W i M A X

Deployment opportunities in Japan and the Netherlands

Martijn Meijering

TU Delft

TWA NETWERK Trendwatchers voor innovatie en technologie
Netherlands Office of Science and Technology, Tokyo

WiMAX

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M.R. Meijering

Graduation Committee

Prof.dr. J.P.M. Groenewegen (Professor E&I)
Dr. ir. W. Lemstra (Senior Research Fellow E&I)
Dr. E.A.M. van de Kar (Assistant Professor SK)
Ing. V. Hayes (Senior Research Fellow E&I)

External supervisor

Prof S. Naoe (Professor Chuo University, Japan)

Faculty Technology, Policy and Management
Delft University of Technology

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Martijn Meijering

Summary

The electronic communication industry is a dynamic industry characterized by a high rate of technological innovation and by a high rate of government regulatory intervention. Two major trends are observed in this industry, the Fixed-Mobile Convergence (FMC) and in the case of wireless communication the development towards a fourth generation (4G) network. The relatively new technology WiMAX will have an important complementary role in such Next Generation Networks (NGN). WiMAX is a wireless broadband technology based on an international standard of the Institute of Electrical and Electronics Engineers (IEEE). The success of WiMAX in being adopted in the industry is strongly promoted by the WiMAX Forum. Numerous powerful global industry players and members of the WiMAX Forum, such as Intel, Motorola, Samsung, British Telecom and many others, are fiercely driving the industry development towards an adoption of WiMAX. For the success of WiMAX, it is now important that on a global level commercial WiMAX networks are or will become available.

It is crucial in the WiMAX case that significant WiMAX equipment sales volumes are reached and the cost structure of a WiMAX network deployment is low in order to become adopted by the mass market. There is a strong interdependent relation between price and volume. A decreasing price causes a rise in demand and volumes to increase. The increased volume causes the price to decrease since economy of scale benefits can be obtained. Consequently, the further decreasing price causes volumes to increase. To stimulate volume growth the venture capitalist Intel Capital, a subsidiary of Intel, for example, is actively investing in network operators to support their WiMAX network deployment plans. An important example is the US$ 600 million investment in US operator Clearwire to deploy a WiMAX network. In the Netherlands, the WiMAX entrepreneur Enertel/WorldMax is cooperating with Intel Capital to deploy a mobile WiMAX network.

It is clear that WiMAX chip manufacturers and equipment manufacturers want to increase the sales volume in order to make profit, but what are the opportunities of WiMAX for network operators. This question leads us to the main research question of this report, which is formulated as:

What are the opportunities of WiMAX for operators in the Dutch electronic communication industry based on the WiMAX experiences of Japanese operators?

This research question has been divided into the following three sub questions:

1. *What are the advantages and disadvantages of WiMAX compared to other communication technologies?*
2. *What are the key issues of WiMAX for operators in the Netherlands?*
3. *What are the experiences and deployment strategies of WiMAX of operators in Japan?*

1. *What are the advantages and disadvantages of WiMAX compared to other communication technologies?*
   There are two WiMAX variants, fixed and mobile, based on two different standards. They both should be compared with different technologies. Fixed WiMAX could be compared with DSL or cable and mobile WiMAX with wireless 3G/3.5G technologies Fixed WiMAX serves fixed wireless applications and does not support movement. The connection to the network cannot be maintained when moving from one place to the other. In other words, no hand-overs between network cells are supported. Mobile WiMAX does support these hand-overs, but the moving speed cannot exceed 120 km/h. Mobile WiMAX can be used for both mobile and fixed applications.

   WiMAX has three main deployment scenarios; wireless access for fixed or mobile applications, backhaul for WiFi hotspots or cellular networks and metropolitan area networks. The last deployment scenario is a wireless network with a large coverage area creating 'hot-zones' in opposition to 'hot-spots' that are local networks covering a small area.

   The main advantages of WiMAX are the following. The spectral efficiency and throughput performance of WiMAX compared with other wireless technologies like HSDPA is significant. The cost-efficiency of WiMAX network deployments is another important advantage. In general, less base stations are needed for the deployment due to the spectral efficiency and throughput performance. However, it is important that the price of the WiMAX equipment, including the CPEs, will decrease. Additionally, the high costs of trenching when rolling out a wired line network, such as DSL and cable, is avoided, because WiMAX is wireless. The various levels of quality of service (QoS) and the support of the IP protocol are two other attractive advantages of WiMAX. One of the most important advantages of WiMAX is the fact that WiMAX is based on a truly international standard and that an international forum, the WiMAX Forum, is strongly driving the development path.

   The disadvantages of WiMAX are the immaturity of the technology and the limited product availability of mostly mobile WiMAX. There are insecurities about the full mobility capabilities of mobile WiMAX and the battery capacity for the mobile WiMAX handsets is an issue. The immaturity of WiMAX will also cause operational difficulties when deploying a network.

2. *What are the key issues of WiMAX for operators in the Netherlands?*
   The broadband environment in the Netherlands is extremely unfavorable for fixed WiMAX deployments. The extremely high rate of broadband penetration and the demographics of the Netherlands make it difficult for fixed WiMAX to get a significant market share. The Dutch 'rural' areas are widely spread. This makes a WiMAX deployment that can serve these underserved broadband areas very expensive and therefore very unlikely.

   However, at the moment two Dutch operators are offering fixed WiMAX services in the Netherlands. WiMAX entrepreneur Enertel Wireless, who is now cooperating with Intel

Capital under the name WorldMax, was the first to deploy a fixed pre-WiMAX network in the five major Dutch cities Amsterdam, Den Haag, Eindhoven, Rotterdam and Utrecht. WorldMax's new strategy focuses on mobile WiMAX, but it does not have a license for it yet. Currently, WorldMax holds the only license in the 3.5 GHz band for fixed wireless broadband applications in the Netherlands. This license is valid until 2015.
The other operator is Casema, a Dutch cable operator. Casema holds the only license in the 2.6 GHz band for fixed wireless broadband applications. This license is valid until 2008. However, its fixed WiMAX network is not as widely available as Enertel/WorldMax is. This network is also pre-WiMAX network. This means that it is not a certified network, which is interoperable with other WiMAX networks. At the moment, there are no certified WiMAX products available for 2.6 GHz frequencies; only for 3.5 GHz frequencies products are available. Casema's future strategy focuses also on mobile WiMAX. However, there are no licenses available for mobile WiMAX yet.

The regulatory environment of the Netherlands shows a very promising future for mobile wireless broadband applications. An enormous amount of spectrum in the 3.4-3.8 GHz bands will most probably become available. However, it will only be available earliest in the first half of 2008. The availability of certified mobile WiMAX handsets is expected to be in the first half of 2007, but these products are specified for the 2.3 GHz and 2.5 GHz bands. It is uncertain when certified mobile WiMAX products for the 3.5 GHz band will reach the market. However, they should certainly be available by 2008, possibly around the same time as the appropriate licenses will become available.

