsers, Microsoft Office compatible software portfolios and standardized interfaces for communication with PCs are standard features on new phones. The manufacturers and cellular network operators are emphasizing the

[2] In-Stat/MDR
[3] SkyLight

benefits of using the cell phones as PDAs to access the Internet. They want to the consumers to use the 2G and 3G networks as an access method to the Internet.

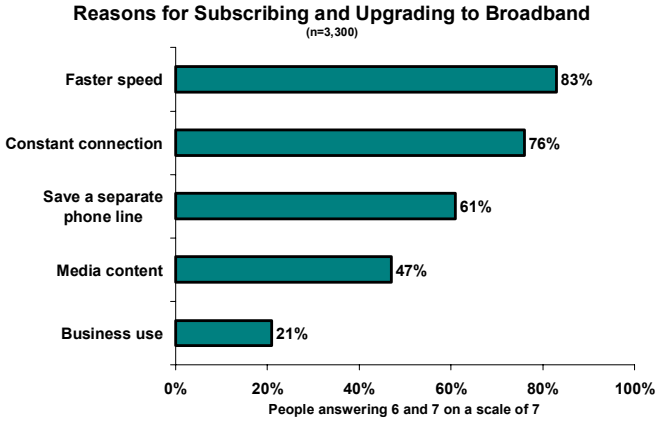
This picture is about to change. The first cellular handsets with integrated WiFi chipsets will soon be in the marketplace. Motorola and British Telecom will launch the Bluephone, the first device of this kind. The Bluephone will be able to use both the 2G and 3G networks and WiFi based broadband networks for voice services. Hutchinson, a Hong Kong-based telecom group has recently launched a new phone/PDA in cooperation with Skype, a supplier of voice over Internet software. This device will use WiFi and voice over Internet as a standard service.

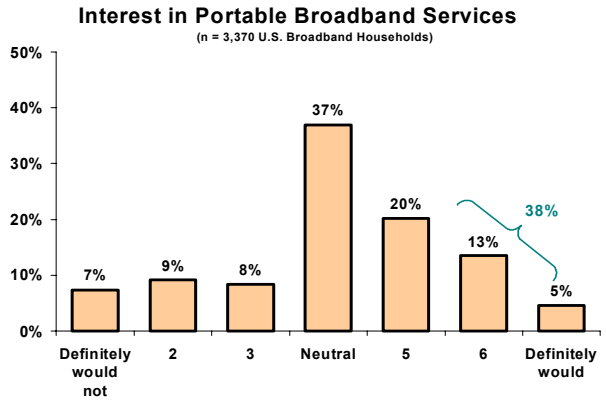
The traditional voice and data based equipment on the CPE side seem to be converging. Major PC manufacturers are already planning to integrate the 802.16 WiMax chipsets as a standard feature in new PCs and PDAs. Based on our view of the future technology trajectory it seems likely that the distinct borders between PCs and phones we have been used to will be wiped out.

3.2. Market development and development of user preferences

Based on our analysis there seems to be several factors driving a rapid growth of WBA. These factors are based on user tastes and user preferences.

One main reason is the demand for faster speed as the consumers are increasing their use of network services on their PCs. Rapidly growing services like music download, video streaming, remote office applications (VPN) and the generally increasing use of the Internet are key drivers. Research carried out by Parks Associates in the US shows the main user reasons for upgrading to broadband (see figure below).

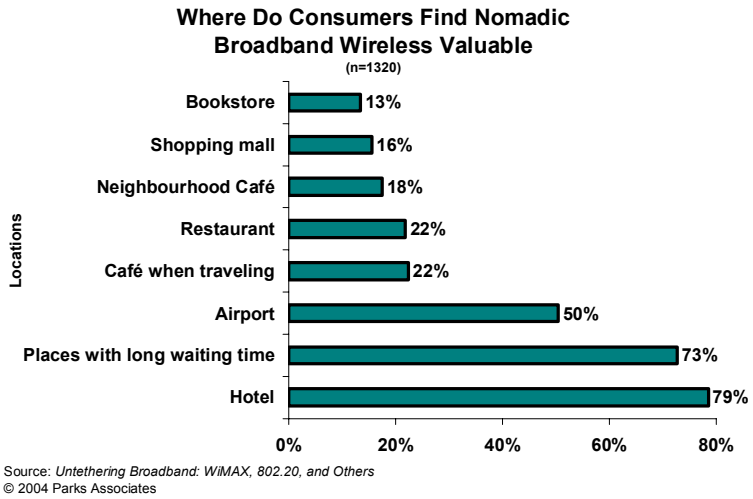




Source: *Unlicensed Broadband Wireless: Solutions and Applications*
© 2004 Parks Associates

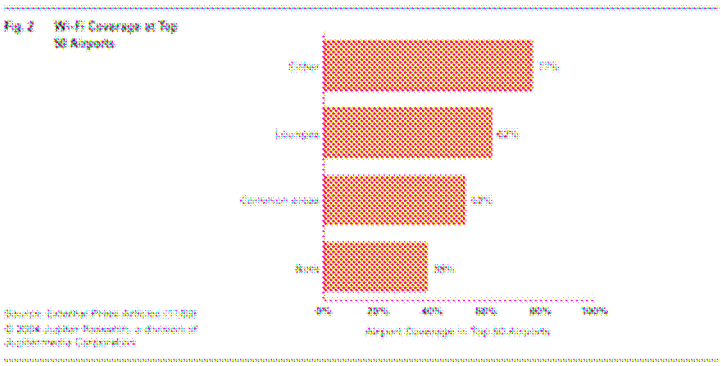
The growing number of portable PCs and PDAs reinforces a user preference for mobile wireless access. People are traveling more and carry their portable equipment wherever they go. They would also prefer to have high speed Internet access wherever they are. Consumer research made by Unlicensed Broadband Wireless in the US market in 2004 shows that 38% of the respondents have got an interest in wireless broadband access (see figure above).

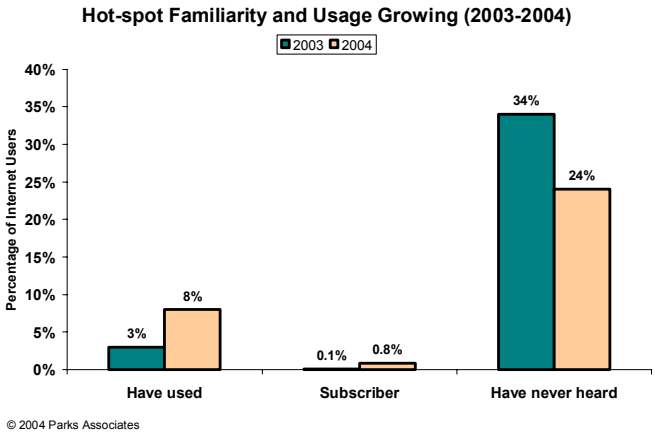
Research from Unthering Broadband in 2004 year shows where the US consumers find wireless broadband access most valuable. There are several public areas where people find access valuable, with hotels and airports at the top of the list. It is also interesting to see that the second highest score is "places with long waiting time". It seems that consumers would like to be able to log on to a wireless broadband when they get into a situation where they have to spend waiting time.



Source: *Untethering Broadband: WiMAX, 802.20, and Others*
© 2004 Parks Associates

Research by Jupiter Research also shows that WiFi based WBA is widely available in airports.





© 2004 Parks Associates

Park Research has measured the knowledge about and use of wireless access in public "hot-spot" areas. The figure shows that both knowledge and use have increased significantly from 2003 to 2004.

3.3. Potential network effects

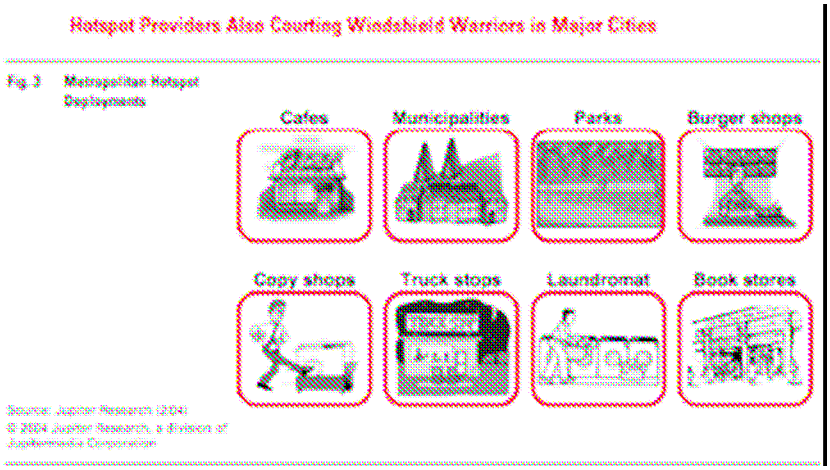
Based on our understanding of the markets and the technology trajectories, there seems to be several network effects in the marketplace that push the development of WBA forward. A likely result of these network effects is a convergence of voice and data in these wireless networks.

One important network effect is the growing use of voice over Internet software and development of user communities like Skype and MSN. The members of these rapidly growing communities are using their PCs (portables) as voice and data communication tools within the community. In the case of Skype, it is also possible to call ordinary phones using the voice over Internet software.

Another potential network effect is the rapid growth of WiFi hot-spots and WiFi access in service areas like coffee shops, fast food restaurants and malls. These establishments often offer free WiFi access to attract customers. The payment for the service is a part of the primary product, such as food and coffee. As soon as some shops in an area introduce such free broadband service, the network effects will soon make it necessary for similar shops to follow suit to remain competitive.

A third potential network effect is related to government visions and public opinion related to broadband services. Tapei, the capital of Taiwan, is making WiFi access available as a public service to its approximately 5 million inhabitants. 90% of the citizens will be covered by the end of 2005. Building this network will require approximately 20,000 wireless access points. The US city of Philadelphia is working to meet a similar goal. Through a large project named Wireless Philadelphia the city is planning to offer WiFi as a public service. The objective is to create a digital infrastructure for open-air internet access. The purpose is to help citizens, businesses, schools, and community organizations make effective use of wireless technology to achieve their goals and provide a better experience for visitors to Philadelphia. Mayor John F. Street has got a vision of bringing affordable broadband data communications anywhere, anytime, to anyone that needs it within the city.

We assume that when major international cities and countries start offering wireless broadband access as a public service it will cause a network effect on other cities and countries, fortifying the growth of global wireless broadband.



3.4. Social, political and environmental signals

3.4.1. Is the use of mobile telephony safe?

Concerns about possible health effects from the use of mobile telephony have been raised from time to time. Media in some cases seem to be able to create a lot of attention over scientific studies, sometimes exaggerating the conclusions and reporting them outside of

their original context. As a result, there is at times a debate on the safety of mobile phones.
The UK Health Protection Agency has issued a statement that summarizes the available research on mobile phones and health[4]. Quoting the UK Health Protection Agency: *The main conclusion is that there is no hard evidence at present that the health of the public, in general, is being affected adversely by the use of mobile phone technologies, but uncertainties remain and a continued precautionary approach to their use is recommended until the situation is further clarified*.