A crucial issue in the Netherlands for operators, that want to deploy a mobile WiMAX network, is acquiring sufficient sites for WiMAX base stations. This is an issue for any wireless or cellular network in the Netherlands, because of the strong opposition to these placements by lobbyist groups and local governments and because of the current presence of several other wireless networks. The acquisition of sites will be a challenging task, especially for operators without a wireless networks, and the operator needs to have a solid strategy for this.

3. *What are the experiences and deployment strategies of WiMAX of operators in Japan?*
The Japanese electronic communication industry is dominated by three large industry groups, NTT Docomo, KDDI and Softbank, and can be characterized as a competitive oligopolistic industry. The Japanese Ministry of Internal Affairs and Communication (MIC) has a strong guiding role in the development path of the industry. The government, the industry and the research institutions cooperate closely.

The Japanese electronic communication industry is interested in mobile WiMAX. Fixed WiMAX is not considered to be feasible in Japan, because of the high DSL penetration rate and the strong growth of the FTTH penetration rate. Additionally, the large majority of the population is located in the southern coastal area roughly between Tokyo and Fukuoka and has access to high speed and cheap fixed broadband (one of the cheapest and fastest globally). The remaining minority of the population living in the mountainous inland area of Japan do not seem to provide a feasible business case for fixed WiMAX.

Yozan is deploying a large-scale fixed pre-WiMAX network in Tokyo. The rollout of the fixed pre-WiMAX network is lagging behind schedule mainly because of operational issues. The momentum for fixed WiMAX seems to be lost and the attention has moved to mobile WiMAX.

NTT Docomo, KDDI and Softbank are all actively researching the possibilities of mobile WiMAX. The operator groups have large in-house R&D centers for wireless technology research. Yokosuka Research Park (YRP) is a wireless technology R&D center of the National Institute for Information and Communication Technology (NICT), which is a government 'owned' research institute. YRP houses one of the largest R&D centers in the world for 3G and future 4G technologies. Japanese cellular operators, such as NTT Docomo and KDDI, play a leading role in these research and development activities. In contrast with Dutch cellular operators, which are much less involved in R&D activities.

The cellular market in Japan is very well developed with millions of users and high APPUs. The 3G networks are facing congestion problems. This drives the industry to actively research new technologies to solve this problem. WiMAX fits well into this context. Additionally, the operators want to improve the cost per bit ratio of their mobile broadband services for the end-users. The goal of the WiMAX trials is to evaluate the performance capabilities of mobile WiMAX and to understand how mobile WiMAX can fit into their existing networks and service portfolio. Mobile WiMAX will have a complementary role in Japan as an overlay network and no nation-wide independent mobile WiMAX networks are expected in Japan.

A critical issue in Japan is the spectrum availability for mobile WiMAX. An amount of 95 MHz of spectrum in the 2.5 GHz band will most probably be secured for mobile BWA applications. There will be three or possibly even four licenses available in the middle of 2007 following the final decision of the Ministry Council of the Ministry of Internal Affairs and Communication (MIC). This will be a crucial moment for the future of mobile WiMAX in Japan. The limited availability of licenses and strong presence of the three industry groups will make it difficult for new entrants to enter the market.

It is expected that NTT Docomo and KDDI will get a license for mobile WiMAX deployments. Another license most probably will go to Willcom, which is developing a mobile wireless broadband system named Next Generation PHS. In the case of a fourth license, it is expected that Softbank will obtain this license. Other operators, as Yozan and ACCA Networks, can operate as MVNOs in order to offer WiMAX services.

The competitive oligopolistic rivalry, the vertical-integrate structure of the industry and the limited availability of licenses determine the mobile WiMAX development path in the electronic communication industry in Japan.

What are the opportunities of WiMAX for operators in the Dutch electronic communication industry based on the WiMAX experiences of Japanese operators?
The opportunity of WiMAX in the Netherlands is limited. Mobile WiMAX offers the most opportunities, especially for wired line operators. They can extend their services with the mobile wireless end by using WiMAX. Operators should be aware of the insecurities that surround full mobility WiMAX. However, mobile WiMAX can be used for not only mobile applications, but also fixed applications.

There is no need for cellular operators to get involved in WiMAX. However, on the long run if their 3.5G networks will be congested and if they want to improve the cost per bit ratio they should consider WiMAX. Any operator, who is actively upgrading its network to an all IP network, should definitely consider WiMAX for the future. WiMAX fits well into the development towards 4G networks. When WiMAX equipment sales volumes increase and equipment costs decrease, WiMAX will become an even more interesting opportunity for operators in the Netherlands.

List of Figures and Tables

Abbreviations and Acronyms

BE	best effort
BS	base station
BWA	broadband wireless access
CPE	customer premises equipment
CPS	common part sublayer
CSMA/CA	collision sense multiple access with collision avoidance
DFS	dynamic frequency selection
ERO	European Radio Organization
ETSI	European Telecommunications Standards Institute
FDD	frequency division duplexing
FMC	fixed mobile convergence
FTP	file transfer protocol
FWA	fixed wireless access
GB	guard band
GT	guard time
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
ISO	International Organization for Standardization
HSDPA	high speed download packet access
LMDS	local multipoint distribution service
LOS	line of sight
MAC	medium access control
MIMO	multiple input multiple output
MMDS	multichannel multipoint distribution service
NLOS	non line of sight
NRA	National Regulatory Authorities
nrtPS	non-real-time polling service
OFDM	orthogonal frequency division multiplexing
OFDMA	orthogonal frequency division multiple access
POP	point of presence
PMP	point to multipoint
PTP	point to point
QoS	quality of service
RLAN	radio local area network
rtPS	real-time polling service
SOFDMA	scalable orthogonal frequency division multiplexing access
SSCS	service specific convergence
TPC	transmitter power control
TDD	time division duplexing
UGS	unsolicited grant service
UMTS	Universal Mobile Telephone System
WiBro	wireless broadband
WISP	wireless internet service provider
WLL	wireless local loop
WRC	World Radiocommunications Conference

Table of Contents

1. Introduction

This chapter presents the design of the research project, working from a brief introduction of the background and the problem exploration to the problem definition. The research objective and questions are formulated and the used methods to solve these are presented.

1.1. Background

More than two decades ago, the electronic communication markets of most countries were dominated by the national PTTs and these markets were characterized as being extremely static. Today, this has completely changed and most markets are dominated by several competitive entities and are extremely dynamic (Steinbock 2003).
What has caused these significant and continuing changes is referred to as the telecom reform process. The purpose of this reform has essentially a threefold of objectives. The reform process is intended to increase customers' choice, lower the price of the service and improve the quality of the service (Lemstra 2005).
The telecom reform process consists of three dimensions: liberalization of the market, privatization of state-owned monopolies and the design of a new regulatory framework (Ubacht 2005)

This liberalization of telecom markets was done for several reasons, including the following five factors. First increasing evidence existed that liberalized markets were able to grow and innovate faster and provide better services for customers than non-liberalized markets. Secondly, in order to expand and upgrade the electronic communication networks and to introduce new services private sector capital should be attracted. Thirdly, technological innovation stimulated the growth of mobile and wireless services, which provided alternatives to the fixed networks. Fourthly, the growth of the Internet led to the introduction of many new operators. Finally the trend of globalization in the telecom market motivated the liberalization (Intven and Tétrault 2000).

The successful transformation of monopolistic electronic communication markets into competitive markets calls for regulatory interventions. This is required for a variety of reasons. In general, regulators must authorize new operators. They have to remove barriers for new operators to enter the market. They have to supervise interconnection of new entrants with incumbent operators. Regulatory intervention may also possibly be needed to ensure that competitive markets do not refuse to serve high cost areas or low-income subscribers. This is generally referred to as providing universal service.
Therefore and for many other reasons, a new regulatory framework had to be designed. This framework needs to be adjusted constantly according to the changing market situation. Some crucial aspects of this new regulatory design were the reform of the electronic communication law and the creation of sector specific national regulatory authorities (NRA).

Fixed Mobile Convergence
A trend in the communications industry is Fixed Mobile Convergence (FMC). The European Telecommunications Standards Institute (ETSI) states that FMC is concerned with the provision of network capabilities that are independent of the access technique. This does not imply the physical convergence of networks. It is concerned with the development of converged network architecture and supporting standards. This set of standards may be used to offer fixed, mobile or hybrid services. The aim is to provide these services with a single device, which can switch between the networks ad hoc. The wireless broadband technology WiMAX could take an important role in this development towards convergence by functioning as a bridge between fixed and mobile networks.

The situation as described above merely touches some of the issues and complexities of the total telecom reform process and the FMC development. In this context, it serves as the background against which the exploration of the forthcoming problem is set.

1.2. Problem exploration

The major importance of information and communication technologies for the economies in the OECD countries is a well known fact (OECD 2003). Also in the European Union the ICT industry is a powerful driver of economic growth and employment. A quarter of its GDP growth and 40% of productivity growth are due to ICT.
The following statement of the European Commission (2004, p.22) explicitly highlights the importance of an ICT strategy for creating future economic growth: 'In order to ensure future economic growth, the EU needs a comprehensive and holistic strategy to spur on the growth of the ICT sector and the diffusion of ICT in all parts of the economy'. This comprehensive strategy starts with a well-defined and clear policy on ICT. At the highest level the European Union is developing this ICT policy. A subsection of this ICT policy is concerned with a policy on broadband. Each EU member state formulates its own ICT policy and thereby its own policy on broadband in accordance with the EU policy. The Netherlands also has a broadband policy in line with the EU policy on broadband.
As mentioned in the Broadband paper (Ministry of Economic Affairs 2004), also in the Netherlands the ICT industry is extremely important for economic growth. The fastest growing sector within the whole ICT sector appears to be the broadband sector. The broadband ambition of the Dutch government is to have a top position in Europe and the world by 2010. According to statistics of the OECD on broadband penetration, this ambition has already turned into a reality; the Netherlands currently has the second highest broadband penetration rate in the world. It is important now to maintain or even improve this position, because other countries are catching up (Figure 1).

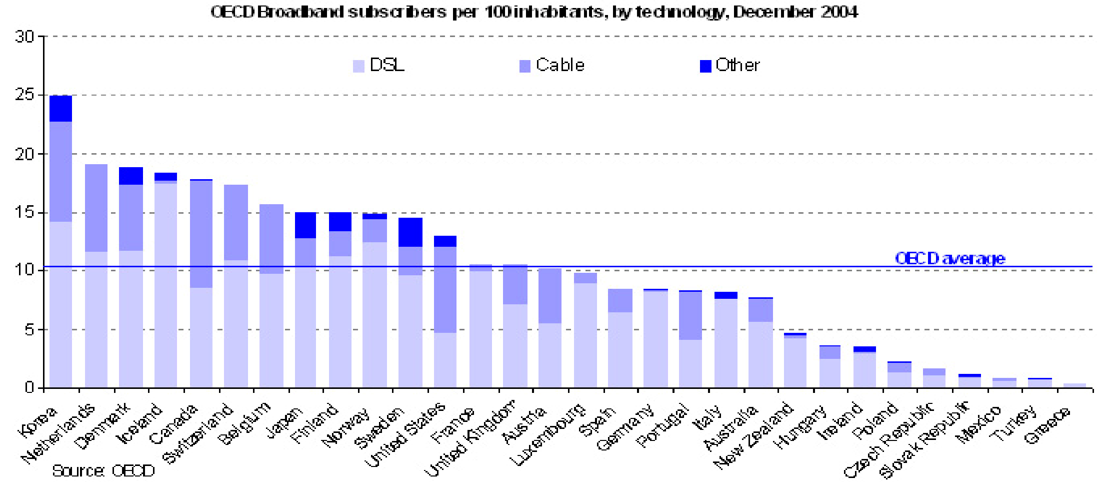

Figure 1. Broadband penetration in OECD countries
Source: OECD, 2005

The most widely used broadband technologies are the fixed broadband technologies, DSL and cable. Wireless broadband technologies are increasingly becoming popular. The wireless broadband technology Wi-Fi is clearly showing the great potential of these wireless technologies.
Another wireless technology with great potential is WiMAX (Worldwide Interoperability for Microwave Access). In the past years a lot of attention is directed towards this relatively new wireless technology and one could say that even a WiMAX-hype has been created. One hears that a WiMAX base station can create coverage of up to 50 km, deliver 70 Mbit/s, will work in unlicensed and licensed frequencies, can deliver non-line-of-sight (NLOS) through trees and buildings and will support mobility. The more than 100 trials or pre-standard deployments of fixed WiMAX in the world and the more than 350 members of the WiMAX Forum clearly show the popularity of WiMAX.[1]

Development towards 4G

The above indicates the rapid technological development of the dynamic electronic communication industry. Network operators are developing their current networks towards Next Generation Networks (NGN) integrating various broadband and cellular technologies. The concept of fourth generation networks (4G) has a central place in the wireless and cellular environment. What 4G exactly is, is a matter of debate. It is difficult to predict accurately what system and services will be provided in the future. Japan is one of the leading countries in deploying this next generation of broadband wireless technologies. Figure 2 shows the different technologies developing towards 4G. It is important to understand that no single technology can provide the consumer with all its

[1] The WiMAX Forum is an industry-led, non-profit corporation formed to promote and certify compatibility and interoperability of broadband wireless products.

application needs, but that an integration of cellular and wireless systems can complement each other in order to fulfill these service needs. The shortcomings of each individual technology can be complemented with the advantages of other technologies.