From this statement, one may conclude that mobile telephony is safe, as far as we can tell at the present time. Health effects, if any such exist, may not be visible in many years. Health concerns do not seem to have affected the proliferation of mobile telephony so far, and there is no reason to suspect that health concerns in any way will discriminate between mobile telephony based on the 2G and 3G technologies on one side and WiFi and WiMAX on the other side.

3.4.1. Political signals

The role of the regulators is discussed in detail in chapter 7.1. There does not seem to be any intention to try to hinder the development of VoIP and WiFi as alternatives to POTS and other forms of wireless communication. It may even be the case that the operations of the VoIP service providers may not be regulated in the same way as traditional telecoms operators. In this sense, the VoIP service providers may have a larger degree of freedom than the traditional telecoms operators.

The idea of WiFi coverage as a part of the public infrastructure is discussed in detail in chapter 3.3. There are plans to build large-scale networks offering WiFi access in many cities. Many cities see this as a natural part of the infrastructure a city offers its citizens. There is an ongoing debate about whether this is a natural role to take on for cities. Some groups think that the development and especially the operation of such an infrastructure should be left to the market. The attention that the concept of "WiFi cities" has gotten clearly shows that the market may be pushed forward by cities and governments.

3.4.2. Social signals

The values of the younger generations may offer some interesting insights into the future of the industries we are looking at. The generation that grows up today has always had access to the Internet and mobile phones. They use it all the time and spend a considerable part of their income on these services. They are also used to downloading movies and music from P2P networks such as Kazaa and Napster. There are legal issues with the copying of content without paying for it, but once people have gotten used to free services it may be difficult to change the established habits. These days, the issue of technology to make it impossible to copy CDs is a hot topic. Many young people do not seem to see the point with copy protection. For many of today's young people the use of

[4] UK Health Protection Agency: Mobile Phones and Health, January 11th 2005, http://www.hpa.org.uk/hpa/news/nrpb_archive/press_releases/2005/press_release_02_05.htm

different gadgets is an everyday activity. Trying a new PDA with WiFi and Skype installed is no big deal. With free WiFi access in a growing number of places, and strong network effects (discussed in detail in chapter 3.3.), it is likely that the use of traditional mobile telephony will decrease. If one transfers these attitudes to telephony services, it seems logical that many people will not be as willing to pay for telecom services in the traditional way with a monthly subscription fee and extra charges according to usage.

In the report from Jupiter Research[5] there are data that shows that people are willing to try to WiFi services in public areas. Giving people free trials seem to increase the use, and some people are willing to pay for the use of the service. How will this work out when an increasing number of providers due to network effects start to offer the service for free?

Paradoxically, it seems that there is willingness to pay for some content. In Europe, customized ring tones, the use of small pieces of music to indicate that somebody is calling you, is increasingly popular. Pictures for use as a display background and jokes sent as text messages are also popular. The users of these services are typically paying 1 to 3 USD pr item. The providers of these services make very nice profits from these services.

These trends put pressures on the traditional business models. The subscribers will not wish to pay for usage. A fixed monthly fee for the subscription may be more acceptable. The question is who will be the first telecoms operator who gives in to these pressures. This change in pricing model may happen in the near future. When the first operator starts to offer this kind of service to the consumers, the others will have to follow suit. The network effects will be strong. This trend is already seen with xDSL subscriptions in many countries, where the subscribers pay a monthly fee regardless of usage. Some 3G data services are already priced according to these models.

If telecoms operators are going to keep their revenue streams at the current level, they will have to come up with some innovative ways of making the customer pay for their services. Cooperation with content providers may be a solution to this challenge.

Today the Internet Service Providers make a good profit from selling internet connections to consumers. For consumers, an internet account does typically have contractual provisions that one should not share this connection with other users. When one does look at discussions on IT websites, there seems to be a lot of people think that these policies are not sensible. Why should one not be able to share an internet connection through a private WiFi network that also gives access to other people? The police and IT security people encourage people to use encryption on their WiFi networks. Otherwise, they claim, criminals may use the networks for illegal activities. The owner of the network may then be held accountable. A growing number of consumers seem to think that this does not make sense. They seem to think of an internet connection as a common good. As long as they have got free capacity, why not share it with other people who

[5] Jupiter Research, Driving Adoption of Public WiFi, MRS04-C10

need it? There are still legal issues that make it unwise to open the home WiFi networks for public use, but it seems that ever more consumers think that sharing in principle is a good thing. Private WiFi networks may in the future even be a part of the public WiFi infrastructure in cities.

3.4.3. Conclusions on social, political and environmental signals

The environmental and political trends that have been covered here do not seem to discriminate between traditional mobile telephony and WiFi and WiMAX-based VoIP. The prospects of great benefits from large-scale WiFi deployment in densely populated areas may even give WiFi operators political goodwill that may be beneficial when dealing with regulators.

The social trends that have been covered here do point to challenges for 3G, but also for WiFi operators. The social trends of peer-to-peer networks and unwillingness to pay for services according to the traditional business models of the telephone companies are growing. This is especially true for the younger generations.

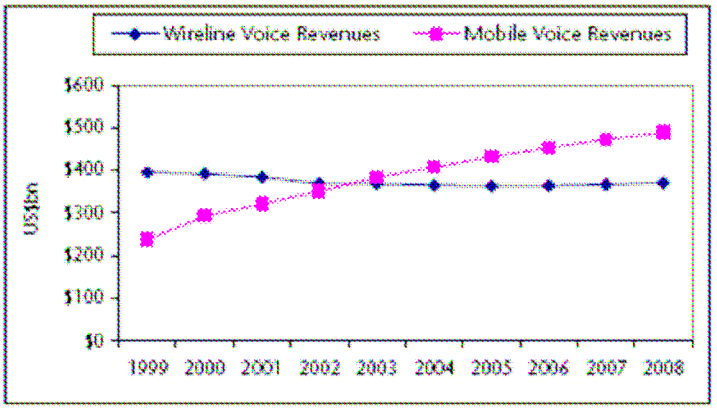
When consumers get used to having WiFi access available everywhere for free, the operators of both 3G services and WiFi will have to come up with innovative business models to be able to keep their revenue streams.

3.5. Other global industry trajectories

Our work indicates that there are several macro indicators and industry trajectories that signal a shift in technology.

One important trend is the shift in voice traffic from fixed networks to mobile networks. Most countries in the world are now facing a decline in fixed network voice minutes. The figure to the right shows forecasts made by Pyramid Research on this shift in revenue.

EXHIBIT 1 Global Voice Revenues, 1999-2008



Source: Pyramid Research Report: *Fixed to Mobile Substitution in Latin America.*

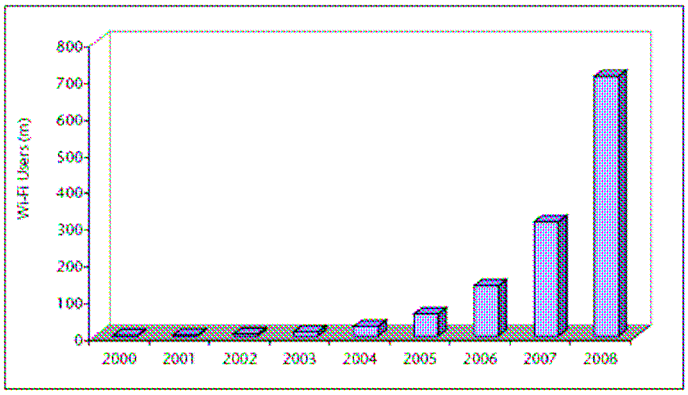
This figure does not take into consideration the shift from POTS to VoIP in the fixed networks. This transition will increase the fall in fixed voice minutes in the years to come.

Interpreting these two development patterns one may expect that there will be a global voice service trajectory where voice services will be mainly mobile and IP based.

Another important macro indicator is the development of wireless broadband, WBA. Pyramid Research has forecasted a rapid growth of global WiFi users, from a level of approximately 50 million in 2004 to 700 million in 2008. (see figure left below)

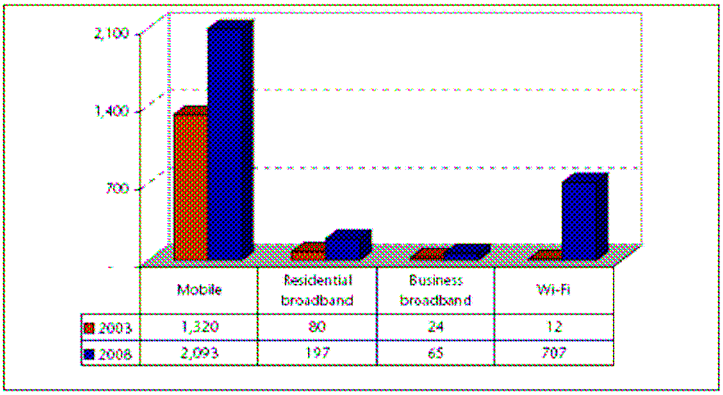
It is interesting to note that Pyramid Research has merged this growth pattern with the expected parallel development of mobile subscribers, fixed residential broadband lines and business broadband lines. The figure (right below) predicts that the main growth up to 2008 will come in the mobile and WiFi areas. All figures are in millions of users. This predicts an interesting trend where both voice and high speed data services become mobile in the same period.

EXHIBIT 5 Telecoms Industry Estimate of Global Wi-Fi Users, 2000-2008



Source: Pyramid Research Report: *Worldwide Wi-Fi.*

EXHIBIT 6 Users/Lines in Service



	Mobile	Residential broadband	Business broadband	Wi-Fi
2003	1,320	80	24	12
2008	2,093	197	65	707

Source: Pyramid Research Report: *Worldwide Wi-Fi.*

Several telecom analysts believe that there will be several drivers in addition to the standardization of the WiMAX technology that will drive growth in the WBA market at a rate above 20% per year for the next years. One major driver is the growing demand for voice and data applications in areas that are currently underserved. Another driver is the growing acceptance of wireless technologies as an acceptable alternative to fixed line services. Service providers are becoming comfortable with using WBA to extend telecom infrastructure where other technologies are not economically viable. The third driver is the conversion on the CPE/handset side into portable broadband multimedia terminals.

4. Technology performance

4.1. Performance of the new technologies compared to the incumbent technologies

According to Christensen the new technology will always have lower traditional performance compared to the incumbent. To analyze this hypothesis one has to look into three different performance aspects.

- Maximum throughput
- Range
- Mobility.

This chart made by Intel shows the performance characteristics of different technologies.