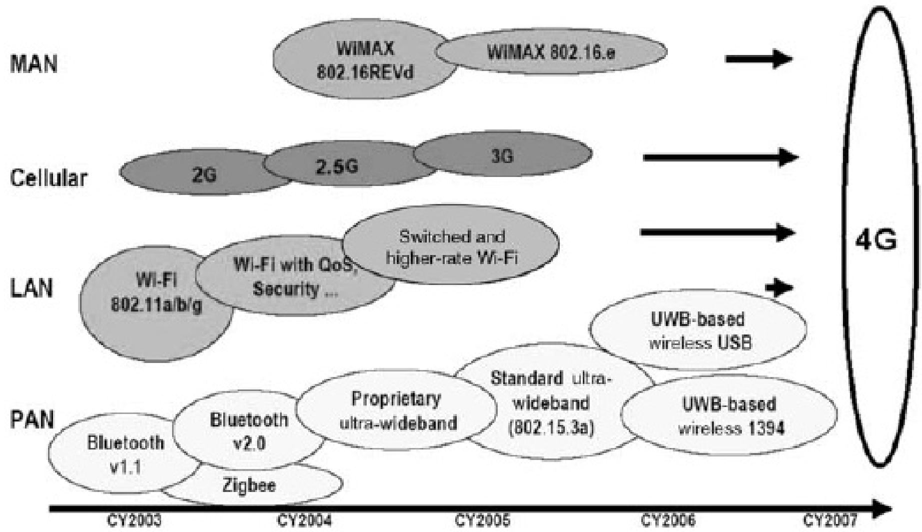

Figure 2. Next Generation Network
Source: Pareek, 2006

Wireless Local Area Networks (LAN) have great potential in their environments. It offers a high bit rate on a short distance of around 100 meters and is relatively cheap to use. Wired networks have dramatically improved and are able to offer extremely high bit rates of many Gbit/s, because of better switching and routing techniques. The biggest advantage of cellular systems is the ability of supporting full mobility. Although the third generation of cellular technologies has significantly increased the bit rate of these systems, the rate is still relatively low.

The existing investments in WLAN and 3G technologies have a major impact on the development path of the NGNs. Taking this into consideration, the NGNs will more than likely converge and integrate architectural, network and application levels of these cellular and wireless systems instead of deploying a completely new network system. In order to deal efficiently with the traffic the NGNs need to be all IP-based.

The position of the wireless broadband technology WiMAX in these NGNs is being determined nowadays. Many service providers, network operators, equipment manufacturers and chipmakers are researching the capabilities of WiMAX and are deploying WiMAX (trial) networks in order to understand what the opportunities of WiMAX in the electronic communication industry are and how WiMAX could exactly fit into the development towards the next generation network.

1.2.1. Problem owner

The problem owner of this research is the network operator in the Dutch electronic communication industry, who is interested or involved in WiMAX. The problem owner is interested in what the opportunities of WiMAX are in the Dutch electronic communication industry. The industry's value chain (§ 3.3) distinguishes service providers and network operators, but often these roles are performed by the same actor. The problem owner of this research is considered to be such actor, taking both the role of service provider and network operator.

To support the Dutch operator in understanding the opportunities of WiMAX in the Netherlands, the Japanese electronic communication industry and especially the role of WiMAX has been analyzed. The decision to focus on Japan was made for several reasons. When this research project started promising news was released on a WiMAX network deployment in the Tokyo area.[2] The scale of the planned deployment of 3000 base stations was impressive and it was one of the first commercial WiMAX deployments of such size globally. Additionally, Japan is known for its advanced electronic communication industry and the fast uptake of new communication technologies. Japan's world leading efforts in deploying the next generation of broadband wireless networks is especially important in this. Therefore, it is expected that the Dutch operator could benefit from the knowledge and experience on WiMAX of Japanese operators.

WiMAX in the Netherlands

When the research project started the involvement in WiMAX by Dutch operators was quite limited and only one operator was active. This was Enertel, a Dutch data and telecommunications operator for the business market.[3] It has deployed a fixed pre-WiMAX network for the business consumer in the cities Rotterdam, Amsterdam, The Hague, Utrecht and Eindhoven.

During the research, the dynamics of the electronic communication industry became apparent. Another operator Casema showed interest in WiMAX by acquiring a license for wireless broadband.

WiMAX in Japan

In opposition to the Netherlands, Japan is more actively involved in WiMAX. Japanese operators are deploying WiMAX networks on a larger scale. A good example is early mover Yozan Inc. It has planned to deploy the first pre-WiMAX network in Japan in cooperation with equipment manufacturer Airspan and it should have been available since Dec 2005. This Tokyo-wide Yozan Metrozone will deliver high-speed IP connectivity and will support services like voice, video and broadband data.[4]

[2] Airspan and Yozan Announce Expansion of Japan's first WiMAX Network, *Combined WiMAX and Wi-Fi solution will deliver self-installable voice, video and data services*, Press release Mar 11, 2005

[3] Enertel is currently operating under the name WorldMAX after its cooperation with Intel Capital, a subsidiary of Intel Corporation.

[4] Airspan and Yozan Announce Expansion of Japan's first WiMAX Network, *Combined WiMAX and Wi-Fi solution will deliver self-installable voice, video and data services*, Press release Mar 11, 2005

This large-scale deployment of 3000 base stations can provide valuable experiences for Dutch operators interested in WiMAX.

Another example is Tokyo based communication carrier Heisei Denden. It has announced to deploy a nation wide WiMAX/Wifi network. This will offer connection speeds of around 75Mbps and cover 80 percent of Japan's population by the end of 2007. However, while executing the research in Japan it became apparent that Heisei Denden is near to bankruptcy. This makes a large investment in a nation-wide WiMAX network very unlikely.

Currently, the most important actors actively involved in WiMAX are the cellular operators. All the three major cellular operators NTT Docomo, KDDI and Softbank Mobile have research programs and deployment plans with WiMAX.

1.3. Project description

Resulting from the problem exploration, the problem definition, the research objective and the research questions are formulated in this section.

1.3.1. Problem definition

The electronic communication industry is developing towards a new industry state by moving to a next generation all IP based network, which integrates and converges fixed, wireless and cellular technologies. The wireless broadband technology WiMAX could play an important role in this development.
In the Netherlands, the experience of the operators with WiMAX is limited and therefore it is difficult to understand the opportunities of WiMAX in the Dutch electronic communication industry. For example, the Dutch operators have not actively deployed small WiMAX trial networks to analyze its capabilities and to understand its advantages and disadvantages in comparison with other technologies.
In helping to understand the opportunities of WiMAX in the Netherlands, the WiMAX experiences in Japan could provide valuable lessons and knowledge. Japan is one of the world leading nations in researching and deploying the next generation of broadband wireless networks including WiMAX. Therefore, this research will analyze the experiences and strategies of Japanese operators with WiMAX. It is expected that Dutch operators can be benefit from this. It should be noted that it is important to take the different contexts of the Netherlands and Japan into account in order to avoid misinterpretations.

1.3.2. Research objective

Given this definition, the research objective can be formulated. The objective of this research project is:

Given the development of the electronic communication industry towards Next Generation Networks and the promising position WiMAX can have in this and given the current limited WiMAX experience in the Netherlands, the objective is to obtain an understanding of what the opportunities of WiMAX are for Dutch operators based on the WiMAX experiences of Japanese operators.

1.3.3. Research questions

Based on this research objective the main research question and the accompanying sub questions are formulated. The research questions show the existing gap in knowledge between the problem and meeting the objective (Verschuren and Doorewaard 2000).

Main question:

What are the opportunities of WiMAX for operators in the Dutch electronic communication industry based on the WiMAX experiences of Japanese operators?

Sub questions:

1. What are the advantages and disadvantages of WiMAX compared to other communication technologies?
2. What are the key issues of WiMAX for operators in the Netherlands?
3. What are the experiences and deployment strategies of WiMAX of operators in Japan?

1.3.4. Delineation of the research area

The problem owner is the operator in the Dutch electronic communication industry. Therefore, only the WiMAX opportunities for operators will be examined and not the WiMAX opportunities for other industry actors like equipment manufacturers or chipmakers. The problem owner could have a dual role of both service provider and network operator. My experience during this research showed me that operators involved with WiMAX in Japan and the Netherlands were performing both of these roles. Therefore, a clear distinction between them is not being made in this report.

The geographic focus is on the Netherlands and Japan. The socio-economic background of the Netherlands is expected to be known since this report is mainly written for a Dutch audience. Therefore, in Chapter 4 on the Netherlands this background is not being discussed in opposition to Chapter 5, which does discuss the socio-economic background of Japan in terms of government intervention and industry structure. Chapter 5 on the Japanese situation has been most thoroughly researched in this report.

The decision to focus on the Netherlands and Japan is based on several reasons. The Netherlands was chosen, because of my background as a researcher is Dutch. My presence in the Netherlands makes it easy to access relevant information and to arrange interviews with industry specialists in order to understand better the Dutch electronic communication industry. Japan was chosen, because of their world leading position in the deployment of next generation broadband wireless networks. The early involvement of some Japanese operators and research centers with WiMAX provide the opportunity to learn from their WiMAX experiences. The large-scale WiMAX deployment plans of Japanese operators Yozan served as an initial lead.
A second reason for this choice is my previous experience in Japan. I had lived and studied before in Japan and was therefore familiar with the country and its culture. This understanding positively supported the execution of my field research in Japan.

Additionally, a few simple similarities can be found between the Netherlands and Japan. Both countries have a very high population density, a high GDP of almost equal level and a high broadband penetration rate.

In any infrastructure related industry both the network infrastructure side and the service/content side are crucial for the industry to function. The focus of this research is on the network side and not on the service/content side for WiMAX in the Netherlands and Japan. However, the application areas of WiMAX in the Netherlands and Japan are fundamental to understand and therefore are being discussed.

1.4. Research approach and methods

The research questions have been formulated and the next step is to specify how these questions are going to be solved. In order to answer these questions research methods such as literature study, desk research and interviews are used.

The literature study is conducted in order to formulate the theoretical framework. This report discusses the structure of the electronic communication industry, the development of the industry and the strategic opportunities of the new technology WiMAX in this industry. Therefore, Industrial Organization (IO) theory and strategic management theory have been analyzed.

The first research question on the wireless broadband technology WiMAX has been addressed based on desk research. The objective is to give a thorough overview of what WiMAX is, who its supporters are, what the regulation issues are and what the advantages and disadvantages in comparison to other technologies are. This should lead to a better understanding of what the possibilities of WiMAX are.

Desk research and interviews have been used to assess the second research question on what the key issues concerning WiMAX for Dutch operators are. The assessment of the key issues will be done first by desk research. Insight should be provided on the key issues concerning WiMAX for operators in the Dutch electronic communication industry. Additionally, interviews with industry specialist and the Dutch government have been held. The parties have been interviewed CapGemini, Casema, DGET, Enertel and T-Mobile. Chapter 4 on the Netherlands will present only a brief overview of the Dutch electronic communication industry, its external environment and the actors, who are active with WiMAX.

The research approach and methods used in answering the third research question on the WiMAX experiences of operators in Japan are the same as have been used for previous research question on the Netherlands. The opportunity to execute the research on WiMAX in Japan was given by the Office for Science and Technology of the Royal Netherlands Embassy in Japan. In cooperation with Professor S. Naoe from Chuo University, Tokyo the Japanese electronic communication industry and the role of WiMAX has been analyzed. The extensive personal network and kindness of Professor Naoe made it possible to execute the many interviews with the industry specialists of WiMAX in Japan. On site interviews have been held with Chuo University, KDDI, the

Japanese ministry MIC, NTT Docomo, Ric Telecom, Sophia University, Willcom and Yozan. The interview methodology will be explained below. The Japanese situation is more thoroughly researched than the Dutch situation.

1.4.1. Survey method

Three type of survey methods can be distinguished the personal interview, the telephone interview and the mail interview. For this research, the personal interview has been selected, because of the importance of obtaining detailed information and to control the direction of the interview situation. This is best achieved by using a personal interview (Frankfort-Nachmias and Nachmias 1992). The personal interview is a face-to-face interpersonal role situation in which an interviewer asks respondents questions designed to obtain answers relevant to the research questions or hypotheses. There are three types of personal interviews, namely the schedule-structured interview, the focused interview and the non-directive interview. For this research, the focused interview has been selected, because of the need for certain flexibility between the interviews according to the relevance of the questions for certain respondents.

The general interview protocol, which has been used for the personal interviews in the Netherlands and Japan, can be found in Appendix A. This protocol is based on the causal diagram identifying the relevant factors concerning WiMAX (Appendix B). By designing this causal diagram a structured understanding of the relevant issues concerning WiMAX is obtained. This structured understanding supports the design of the interview protocol. The results of the interviews are the source of information for the Chapters 4, 5 and 6. The results of all the interviews can be found in a separate document: the Interview Appendix.

The questions of the interview protocol correspond to a factor or group of factors of the causal diagram. The interview protocol is not a static protocol, but has been adjusted during the interview process according to the need or relevance of the questions. The protocol consists of some more or less redundant questions. This was done deliberately in order to obtain balanced information of the respondent. The part of the interview protocol on the 'Dutch/Japanese context' is based on a PEST analysis structure. This PEST analysis is an integral part of the theoretic framework of this research (§ 2.2.1 and § 2.3.2).