Technology	Standard	Usage	Throughput	Range	Frequency
UWB	802.15.3a	WPAN	110-480 Mbps	Up to 30 feet	7.5 Ghz
Wi-Fi	802.11a	WLAN	Up to 54 Mbps	Up to 300 feet	5 Ghz
Wi-Fi	802.11b	WLAN	Up to 11 Mbps	Up to 300 feet	2.4 Ghz
Wi-Fi	802.11g	WLAN	Up to 54 Mbps	Up to 300 feet	2.4 Ghz
WiMAX	802.16d	WMAN	Up to 75 Mbps (20 Mhz BW)	Typical 4-6 miles	Sub 11 Ghz
WiMAX	802.16e	Mobile WMAN	Up to 30 Mbps (10 Mhz BW)	Typical 1-3 miles	2-6 Ghz
WCDMA/UMTS	3G	WWAN	Up to 2 Mbps (Up to 10 Mbps with HSDPA technology)	Typical 1-5 miles	1800, 1900, 2100 Mhz
CDMA2000 1 x EV-DO	3G	WWAN	Up to 2.4 Mbps (typical 300-600 Kbps)	Typical 1-5 miles	400, 800, 900, 1700, 1800, 1900, 2100 Mhz
Edge	2.5G	WWAN	Up to 348 Kbps	Typical 1-5 miles	1900 Mhz

Source: Intel

4.2. Performance Metrics

4.2.1. Maximum throughput

The maximum throughput for wireless technologies should not be considered as static. Using the framework of Adler and Clark[6], we can use the following concepts

"*technological potential,* which represents the maximum achievable performance given the product's base of fundamental technology"

And

"*technological yield,* defined as the ratio of actual realized performance divided by technological potential"

In theory, there is no boundary to the data rate that can be successfully transmitted on a channel unless the channel is noisy. This capacity of a noisy channel is

[6] Adler and Clark, Behind the Learning Curve: A Sketch of the Learning Process, Management Science, Vol. 37, No. 3, March 1991, pp. 267-281

$$C = W\log_2(1 + P/(N_0W)) \text{ bits/sec},$$

where W is the channel bandwidth, P is the received signal power and N_0 the noise density. As the signal to noise ratio ($P/(N_0W)$) is dependant on frequency reuse and thus the total load of the system, W remains as an upper bound of throughput for a given load, assuming that the efficiency of the modulation of the technology remain comparable. This assumption is validated by the fact that multilevel quadrature amplitude modulation and Reed-Solomon and concatenated coding or Turbo Coding are used both in cellular and in high performance WiFi/Wimax modes.

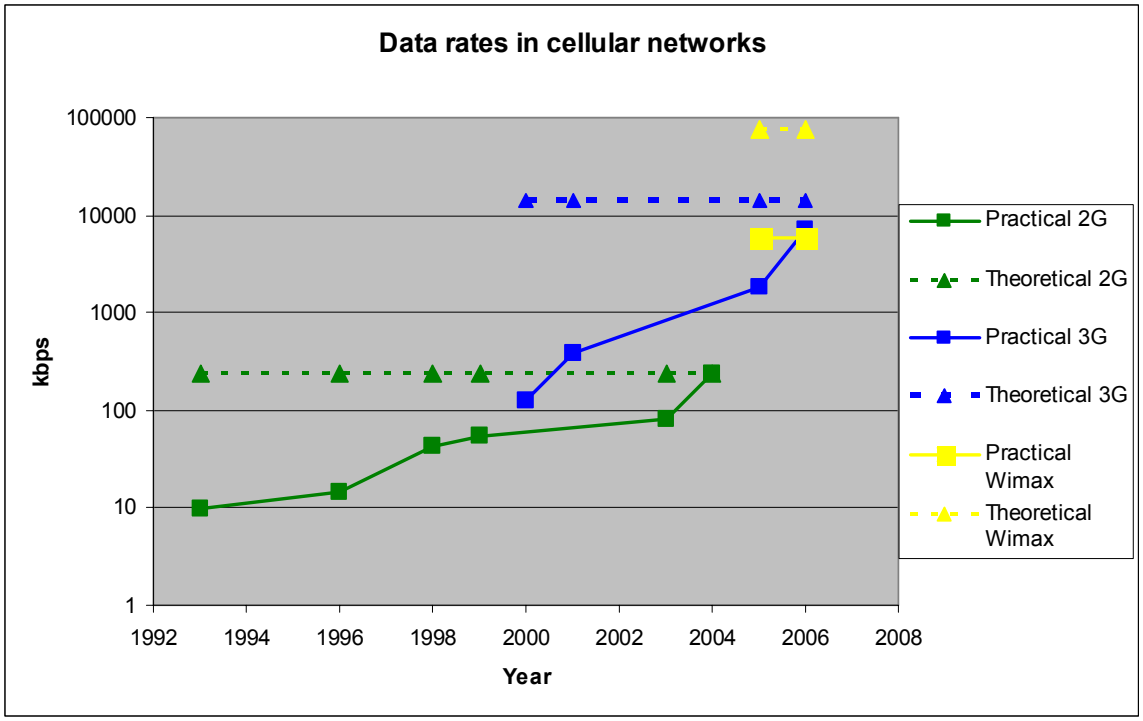
In a real network, these parameters vary significantly as a function of the design parameters of the network and the local conditions. Most radio technologies therefore use adaptive modulation to match the coding density (or modulation density) to the radio conditions (GSM, GPRS, EDGE, WCDMA, WIMAX…), and the system capacity therefore is some function of the frequency spectrum available and the number of nodes available.

For WiFi, our conjecture is that diffusion of wireless routers will mainly be in homes and offices, and to a lesser extent be deployed in public areas by operators. For comparison with cellular technologies, we need to assume similar configuration. The WIMAX suite of standards that is applicable to this purpose is used for comparison, and similar path losses and frequency band is assumed. Most European countries have 3.5 MHz channelization in bands allocated to fixed wireless access (WIMAX and similar) and 5 MHz in 3G bands

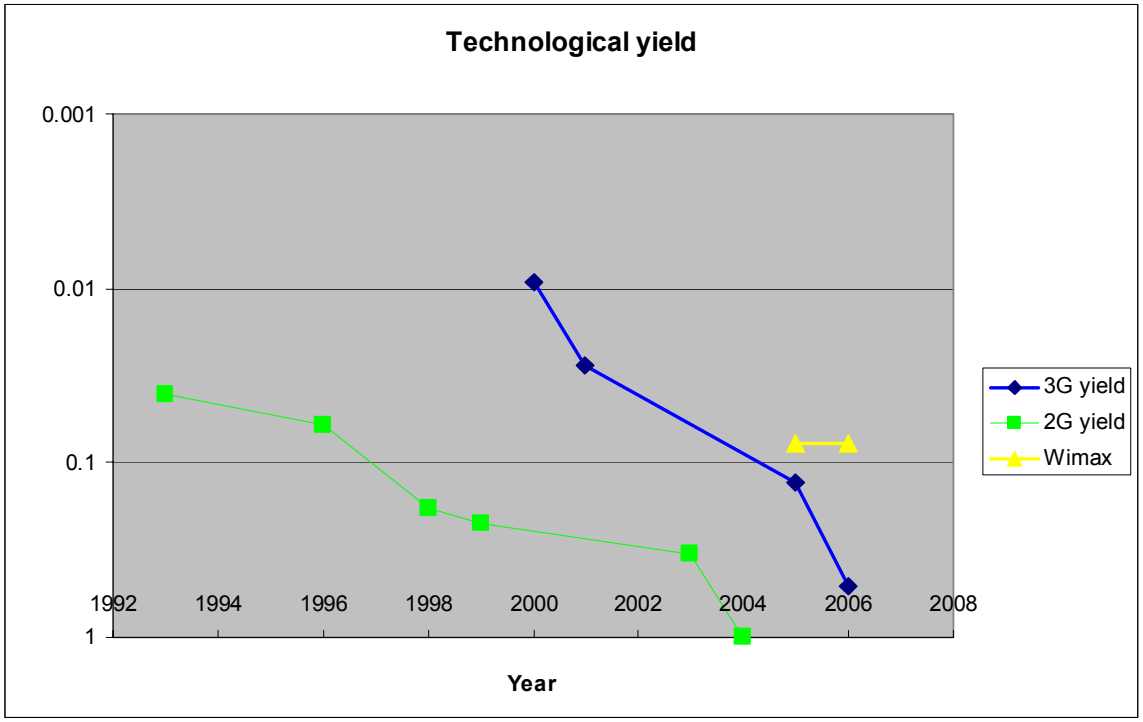
As technological potential, we have taken the pragmatic approach of fixing the boundary to the highest performance achievable with the maximum modulation scheme efficiency and the channel structures defined for GSM and UMTS by 3GPP.

As practical, or “actual realized” performance we have taken the highest performance achievable with the maximum modulation scheme efficiency and channel structure *available*, i.e. in operation in real networks. In addition, the requirement of available handsets constrains further the practical performance. For 2005 and 2006, numbers are based on manufacturer product roadmaps.

Technological yield is the ratio of the practical performance to the technological potential.



Sources: 3GPP, IEEE, www.ericsson.se, www.lge.com



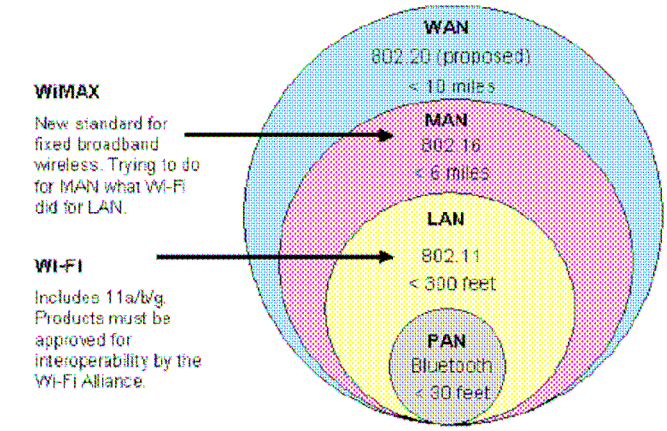
We can see that 3G matures so fast that the performance will rapidly approach its technological potential and the levels of WiMAX. As it is shown above, only the channel

bandwidth determines the maximum bandwidth under otherwise equal conditions. In cases where performance is not interference-limited, WiMAX could achieve higher bitrates by offering several simultaneous channels to an individual user, and thus approach what has here been set as technological potential.

4.2.2. Range

When it comes to range the picture is different. As shown in the Intel table above both the 2,5G (EDGE) and 3G technologies are outperforming the present WiFi technologies. The 2 and 3G technologies typically have a range from a base station in the range from 1 to 5 miles. The present 802.11 technologies are limited to 300 feet. This will change when the WiMAX 802.16 technologies are introduced, with a range up to 6 miles, but then with a significantly reduced useful bandwidth. We should then see a shift in performance according to Christensen's model. This is further intensified by the planned next generation WiMAX based on the IEEE 802.20 protocol. The specifications for this technology are outperforming both 2G, 3G, 802.11 and 802.16 with a range of close to 30 miles from a single base station and a bandwidth up to 16 Mbps per cell. As the figure from Pyramid Research[7] shows, the 802.20 is planned to be the future wireless wide area network.

EXHIBIT 10 From PAN to WAN



Source: Pyramid Research.

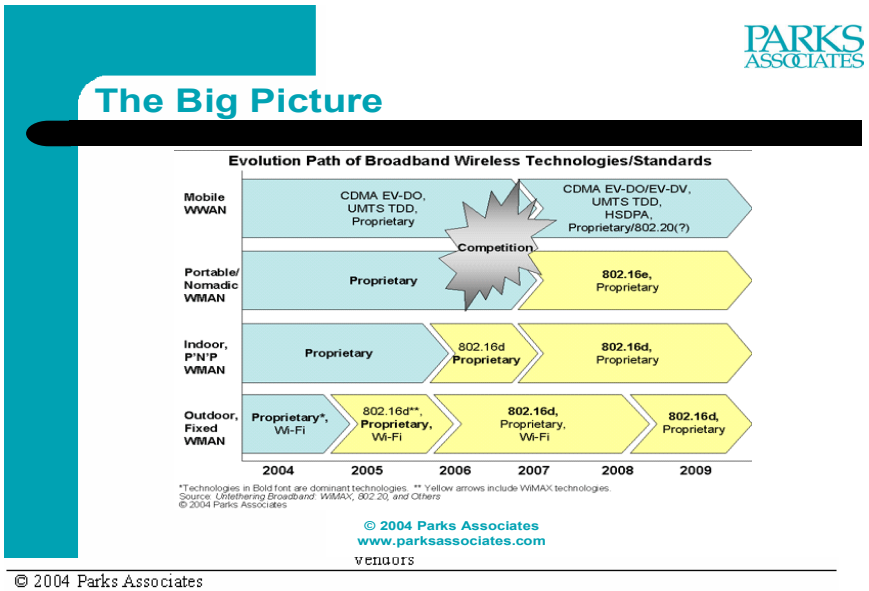
When it comes to performance measured by range of the different technologies one could say that this development path is in compliance with Christensen's model. This is illustrated in his model above. As we can see the initial 802.x technologies have a lower range in miles, but as new versions of the technology evolve the performance exceeds the incumbent technology. It is underlined that these measures are ranges from single base stations only and not the coverage of a network using supplementary technologies like repeaters to extend the range.

Some environments look at the upcoming 802.20 as an evolution of today's 3G technologies. This is indicated by the proposed evolution path of the WBA technologies by the research firm Park Associates, illustrated in the figure below[8]. Park Associates describes the 802.20 technology as an evolution path of the present 3G technologies due to its mobility features.

[7] Pyramid Research report: WiFi and WiMAX: Unwiring the world, November 2003

[8] Presentation by Parks Associates, Untethering Broadband WiMAX, 802.20 and Others by Senior Analyst Michael Cai

Such a view on the evolution paths are according to our understanding somewhat illogical for several reasons. First the 802.20 is a standard set by the IEEE in the 802.x family. The history of 802.x is related to the data communication world and packet switched world, such as the famous Ethernet 802.3 and Token Ring 802.5. ITU (International Telecom Union) is the traditional body setting out the standards for telecommunication, historically meaning voice services.



© 2004 Parks Associates

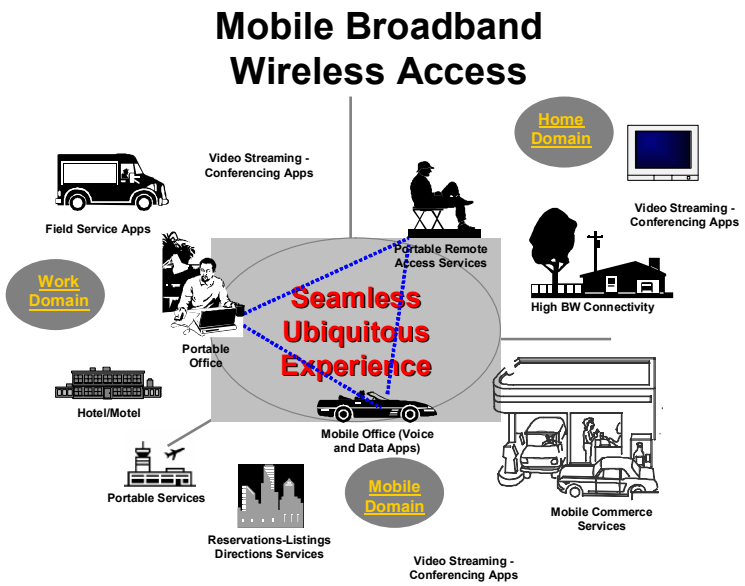
Secondly the 802.20 is a packet-oriented network architecture. The 3G architecture is circuit-oriented, as all major voice network technologies. Third, and perhaps most important, even if 802.20 is viewed as an evolution of 3G, this will still mean a disruptive situation to the present 3G base station and network technologies. A shift from the present 3G to 802.20 will require completely new equipment and large new investments, and probably a financial write-off or fast depreciation of the present equipment. Thus, even when looking on 802.20 as an evolution of 3G one could say that Christensen's model is valid.

4.2.3. Mobility

The third important performance measure of the wireless technologies is the mobility. Mobility means the technology's ability to handle seamless services across base stations when the CPE/user equipment is moving. From a user perspective this means the ability to handover a voice call or an online data session between base stations without interruption or loss of quality of the service. At what speed will the technology be able to handle seamless handover between base stations. Will it work for users driving a car or sitting in a train?

As of today the present 802.11 and the emerging 802.16 technologies are outperformed by the incumbent technologies of 2G and 3G when it comes to mobility. Today's WiFi on 802.11 does not have any mobility features, meaning that if for instance are using a Voice over Internet service on your laptop or PDA (i.e. Skype) when moving, your call will be cut off when moving out of the range of the initiating base station. The early versions of WiMax 802.16 specifications (a to d version) are able to handle some easy handover functions, but not at the quality level we are used to with cellular 2G and 3G networks.

This picture is expected to change when the 802.16e and 802.20 technology is introduced in the marketplace. 802.20 is planned for seamless handover in speeds up to 155 mph. This technology is developed for seamless, high quality mobile services covering data, video and voice, as illustrated in the figure to the right[9].



Using Christensen's model, the evolution path of the performance measure mobility will show the same picture as is the case with range. The incumbent technology will initially have a far better performance, since the present 802 technologies do not have any mobility features. When the 802.16e and 802.20 are implemented there will be a shift in the performance curves. The new technologies will have full handover functionality for data, video and voice with high bandwidth at high speeds. The new technology should then outperform the 3G technology.

4.3. Over performance of the old technology

Measured along the performance metrics discussed above it is difficult to find any evidence of over performance related to range and mobility. But when it comes to bandwidth the case seems different. The usage patterns of the 2G and 3G networks, at least in Europe, are primarily linked to the voice services. The network operators and their service providers have been focusing on development and sale of value added services requiring use of bandwidth, like WAP online services, interactive games, TV/video streaming and the use of the cellular as a network data terminal. They have not been very successful at this. Most users use their cellular handset as mobile POTS-terminals only, and do not activate or use all the additional services and features available in the network or the handset. As data collected by Credit Suisse First Boston for Spanish users show[10], only very few cellular users seem to need the increased performance offered by 3G.

[9] Presentation by Parks Associates, Untethering Broadband WiMAX, 802.20 and Others by Senior Analyst Michael Cai

[10] 3G Fat pipe but what will fill it? CSFB Jan 25th 2005

	Q4 2003	Q1 2004	Q2 2004	Q3 2004
MMS	500,000	650,000	780,000	800,000
of base	2.54%	3.25%	4.18%	4.28%
i-mode	170,000	300,000	450,000	500,000
of base	0.86%	1.50%	2.41%	2.76%
GPRS	1.4m	2.15m	2.5m	2.8m
of base	7.10%	10.78%	13.44%	14.97%

In some European countries there is a slightly different pattern. There are markets with an extensive use of the cellular phone as a messaging terminal using the Short Message Services (SMS). Several of these countries also seem to have an increasing use of Multimedia Messaging Services (MMS), mainly for sending and receiving pictures. In the UK market and some south-European countries (Italy, Spain) there have been a fast growth in specialized messaging terminals with full keyboards (Blackberries). All these messaging services do not require being online with open channels and they require very low bandwidth. Thus there is a significant over-performance in the 2G and 3G networks.

4.4. Summary Performance vs. Market Demand

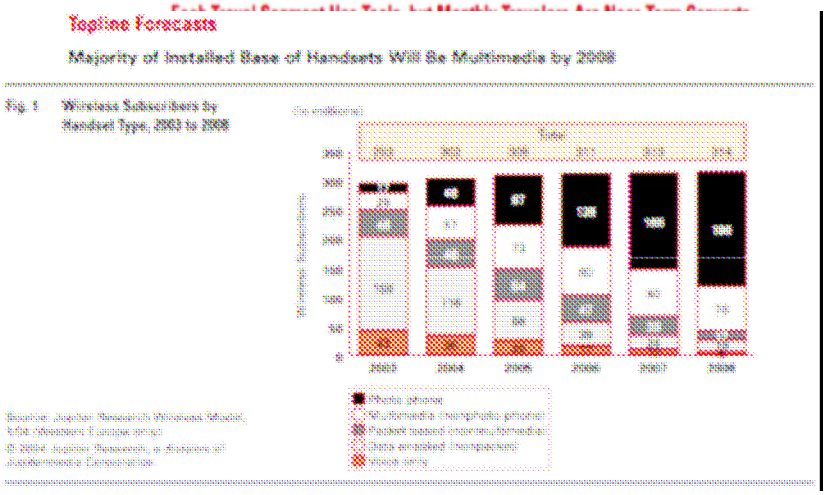
According to our understanding of the markets the mobile users are generally satisfied with their mobile voice service in terms of quality, availability and mobility. The majority of the cellular users neither use the cellular networks for bandwidth demanding services nor for a significant number of the features available in their handset. The cellular voice market has become a commoditized market with high price pressure and it is very difficult to differentiate the services.

A significant share of these users are also PC users, or users of PC compatible equipment such as PDAs. There is a rapidly increasing demand for high bandwidth communication and mobility from the data/multimedia side. The key question will be whether this growing demand will be met by an expansion of the present data networks and technologies, by an evolution of the present cellular 2G and 3G networks or a symbiosis of the two.

5. Product and technology architectures

Broadband mobile communication has got several levels of system and product architectures. First, there is the network architecture. It includes the transmission technologies from the air interface to the backbone network. It also includes the physical layout of the network, the transmission protocols. Second, there are the user terminals. Third, the user terminals have some common hardware and software platforms.

At network level, there are several competing architectures. There are 3G WCDMA-based networks, WiFi-hotspots, and eventually WiMAX networks. As explained in this report, WCDMA and WiMAX are fundamentally different ways to implement WBA. Thus, at the architecture level we do not have a dominant design, and it is not likely to emerge anytime soon, since both camps have powerful supporters (Ericsson, Nokia and other traditional telecommunication vendors versus Intel, Cisco and other IP-vendors).