The frame 'Technological capabilities' of the causal diagram (Appendix B) corresponds with question 2 and 3 of the interview protocol (Appendix A). The respondent is asked for his opinion on the technological capabilities of WiMAX. The factor 'Degree of competition other technologies' is the basis for questions 1, 5, 22, and 23 of the protocol. In number of different ways the respondent is asked to identify the competitive environment of WiMAX. The factors 'Expected revenue' and 'ARPU' correspond to the questions 20 and 21. Unfortunately, often these questions were not answered satisfactory, because of the premature state of WiMAX deployments or confidential nature of the information. The frame 'Regulatory environment' directly corresponds with question 8. The information obtained mostly focused on spectrum management and availability. For a more thorough analysis of the regulatory environment in the Netherlands and Japan, interviews have been executed with the relevant governmental institutions: the Dutch Directorate General of Energy and Telecommunications and the Japanese Directorate General of Radio Department. The interview protocol was adjusted completely for these interviews in order to obtain the most relevant information. The factor ‘Expected number of customers’ corresponds with the market questions 15, 16, 17 and 18. It is interesting to note that most operators did not have a clear objective on this. Only sometimes very vague estimations were provided.

In case of Enertel/WorldMax, Casema and Yozan, who actually deployed WiMAX networks, investment questions were asked corresponding to the factor ‘Cost of deployment’. However, because of the confidential nature of this information it kept a secret.

1.5. Structure of the report

The structure of the report is presented in Table 1. The chapters are associated with a research question and/or a research method.

Table 1. Structure of report

Chapter	**Research question**	**Research Method**
1. Introduction		
2. Theoretic framework		Literature study
3. WiMAX	What are the advantages and disadvantages of WiMAX compared to other communication technologies?	Desk research
4. WiMAX in the Netherlands	What are the key issues concerning WiMAX for Dutch operators?	Desk research and interviews
5. The Japanese electronic communication industry and WiMAX	What are the experiences and deployment strategies of WiMAX of operators in Japan?	Desk research and interviews
6. Conclusion and recommendations	What are the opportunities of WiMAX for operators in the Dutch electronic communication industry based on the WiMAX experiences of Japanese operators?	
7. Reflection		
References		
Annex		

Chapter 1 consists of the description of the background, the problem exploration, the problem definition and the research objective, questions and methods.
Chapter 2 describes the theoretical framework, which serves as the theoretical basis of this research project.
Chapter 3 describes the WiMAX technology by addressing the standard, the WiMAX Forum, deployment scenarios, costs and performance analysis.
Chapter 4 addresses the key WiMAX issues for the Dutch operators.
Chapter 5 examines the WiMAX experiences of Japanese operators
Chapter 6 is the final chapter and presents the conclusions and the recommendations of this research.
Chapter 7 is a reflection on the used framework of analysis and the theory.

2. Theoretic framework

This chapter will outline a theoretic framework that will be used as the basis of this research report. In order to construct this framework I first started with an exploration of the available and relevant literature to find a suitable theory or theories to address the research objective and questions, formulated in the previous chapter.

2.1. Exploration of theory

I started with examining the Industrial Organization (IO) theory to describe the electronic communication industry by using the Structure-Performance-Conduct paradigm. It became clear however that the traditional IO model is based on a static industry (Sampler 1998). The topic of this research report, being the electronic communication industry and WiMAX, asks for a more dynamic model approach. According to Waldman and Jensen, 'dynamic models are strategic and tend to emphasize technological change more than static models do' (2001, p.9). The nature of the electronic communication industry is highly regulated and characterized by rapid technology development and this therefore has reduced the utility of the tradition IO model for this research project.
I then shifted my attention to the Strategic Management theory in order to find a more dynamic approach of analyzing an industry.

2.1.1. Strategic Management theory

The Strategic Management theory showed me the well-known strategist Porter and his Five Forces model (1980). It can be observed that Porter's model is based on the Industrial Organization theory. In this model, Porter presents a structural analysis of industries by specifying five forces, which constitute the elements of an industry structure. The forces are the following: the entry of new competitors, the threat of substitutes, the bargaining power of buyers, the bargaining power of suppliers and the rivalry among existing competitors. These five forces determine the profitability of the industry, because they influence the prices, costs and required investment of firms in an industry. Porter argues that 'two main questions underlie the choice of competitive strategy'. First managers must select a competitive domain with attractive characteristics and second they must position the firm in regard to the five competitive forces encountered (De Wit and Meyer 2004).
The model can be determined as an outside-in approach, where the direct industry environment is analyzed in order to create a competitive advantage for a firm. This contrasts with the resource-based view, which has become to dominate in the field of strategic management (De Wit and Meyer 2004). The resource-based view can be determined as an inside-out approach, which explores the internal resources that are characteristic for a firm as the base of superior performance (Barney 1991).

The classical Five Forces model of Porter can be used to analyze the current state of the structure of an industry by focusing on the supplier and buyers, the substitutes and new entrants and the rivalry among existing competitors. This model presents a static view of the status quo of the industry.[5]

This outside-in approach of Porter's Five Forces model puts an emphasis on the firm's industry environment With the exception of the 'government policy', that Porter mentions as one of the possible entry barriers, there is barely attention for the broader external environment. It can be argued that knowing just the industry environment is not enough for determining a successful strategy and that knowing the external environment or industry context is also essential (De Wit and Meyer 2004, p. 421).

Another useful approach to analyze the various actors in an industry, like the incumbent rivals, suppliers and buyers, is represented by the concept of the 'value network'. This concept represents all the different important actors in an industry and the mutual dependent relations between them. In a value network the actors, their roles and their way of interaction change (Van de Kar 2004). In appendix C, the value network concept has been used to describe the WiMAX industry.

2.1.2. Level of strategy

A strategy can be designed or executed on different levels within an organization and these levels imply different strategic tools or theories. These levels are categorized in three general groups within a corporation and an additional fourth category on a supra-organizational level has been added. On every level the strategy needs to be internally consistent and it must fit well with its environment. The levels of strategy are the following:

- Functional level strategy
- Business level strategy
- Corporate level strategy
- Network level strategy

Since this research project is an industry wide analysis, the level of strategy on which the focus will be is the network level strategy. On this level, various firms are cooperating to create economic value. The number of firms making up such network can vary from two organizations to thousands organizations. The network group must develop a strategy that matches well with the demands of the relevant environment.

[5] However, since the formulation of this model the view of Porter on the nature of competition has changed to a more dynamic focus. De Man, A. P. (1994). "1980, 1985, 1990: A Porter Exegesis." Scandinavian Journal of Management **10**(4): 437-450.

2.2. External environment

As mentioned-above, in determining a successful strategy it is essential to know the external environment as well as the industry environment, especially in the case of the electronic communication industry. A well-known tool for this is the PEST analysis.

2.2.1. PEST analysis

In order to get a better insight into this external environment a PEST analysis can be executed (Reve 1990). The Reve model consists of the following four factors: political/regulatory, economical, socio-cultural and technological.
Typically, the PEST factors are viewed as having no direct connection with the organization. However, in the electronic communication industry, regulatory and technological factors have been the most influential factors causing the state of the industry to change.