At the user terminal level the situation is also very fluid. WiFi and WiMAX-equipped laptop computers and PDAs are getting more and more common. Furthermore, recent research by Jupiter research (see the graph above) suggests that laptops are much more prevalent among travelers than mobile phones with broadband capabilities. This can lead to different usage of different mobile terminals: Laptops and PDAs for WBA, and 2G mobile terminals for mobile phone calls.

A quick look at the available 3G WCDMA phones also reveals a bewildering variety of designs. Most terminals have color LCD screens, but the number and size of screens varies largely. The input methodology also varies: Some use keyboards, others use touch screens. Most have got a camera (for still and video pictures), and some have got two or more cameras (for videoconferences). A similar variety of models is likely to be available once the first WiFi and WiMAX equipped phones arrive in the market. Given the estimates that the majority of the installed base of user terminals will be multimedia enabled, this variety is going to keep industry rivalry high in the near future.

6. Cost structures compared to the incumbent technology

According to Christensen a disruptive technology will always have lower cost than incumbent technology. This theory is difficult to measure and test in the emerging wireless market for several reasons. One is to define, delimit and compare the relevant parts of the networks and technologies as they are built and configured differently:

- Front end network – base stations
- Backbone infrastructure
- Switches and service platforms

Second, as we are talking of networks that both historically and in the future will be capital-intensive, a cost comparison also has to be based on equal principles of capitalization. If the levels of expensing vs. capitalization, OPEX vs. CAPEX, are very different, the short term cost picture will also be very different.

Third, when it comes to end user equipment/CPE, this is also a challenge. An intuitive starting point here might be to compare the cost of cell-phones with portable PCs and PDAs. The problem is that a portable PC contains a large variety of functionality that is network independent and irrelevant for a cell phone. It is also likely that the consumers already have got or will buy a portable PC/PDA for other reasons than for mobile network services. Thus, the presence and penetration of end-user equipment will be very high at the point in time were the convergent technologies and networks are launched.

From a cost point of view the lack of standardization is one of the major challenges for the present Wireless Broadband Access (WBA) technologies. This is especially relevant for the point to multipoint radio technologies. Within the WiFi area (802.11x) the technology has been standardized with a price/performance curve as we know from the PC-component industry. The standardization work related to WiMAX is expected to create a similar price/performance curve. WiMAX is based on the 802.16e (OFDMA) industry standard and can be implemented without the costly, proprietary interfaces and royalties found in 3G networks.

Roth Capital Partners[11] expect that the development of WiMAX industry standards (802.16 and 802.20) will significantly improve the economics for both network equipment and CPE. Major manufacturers like Intel, Motorola, Fujitsu, Siemens and Alcatel are already committed to development in accordance with these new standards. They focus is on bringing scale to the market. Nearly all laptops and a large number of PDA's and cell phones are already WiFi enabled. It is expected that chipset manufacturers like Intel will target standardizing and embedding WiMAX chipsets in laptops and other mobile devices within 2006.

The manufacturers of WBA equipment are also always interested in less expensive chipsets. A standardization of WBA technologies will result in interoperability, which in

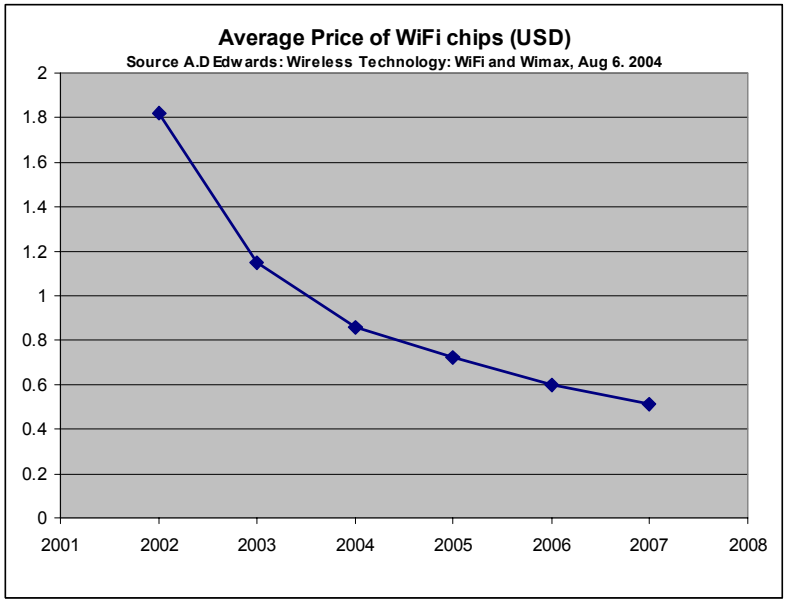
[11] Industry Report: Broadband Wireless Access Market Still, September 1. 2004

turn will bring plug-and-play products. That should imply that in the years to come WiMAX vendors no longer have to provide end-to-end solutions in a complete network. They can specialize on different components like base stations or wireless modems. Such specialization will result in competitive pricing and value-added innovations.

The standardization of the WBA technologies will also most likely provide easier upgrade paths to future technologies, without the costly need to dispatch technicians or physically run wires. OFDMA based systems require only the use of simpler receivers (Fast Fourier Transform -FFM), while CDMA requires the higher complexity receivers (RAKE). It may also be simpler to implement equalization, interference cancellation and adaptive antenna array algorithms with OFDMA, because the algorithms are done in the frequency domain. There are proposals to perform such operations for CDMA, but it would require transformation from time domain to frequency domain and back, making them more complex than OFDMA.

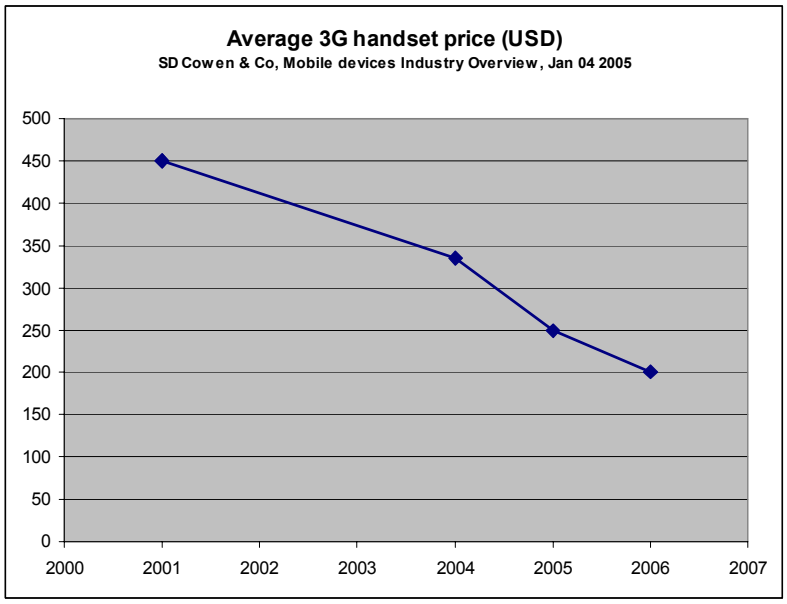
Even today WBA already seems to represent an economically viable alternative in rural areas, which often are underserved in terms of broadband access. An xDSL cable based deployment will have a significant higher capital costs than a WBA deployment. xDSL capital costs can range from $100K to millions of dollars while the cost of a WBA base station range from $10K to $100K. The economics generally become better where the wired infrastructure is poor and the geographic region is more dispersed.

According to Intel, there is little reason to believe that WiMAX chips will not follow the same trajectory as WiFi chips.



Proliferation of WiMAX-enabled laptops could therefore seem probable given sufficient deployment of coverage.

Also 3G devices prices exhibit a learning curve: The average non-subsidized price of a 3G handset is approaching the 2G average price of USD 160 (ref graph below)


Average 3G handset price (USD)
SD Cowen & Co, Mobile devices Industry Overview, Jan 04 2005
500
450
400
350
300
250
200
150
100
50
0
2000
2001
2002
2003
2004
2005
2006
2007

7. Patents and standards

7.1. The role of standards

Standardization is necessary to make it possible to build and operate complex telecommunication systems. Without established standards, it will not be possible to have equipment from several different vendors work together.
Standardization work is typically done by international bodies like ITU (International Telecommunications Union) and IEEE (Institute of Electrical and Electronics Engineers), where representatives from the different countries and the industry work together to establish standards.

The technologies that are covered in this report are:

- 2G (GSM)
- 3G (UMTS)
- WiFi (IEEE 802.11)
- WiMAX (IEEE 802.16)

7.2. The role of patents

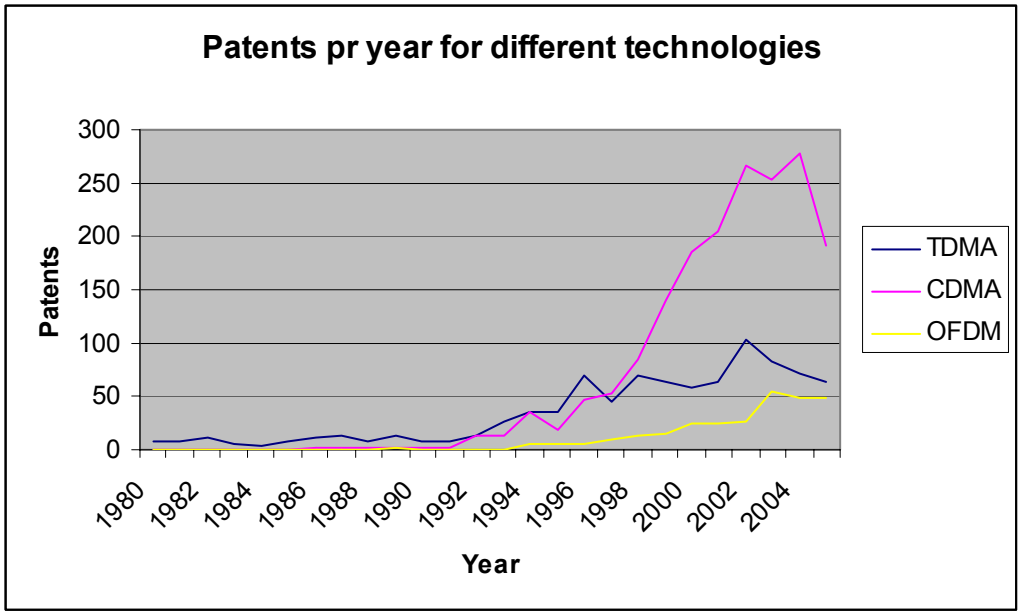
The different companies in the industry do research and file patents. To make the systems that are defined by the UMTS 3G standard, intellectual property protected by several thousand patents must be used. Patents will be licensed between the different companies in the industry.

To get an impression of the patent activity in the industry, searches[12] on the US Patents and Trademark Office homepage have been done on key technologies for the different standards.

- TDM (Time Division Multiplexing) is used in 2G (GSM)
- CDMA (Code Division Multiplexing) is used in 3G (UMTS)
- OFDM (Orthogonal Frequency Multiplexing) is used in WiFi and WiMAX

There are some sources for errors in this kind of search. The technologies that are used as search terms may also be uses for other applications than mobile telephony (i.e. satellite communications). However, the broad picture is probably not affected.

[12] The number patents for 2005 have been forecasted based on the number of patents so far in 2005.



The data material is not very rich here and one should be cautious to draw too strong conclusions from this material, but the patent activity seems to correlate with the maturity of the technology. OFDM is the most recent technology. It is used in WiFi and the future WiMAX standards. It seems reasonable that the patent activity is growing here. CDMA has had a peak of patent activity. CDMA is an older and more established standard, and it makes sense that patent activity has peaked. For TDM, there has been patent activity for a long period of time, but it now seems to have peaked.

7.3. Regulatory issues

The telecoms industry has got a long history of regulation. The telephone as a means of communication has been around for more than hundred years. In many countries there used to be only one organization providing telecom services and this organization was in many cases a government entity. The days of the government-owned monopoly provider are over in most countries. The telecom operators have been privatized and new competitors have been established in most markets.

The split-up of the old AT&T monopoly in the USA is one example of this trend; another is the privatization of BT in the UK.

With telecom services regarded as a utility, they have been subject to some requirements that have been enforced by a regulator. Examples of regulators are Federal Communications Commission (FCC) in the USA and Office of Communications (Ofcom) in the UK. The regulators impose quality requirements on the telecom companies and they also regulate the markets in cases where the incumbent has got a large market share, as is the case in many countries.

Mobile telecommunications is a regulated industry. The frequencies required to operate a cellular network (also called spectrum) can be seen as a scarce natural resource. The government regulators will try to allocate the spectrum in accordance with the best interest of the society. Some parts of the spectrum are used for military purposes, air traffic control or broadcasting, while other parts are dedicated for mobile telecommunications. Spectrum is assigned according to international agreements and national regulations.

Through spectrum assignment the regulators exercise a great deal of influence over the development of the industry. The regulator can open new areas for product development. Good results can be achieved when technological visionaries and regulators work together, The Economist claims[13]. In 1985 the FCC did something that had not been done before. Parts of the spectrum were opened for unlicensed usage for telecommunication purposes. After quite a few years of experimentation, what is known as WiFi today (IEEE 802.11) emerged. This example shows how a regulator can stimulate innovation. Unfortunately, there are also many cases where regulators have stifled innovation. The lack of coordination of frequencies in the USA made it difficult to develop a 2G mobile telephony system there.

The spectrum assignment policies of the regulators are important. Appendix 2 shows how the different frequencies are used for WBA in the UK.

The traditional fixed line (POTS) and mobile telecommunications have a long tradition of regulation. What happens when new services emerge from the IT industry, an industry that has not been regulated?

What is Voice over IP (VoIP)? Is it a data service, since it in essence is a matter of transferring bytes of data? Or is it a telecommunication service since it transfers speech, which was the origin of the telecommunications?

So far the regulators do not quite seem to know what to do. In many case the laws and other regulations that provide the regulatory framework are out of date.

The EU commission has issued a working document on "The treatment of Voice over Internet Protocol (VoIP) under the EU Regulatory Framework"[14]. The document points to a number of challenges when VoIP is introduced. The document aims to start a debate on how to resolve the challenges and call for the major players in the markets to work together to resolve the issues.

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[13] A brief history of WiFi, The Economist, June 10th 2004, http://www.economist.com/displaystory.cfm?story_id=2724397

[14] EUROPEAN COMMISSION, Information Society Directorate-General, Brussels, 14 June 2004, COMMISSION STAFF WORKING DOCUMENT on The treatment of Voice over Internet Protocol (VoIP) under the EU Regulatory Framework, An Information and Consultation Document http://europa.eu.int/information_society/topics/ecomm/doc/useful_information/library/commiss_serv_doc/406_14_voip_consult_paper_v2_1.pdf

The FCC in the USA faces similar challenges and still does not seem to have decided on a coherent policy for regulation of VoIP. There are cases where VoIP service providers get caught in legal proceedings with states over the qualities of the services they provide[15].

Quite a few of the challenges are of a technical nature, and related to the interconnectivity of the different networks. These issues must be resolved in order to ensure a working telephony system.

Other challenges may be more related to the use of the VoIP services, rather that ensuring that they work properly. Telecommunication companies must keep records of the traffic in their networks. Under certain circumstances this information must be released to the police or other government entities, for use in criminal investigations or for national security purposes. A court order is usually required to release this information. It is still unclear how this can be done for VoIP calls. For VoIP calls made through a subscription from a service provider, this may be a logical extension of the current regulatory framework. Regulating services provided by companies like Skype may be more challenging.

Requirements for providing emergency services such as 911, especially with geographic localization of the caller, may be challenging to meet for some VoIP providers.

The regulatory frameworks do not seem to have kept up with the rapid technological development in the VoIP area, both for fixed VoIP and mobile VoIP through WiFI or WiMAX. It does not seem that there is any intention to try to stop the proliferation of VoIP just because the regulatory framework is outdated. To governments around the world the benefits to society from VoIP seem to be too big to try to stop VoIP.

The VoIP provides may be met with some new requirements from the regulators. Such requirements may cause some technical challenges and some costs, but it is not likely to have a strong negative influence on the the growth of VoIP.

It does not seem likely that the regulatory framework will discriminate between the services offered through traditional telephony services and VoIP-based services as such. The frequencies required by the operators will be regulated in bothe cases. There may be a difference in the way that the operator's businesses are regulated. The businesses of the telecom operators are regulated, but it is unlikely that the businesses of the VoIP operators operations are going to be regulated.

The VoIP train is rolling, and it probably can not be stopped by the regulators, even if they had wanted to do so.

[15] Consumer VOIP Could Be on Its Way to the Gallows, eWeek Enterprise News and Reviews, http://www.eweek.com/article2/0,1759,1778935,00.asp

8. Dominant design

8.1. Is a dominant design emerging?

The emergence of a dominant design is major event in an industry. A dominant design changes the conditions of doing business, and has got a dramatic effect on the future prospects of the competing firms. In this chapter we first explain what a dominant design is, how it emerges and what changes it causes in the industry. Second, we explain the ways in which we can recognize a dominant design. Third, we examine the WBA industry and try to see whether a dominant design has emerged, and if not, whether it is likely to emerge in the near future.

8.2. What is a dominant design

According to Utterback[16], a dominant design is the one that wins the allegiance of the marketplace. To be specific, a dominant design is a new architecture which puts together individual innovations that were introduced independently in earlier products. A dominant design makes many performance requirements and product features implicit. All products in the market must adhere to the dominant design in order to meet the fundamental customer needs and expectations.

8.3. Emergence of a dominant design

The emergence of dominant design is a partly a result of technological innovations[17]. In addition, several other factors play significant roles.

- Firms which possess collateral assets (brands, market channels) may have may be able to win over its competitors, and establish their own design as the dominant design.
- The industry itself may agree on the dominant design by establishing standards.
- Governments may use their regulatory powers and limit the possible design variation.
- An individual firm may be able to out-maneuver their competitors by, for example, creating large alliances, and be able to establish its design as the dominant design.
- A firm may be able to stay close to its customer and learn from them, and use the learning to come up with the new architecture, which then becomes the dominant design.

The emergence of dominant design changes the industry in many ways. The number of firms in the industry is likely to decrease as the industry moves from the fluid phase, via the transitional phase, to the specific phase. At the same time, it becomes harder to enter the industry and the failure probability of new entrants increases[18].The products become

[16] Utterback[1994], p 24
[17] Ibid, p 27-29
[18] Ibid, and also Christensen et al [1998],p 212

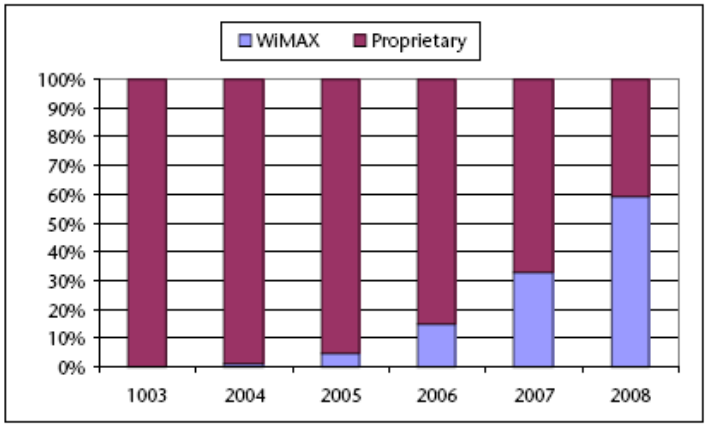
more commoditized. This increases cost pressures and moves innovation from products to processes. The result of this shift is longer product cycles. It also becomes harder to differentiate products of different manufacturers as they all conform to the dominant design.

8.4. Recognizing dominant design

According to Utterback[19], recognizing a dominant design before or at the time it crystallizes is difficult, if not impossible. After it has crystallized, recognition is usually easy. The products get more and more alike and the number of firms in the industry starts to decline. This behavior allows for testing whether the dominant design has already emerged. If the number of firms in the industry is not decreasing, the product variety is still increasing and products have got very different architectures it is unlikely that the industry has reached a dominant design. We will now investigate what the situation is in the WBA industry.

When the WiMAX 802.16 standards are established, a change in the use of proprietary WBA equipment is expected. When the standard is concluded and supported by major manufacturers like Intel, Motorola, Fujitsu, Siemens a rapid growth in the use of standardized equipment is expected. Pyramid Research[20] forecasts that already in 2006 15% of the equipment sold is expected to be standardized WiMAX, growing to 60% in 2008.

EXHIBIT 39 Global WiMAX Equipment Market Share



Source: Pyramid Research.

8.5. Conclusion on dominant design

Given the variety of different designs, a dominant design clearly does not exist, neither on the network architecture level nor on the user terminal level. The WBA industry seems to be in very fluid phase, and a dominant design is not likely to emerge in the near future. A dominant design will ultimately most likely emerge – after all there is a dominant design in the 2G GSM networks and continent wide dominant designs in 2G mobile phones.