This analysis makes a scan of the external environment in order to understand which aspects could have an impact on the industry and a firm’s strategy. These influences can have a positive or negative effect.

Political/regulatory
Other important actors of the external environment are governments, political parties, special interest groups, regulatory bodies and international institutions. This holds especially true for the electronic communication industry.

Economic
These economic factors can influence the industry and its future development, for example economic growth, labor productivity and changing exchange rates.

Socio-cultural
To this group individuals or organizations belong who can have a significant impact on the industry environment, for example the media, community groups, charities, religious organizations and opinion leaders.

Technological
To this group individuals or organizations belong who influence the development of the industry environment, such as research institutes, universities, patent offices, government agencies and standardization bodies.
The introduction of innovative technologies and communication standards are important drivers of the direction path of an industry.

2.3. Framework of analysis

Having examined the theory on the industry and external environment, the framework of analysis of this research project will be presented. The dynamics of the electronic communication industry ask for a dynamic approach. The industry development model presented in Figure 3 is such a dynamic approach. The challenges are not in assessing the advantages and disadvantages of the wireless technology WiMAX, but in anticipating what WiMAX will become in the future.

The key issue here is how industry development takes place. Is the industry influenced by an individual firm and in what way does the industry context drive particular types of firm behavior? The issues concerning industry development can be categorized into four groups; its dimensions, its drivers, its inhibitors and its direction or path (De Wit and Meyer 2004). These are shown in Figure 3. The focus of this research report is mainly on the drivers of industry development and partly on the dimensions of industry development. For completeness, the other two issues, inhibitors and path, are briefly presented.

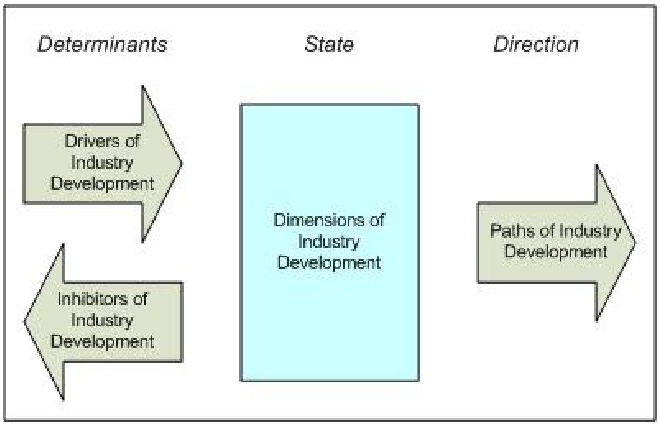

Figure 3. The issues of industry development

2.3.1. Dimensions of industry development

Industry development, which Porter refers to as ‘industry evolution’, implies that the structure of the industry changes. It has the following dimensions although there are more dimensions imaginable:

Convergence-divergence
The industry moves towards convergence when the business models that the firms are using are becoming more and more similar to each other. On the contrary, divergence takes place when many firms are introducing various new business models.

Concentration-fragmentation
An industry becomes more concentrated when an increasing large share of the market is owned by just a few organizations. In contrast, when the average market share of the largest companies is decreasing the industry will become more fragmented.

Vertical integration-fragmentation
The industry moves toward a vertically integrated structure when the firms are increasingly involved in more value-adding activities in the industry column. Conversely, when firms focus on their core business and bounce off value-adding activities then the industry will become more vertically fragmented.

Horizontal integration-fragmentation
When the strict boundaries between different businesses, both in the intra- and inter-industry domain, are increasingly degraded then the industry will become more horizontally integrated. When the opposite happens then the industry will become more horizontally fragmented.

International integration-fragmentation
International integration takes place when the international boundaries between the different geographic areas are increasingly vaguer. In contrast, when the competition in an industry is limited to a certain region then the industry is said to be international fragmented.

Expansion-contraction
An industry is said to be expanding when the demand for its products and/or services is continuously growing. When the demand is declining then an industry is moving towards a contracted state.

2.3.2. Drivers of industry development

As can be seen in Figure 3 the state of the industry is determined by drivers and inhibitors of industry development. Here the drivers will be further discussed. There are numerous factors in the industry and external environment that may change the state and direction of an industry. As discussed in paragraphs 2.1 and 2.2, it is suggested to combine an analysis of the industry environment with an analysis of the external environment of an industry. The change drivers of the industry environment of an industry are based on Porter’s categorization and divided in suppliers, buyers, new entrants, substitutes and incumbent rivals.
As proposed by Nalebuff and Bradenburger (1996) an additional change driver should be added, namely the complementor. In industries that are characterized as highly capital intensive and technology oriented, like the electronic communication industry, firms would be better off to behave as complementor, because increasing the size of the market would be more beneficial than competing over the shares of the market.

The change drivers of the external environment, based on the PEST model, are grouped in political/regulatory, economic, socio-cultural and technological forces for change. The combined model is shown in Figure 4. The substitutes and the complementors are grouped together in one rectangle.

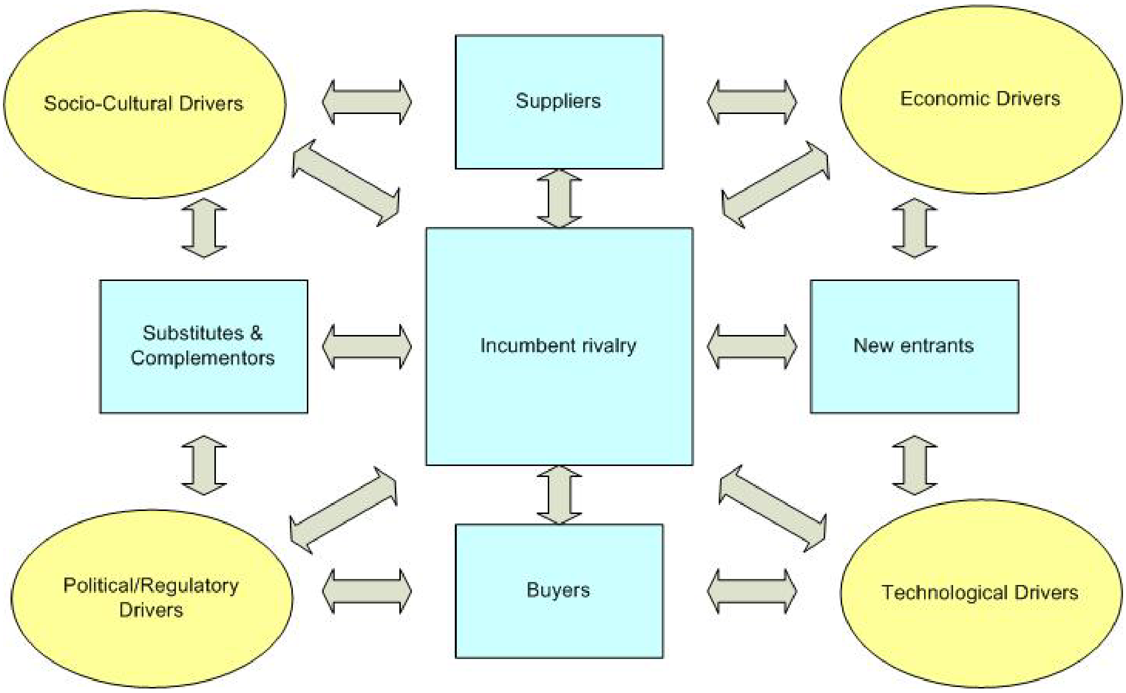

Figure 4. The internal and external drivers of industry development

The yellow ovals represent the four different drivers of the external environment. The little blue rectangles represent the five different drivers of the industry environment. The grey arrows represent the mutual influence each driver on another internal or external driver. The abundance of arrows shows the complexity and the dynamics of industry development. It should be pointed out that change in the industry could be the result of an individual driver or of a combination of several drivers together.