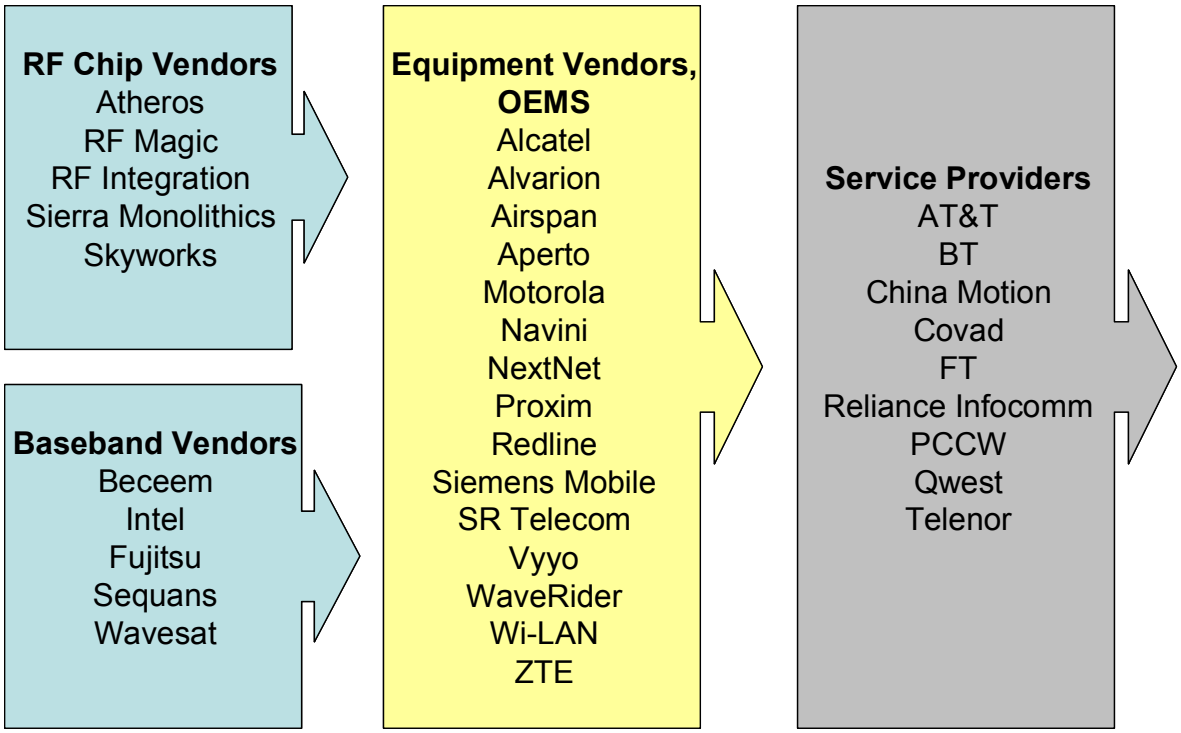
[19] Ibid, 49
[20] Pyramid Research

9. Market players

9.1. Formation of new companies

The industry structure is changing. Several established companies are leaving and new companies enter the industry. Telecom equipment giants like Nortel, Agere, Marconi and Lucent have all exited the fixed wireless business. New companies like Alvarion, Airspan and Proxim have entered the industry. These new entrants are significant players in developing the new WiMAX standards. As the market grows the number of vendors is also expected to increase. Today there are numerous small WBA vendors. To be able to survive they will have to find profitable niches or be acquired. Otherwise, they will eventually die.

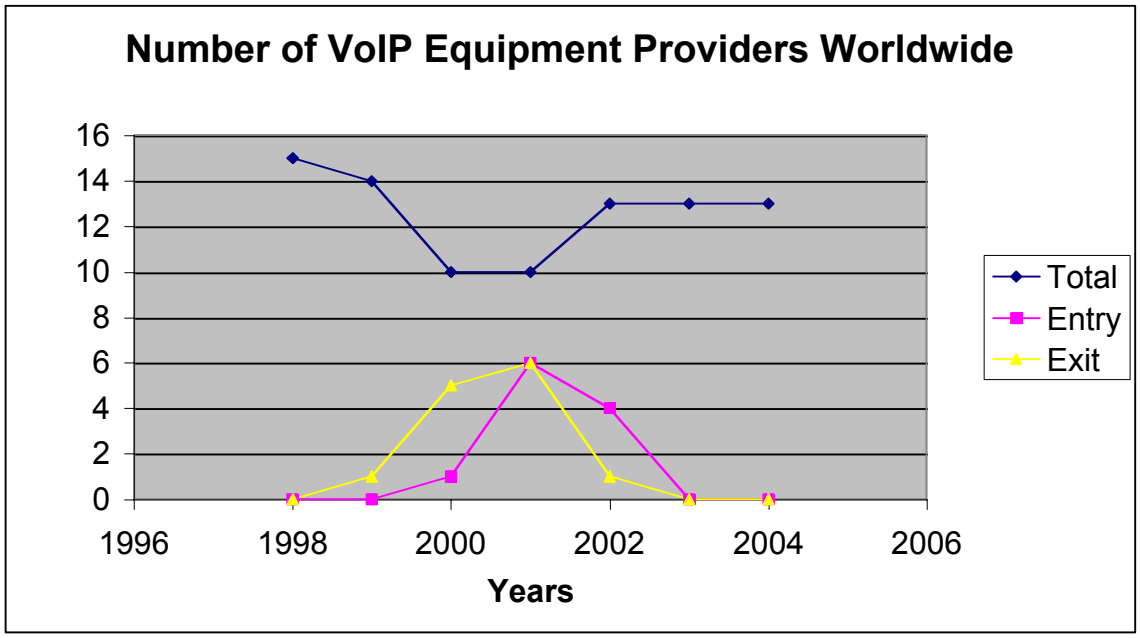
The figure below shows the value chain and some of the major companies involved in the development of WiMAX. In addition to these companies, there are a lot of smaller and larger companies that also have an interest in the development of WiMAX.



The market is entering a period of transition and it is expected that the industry will mature from its current niche position and move towards consolidation.

9.2. The number of firms

In the fixed voice of IP (VoIP) industry the number of firms has developed according to the following chart[21].



The chart shows that the number of firms is not decreasing in the fixed VoIP-industry. Thus it is not likely that a dominant design has emerged. Since the fixed VoIP-technology is simpler and more established than WBA technology, the same should be the case in the WBA industry.

The WiMAX-forum has got 231 members at the time of writing[22]. This kind of a forum always has a lot of members. They may not be very active in the industry, but may just want to stay up to date on the development of the technology. According to Pyramid Research[23], the table on the right lists the most important players in the WBA equipment industry. It is remarkable to note that large telecom vendors like Siemens, Nokia, Ericson, NEC, and Nortel are not in the list. The only major telecom vendor on the list is Motorola. This fact may suggest that the major telecom vendors still consider the market to be too immature to be interesting to them.

Furthermore, Pyramid Research[24] says that

[21] Source: Voice over IP (VoIP) Worldwide Market Shares, Synergy
[22] http://www.wimaxforum.org/about/Current_Members/
[23] Wi-Fi and WiMAX: Unwiring the World Sizing the Opportunity, Analyzing the Players, Demystifying the Hype (Pyramid Reseach, November 2003)"

[24] Ibid.

WiMAX has split the vendor community into two not-so-evenly divided camps. Because WBA vendors see such dramatic (and painful) changes coming, many are lining up against WiMAX. Expect the chorus of pros and cons to grow louder and a bit nastier in the months ahead.

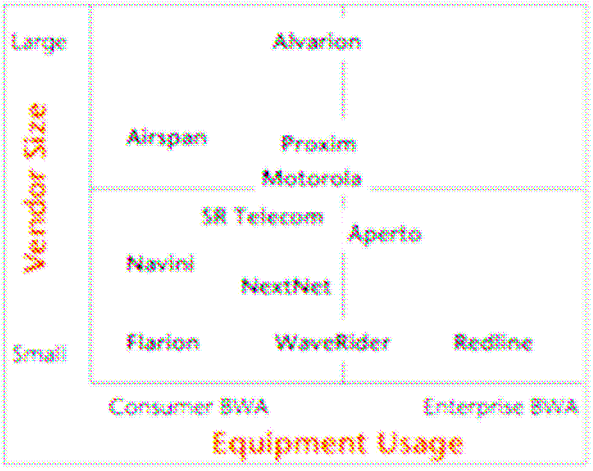
and that

"WiMAX is anyone's game WiMAX blurs the line between fixed and mobile service; as such, it has attracted the attention of both fixed and mobile providers. Fixed providers tend to embrace wireless broadband as a means of extending their network into rural areas as well as stemming churn from their enterprise T1 clients. Mobile providers look at wireless broadband as a way to gain enterprise clients and increase revenue per user. Mobile providers also have the infrastructure upon which to overlay WiMAX networks. Finally, there are the wireless ISPs (WISPs). These companies tend to be small and tend to operate in the unlicensed bands. We expect a wave of consolidation to begin as the larger WISPs seek to expand their networks and major carriers seek new revenue opportunities."

Furthermore, the chart shows that most of the WBA vendors are small.

The picture that emerges from this information suggests that the number of firms in the industry may increase or decrease. The structure of the industry is very fluid. A dominant design does not seem to have emerged.

EXHIBIT 41 BWA Vendors by Equipment Application



Source: Pyramid Research

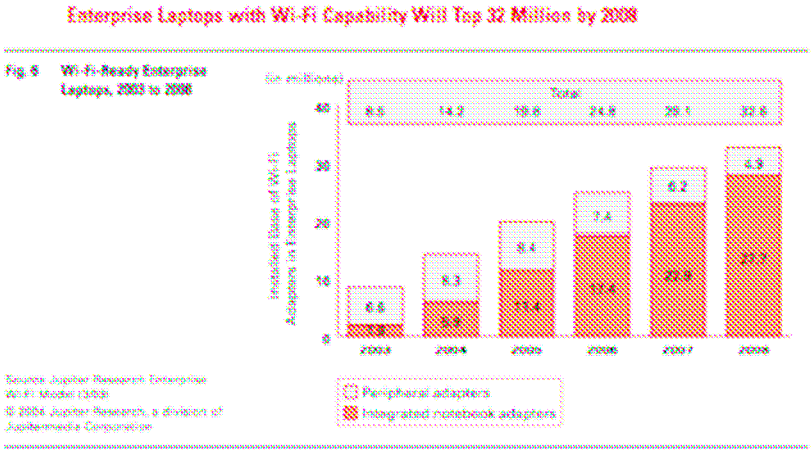
10. Summary and conclusions

10.1. Technology and cost

WiMAX 802.16 and the later 802.20 represent a substantial effort by major IT and telecom players to expand the commercialization of WBA technologies and to create convergent technologies with seamless handling of voice, data and video. The WiMAX objectives are to standardize the WBA technologies, drive down end-user costs and make WBA solutions available to a broader marketplace. The rapid growth and development of the WiFi technology has caused a "kick-start" for the new standards.

Intel and other chipmakers focus their efforts on bringing scale to the market. WBA vendors are always interested in less expensive chipsets. The WiMAX Forum plans to enforce standards compliance among vendor members in the same way that the WiFi Alliance has worked. Compliance to standards results in interoperability, which in turn leads to plug-and-play products. In the coming years WiMAX vendors no longer have to provide end-to-end solutions. They can specialize on base stations or wireless modems. Specialization will result in competitive pricing and value-added innovations.

Nearly all laptops are already WiFi enabled. An increasing number of PDAs and home entertainment devices are enabled with WiFi chips, as well as a growing number of cell phones. It is expected that WiMAX chipsets will be embedded in laptops and other mobile devices within 2006.



Intel and other vendors believe that the next step in promoting WiFi is to make wireless broadband both ubiquitous and affordable. WiMAX promises to drive down the costs of broadband wireless equipment. This will allow the operators to expand their networks and provide wireless broadband access at lower prices.

In terms of technology, WiMAX will improve the performance characteristics of WBA. This makes it possible to provide reliable voice, data, and video services across wider operating environments.

As equipment prices fall, operators will embrace standards. At the end of the day WiMAX is all about delivering low-cost wireless broadband access (WBA). Regardless of which vendor comes out on top after the dust settles, the millions of people in rural and developing markets will be the ones who stand to gain the most from the projected growth of WiMAX.

From the technical network comparison of the OFDMA (WiMAX) and CDMA (3G) based technologies, we can conclude that WiMAX systems will have better performance (interference rejection, spectral efficiency, multipath tolerance), high data quality of service support (data oriented MAC, symmetric link) and lower future equipment costs (low chipset complexity, high spectral efficiencies). This creates a huge dilemma for the cellular 3G carriers. They may be facing a situation were the 3G networks are disrupted by the new technologies. One option is to work closely with equipment vendors to ensure that their 3G infrastructure can be migrated to adopt OFDMA technologies in the near future. There are standardization initiatives in progress that are focusing on WiMAX by the 802.20 standard, which is intended to serve as a potential next step in the evolution of the 3G networks. There is also another ongoing standardization initiative that is trying to develop a potential combination of the WiMAX and CDMA standards called 4G. Both development paths will require significant investments in the 3G networks to upgrade systems and infrastructure.

10.2. Markets

The WiMAX standard will represent a great opportunity for emerging markets, rural areas in developed countries as well as populated areas with a demand for “hot-spot” wireless broadband services.

For the emerging markets this new technology will decrease infrastructure costs significantly. Thus the Asian and Eastern European markets are expected to experience a rapid growth of in the use of WBA technology in the years to come. The same scenario is expected for South America. In these markets the operators are interested in using WiMAX for low-cost voice transport and delivery.

The development of these previously underserved markets will establish economies of scale for the equipment and chipset vendors. Costs will be driven down. This will lead to a fast progression to WBA low-cost connectivity all over the world. WiMAX is expected to bring broadband to the masses.

In densely populated areas in the western world WiMAX will further build on the success of WiFi. WiFi has increased the growth of wireless broadband significantly. As more people become comfortable with WiFi they will demand coverage in a greater number of places. In these markets WiMAX is all about broadband Internet access. Traditional WiFi access points can only cover a limited area. WiMAX will fill in the wide gaps between the areas covered by WiFi. WiMAX will also be complementary to the WiFi deployments by providing seamless connectivity between the hotspots.

Analysts expect WiMAX to succeed as a new global standard in every geographic market, but for different reasons. The markets without any fixed infrastructure pose the greatest opportunities. Regardless of WiMAX, broadband wireless will continue to grow rapidly. Second-stage WiMAX 802.16e which will be able to handle voice mobility in metropolitan areas is expected to boost subscriber numbers even higher.

10.3. Operators

WiMAX can and probably will represent both opportunities and threats for both fixed and mobile operators. The distinction between fixed and mobile will become blurred. One may expected that a chaotic mixture of established fixed, established wireless and new providers that will pursue WiMAX deployments. Analysts expect local and regional wireless ISPs to be targets for acquisition as large carriers, particularly fixed, turn their attention to rural areas and enterprise accounts. Many operators seem to be confused right now. What opportunities and threats will the new technology bring?

There is more cause for concern for the cellular operators and vendors of CDMA technology/products. These mobile carriers and vendors are expected to try to delay the 802.20 development for as long as possible. Regardless of the outcome of attempts to slow down the 802.20 development, their major challenge will be that a large number of the fixed operators, service providers/ISPs and new WBA operators will deploy WiMAX zones. This may be both new WiMAX zones and upgrades of existing WiFi hot-spots in order to compete with or complement the 3G networks. Analysts expect to see a significant increase in WBA subscriber lines, services offered and revenues by 2007. At about the same time the launch of the second stage of WiMAX is expected. This is the birth of metro-area portability using the 802.16e standard. Combined with the assumption that WiMAX chipsets will be embedded in laptops and other mobile devices as a part of a standard configuration and a rapid development of wireless zones by existing and new WBA operators, this second stage of WiMAX could be very disruptive to 3G operators.

It is too early to predict that WiMAX will "kill" 3G, but there is certainly room for concern. The economics of low-cost fixed wireless are compelling when compared with 3G. If one further assumes that WiMAX becomes just another feature embedded within laptops, PDAs and phones, there is good reason for operators to look at WiMAX instead of 3G for broadband delivery. WiMAX does not support full mobility in its first versions, but the deployment of 802.16e and later 802.20 will also solve this issue. The question is whether consumers really are focused on mobility on the cellular level when they are consuming broadband services. Even today most cellular calls, except when used in cars and trains are carried out in buildings and within a limited geographical area. 802.16e will offer mobility at that level.

10.4. Conclusion

We expect the cellular 2G networks and the WiFi/WiMAX technologies will be symbiotic for the coming years.

The upcoming WiMAX technologies will be disruptive to the 3G technologies. We expect that the 3G vendors and operators either will be forced undertake further significant investments in their technology and networks to upgrade to the future OFDMA standards (802.20) or to accept to write off a large part of their 3G investments. If the latter happens, the major operators will still be a significant part of the "food chain" since they have got a complete backbone infrastructure. An alternative trajectory could be

to move towards a role of wholesale and being the carrier's carrier. The operator would in this case get its revenue from selling bandwidth and network services to different WBA operators and service providers.

Appendix 1: Key Terminology

CAPEX	Capital Expenditures
CATV	Cable Television Network
CDMA	Code-Division Multiple Access
CPE	Customer Premises Equipment
EDGE	Enhanced Data rates for Global Evolution, also named 2,5G
ETSI	European Telecommunications Standards Union
FDD	Frequency Division Duplexing
FFT	Fast Fourier Transform
FWBA	Fixed Wireless Broadband Access
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications, also named 2G
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ISP	Internet Service Provider
LAN	Local Area Network
LMDS	Local Multipoint Distribution Service
MAN	Metropolitan area network
MMDS	Multipoint Microwave Distribution System
OECD	Organization for Economic Co-operation and Development
OFDM	Orthogonal frequency division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplexing Access
OPEX	Operational Expenditures
PAN	Personal Area Network
PDA	Personal Digital Assistant
PoP	Point to Point
PoMP	Point to Multi Point
POTS	Plain Old Telephony Service
QoS	Quality of service
RAKE	Receiver technique using several base-band correlators to individually process several signal multipath components.
RF	Radio Frequency
SDMA	Space Division Multiple Access
TDD	Time Division Duplexing
TTI	Transmission Time Interval
UMTS	Universal Mobile Telecommunications System, also named 3G
UTRAN	Universal Terrestrial Radio Access Network
UWB	Ultra-Wide Band
VolP	Voice over Internet Protocol
WAN	Wide Area Network
WBA	Wireless Broaband Access
WCDMA	Wideband Code-Division Multiple Access
WiFi	Wireless Fidelity. Used generically when referring of any type of 802.11 network, whether 802.11b, 802.11a, dual-band.
WiMAX	Worldwide Interoperability for Microwave Access
WISP	Wireless Internet Service Provider
WLAN	Wireless Local Area Network

WMAN	Wireless Metropolitan Area Network
WWAN	Wireless Wide Area Networks
xDSL	xDigital Subscriber Line, were x can be A =Asymmetric, S =Symmetric or V =Very high bit-rate

Appendix 2: Frequencies used for WBA in the UK

Source: OFCOM WBA update April 2005, Annex 1. www.ofcom.org.uk

Frequency band designation	UK assignment	UK status	Assignment per operator	Availability	Technical characteristics and capabilities	Remarks
2.4 GHz	2.4 – 2.4835 GHz	Licence exempt	Wide Band modulation techniques allow operation across the band.	Commercial public services allowed since July 2002.	Limited power at 100mW eirp restricting range. Broadband devices giving about either 54 Mbps (20Mbps MAC throughput) and 11 Mbps (5MBits MAC throughput) divided by the no. of users on a system.	Free access but proliferation of devices may cause congestion. Providing it meets UK technical requirements in IR2005. 802.11b and 802.11g equipment may be used
3.4 GHz	3.48-3.50 GHz paired with 3.58-3.60 GHz	Licensed	2x20 MHz per licence.	15 regional licences awarded in June 2003 following an auction to: Poundradio (13 licences), Red Spectrum and Public Hub.	Range typically 10 kms. New technologies may facilitate non- line of sight operation. Bandwidth available will allow up to 2 Mbps per customer.	Good equipment availability.
3.6 GHz	3.605-3.689 GHz paired with 3.925-4.009 GHz	Licensed	2x36 MHz	Licensed nationally to Pipex Communications. Serves urban areas in Thames Valley, south London, Berkshire, Midlands and Yorkshire.	Services provided include data services at 384 kbps per customer but higher rates possible.	Band under consideration for further licences. Sharing with other services will need careful co-ordination and subject to further study.

Frequency band designation	UK assignment	UK status	Assignment per operator	Availability	Technical characteristics and capabilities	Remarks
5 GHz Band A	5.15-5.35 GHz	Licence exempt.	Not applicable.	Commercial public services allowed from 12 February 2003.	Indoor use only. Limited power at 200mW eirp. Can provide up to 54Mbps (20 Mbps throughput) but depends on no. of users. Has interim arrangement for systems without full DFS. Mobile/nomadic use only allowed.	Technical requirements set out in Interface Regulation (IR) 2006, including requirement for Dynamic Frequency Selection (DFS) and Transmit Power Control (TPC) implementation. 802.11a devices will comply with current (interim) IR. 802.11h devices will include DFS and TPC.
5 GHz Band B	5.47 – 5.725 GHz	Licence exempt.	Not applicable.	Commercial public services allowed from 12 February 2003.	Limited power at 1W eirp restricting range. Can provide up to 54Mbps (20 Mbps throughput) but depends on no. of users. Has interim arrangement for systems without full DFS. Mobile/nomadic use only allowed.	See above.
5 GHz Band C (5.8 GHz)	5. 725-5.850 GHz	Licensed. (Electronic Registration)	Users will be able to operate across 5.725-5.850 GHz, with the exception of 5795 - 5815 MHz and some geographical	Licence holders able to register terminals from 2 February 2004.	Power limited to 2W. Can provide up to 155Mbps (100 Mbps throughput) P to P Can provide up to	Final version of IR 2007 sets technical requirement for DFS and TPC.
			exclusion zones in order to protect other users.		54Mbps (20Mbps throughput) using 802.11 equipment but depends on no. of users. 802.16 equipment is also expected to be used in this systems looking to provide ATM type QOS. Fixed use only.	