In Strategic Management theory a distinction can be made between the industry leadership perspective and the industry dynamics perspective (De Wit and Meyer 2004). If the main driver for change is an individual firm then this refers to the industry leadership perspective. When the development of an industry is caused by the combination of several change drivers then this refers to the industry dynamic perspective.

2.3.3. Inhibitors of industry development

The change drivers do not always change the state of the industry without opposition. The change drivers can be prevented from changing the state of industry by factors inhibiting industry development. In the following six of such inhibitors are briefly discussed.

Underlying conditions
Some aspects of an industry are inherent to that industry. This prevents a certain change in an industry to happen since the underlying conditions are fixed. For example, in the airplane manufacturing industry economies of scale are essential.

Industry integration
In some industries the interrelation between various elements of it are very strict making it difficult to change the state of this industry.

Power structures
Powerful industry players who believe they are better of with the current state can also inhibit change of the industry state. For example, the incumbent of an industry is blocking the industry to move in a certain direction.

Risk averseness
A change is not always without a risk. Therefore, the more industry players are averse to risk taking the more this will inhibit the industry from changing its state.

Industry recipes
'An industry recipe is the cognitive map shared by industry incumbents about the structure and demands of an industry' (De Wit and Meyer 2004, p. 428)). Such recipe formed by consensus of how the industry works can also prevent the industry from changing to a different state.

Institutional pressures
Organizations can meet with fierce pressure from various institutions, like governments, trade unions, pressure groups or consultants, dictating its activities. If organizations are conforming to such pressure then this can inhibit an industry from changing.

Additionally, it should be noted that industry development is path dependent and previous states of an industry determine the future possible or direction of the industry.

2.3.4. The path of industry development

The direction of the industry development can be of various natures. It can be evolutionary or revolutionary, continuous or discontinuous. A useful and well-known tool in determining the strategic path of industry development in case of the introduction of an innovative technology in the market is the technology adoption life cycle. More information can be found in appendix D.

2.4. International perspective

An extra dimension of the research project is its international context. It is important to understand the differences in the external and industry environment between Japan and the Netherlands. How does the Japanese electronic communication industry structure differ from the Dutch industry structure? What are the differences in the interdependent relations between the external environment and the industry environment of Japan and the Netherlands. The grey relational arrows of Figure 4 might be very differently constructed in Japan and the Netherlands.
The classical strategic management theory of Porter and Reve is originally designed for an Anglo-Saxon or Western environment. Therefore, it is important to question if this theory and the constructed framework of analysis is equally valid for the Japanese

context. To what extent are they useful in the Japanese environment? These aspects will be discussed in Chapter 7 at the end of the report, which presents a reflection of the research project.

2.5. Conclusion

The model shown in Figure 4, which combines the five forces model and the PEST model, is used in this report to analyze the external environment and industry environment of the Dutch and Japanese electronic communication industry. The driving forces of the external environment give this model a certain dynamics, but the model is not a truly dynamic model. When analyzing the literature it appears that there is still a lack of an industry dynamic model. Such model is much needed especially when analyzing the electronic communication industry, because of its dynamic character in terms of rapid technological development and changing regulations.

Nevertheless, the model of Figure 4 is used to analyze the Dutch and Japanese electronic communication industry and the opportunities of WiMAX in this industry. In order to understand what the position of WiMAX in the Dutch market can be, it is important to understand the competitive environment of WiMAX and the regulatory possibilities for WiMAX. With which technologies does WiMAX have to compete in the Netherlands and is there spectrum available for WiMAX. These aspects are analyzed in a structured way by using the model in order to understand the key isssues of WiMAX in the Netherlands. In understanding the opportunities of WiMAX in the Netherlands it is expected that the Japanese electronic communication industry and its advances in the field of WiMAX can provide valuable lessons about its experiences and strategies with WiMAX.

The same model of Figure 4 is used for the Japanese environment. It is used to analyze the Japanese electronic communication industry structure, its external environment and what the relations between the external environment and the industry environment are. These relations are important to understand, because they could appear to be crucial for the WiMAX opportunities in Japan. How is WiMAX being deployed in this context and what lessons can be learned from this for the Dutch situation?

3. WiMAX

In the previous Chapter 2, the framework of analysis has been presented. Before an assessment of the markets in the Netherlands and Japan will be executed, first an in-depth examination of what the wireless broadband technology WiMAX comprehends will be done.

3.1. What is WiMAX?

The term WiMAX is used by the industry and the media in many different ways and there seems to be some confusion in what WiMAX actually is. WiMAX stands for Worldwide Interoperability for Microwave Access and it is neither a technology nor a standard. It is rather a certification mark or stamp of approval of the WiMAX Forum. The WiMAX Forum is an industry-led, non-profit corporation formed to promote and certify compatibility and interoperability of broadband wireless products such as IEEE 802.16 and HiperMAN.[6] The certification mark is given to equipment that meets specific conformity and interoperability tests for the Institute of Electrical and Electronics Engineers (IEEE) 802.16 family of standards.
In this respect, the term WIMAX and WiFI are analogous. WiFi is also not a standard or technology, but rather a trade name that can be applied to a series of 802.11 IEEE standards.

This incorrect usage of the terms WiMAX and IEEE 802.16 could cause problems, because there is the possibility that equipment manufacturers make products, which are based on the IEEE 802.16 standard, but are not certified under the WiMAX label.

In the context of this report, the term WiMAX refers to WiMAX certified equipment, which is based on the IEEE 802.16 standards. When referred to WiMAX technologies it implies the IEEE 802.16 standards that are the basis of the WiMAX certification.

Since July 1999 the 802.16 Working Group on Broadband Wireless Access (BWA) has been developing several standards for Wireless Metropolitan Area Networks (WMAN) with worldwide applicability. An overview (Figure 5) shows the various wireless network standards and the position of the IEEE 802.16 standards within.

[6] WiMAX Forum available at www.WiMAXforum.org

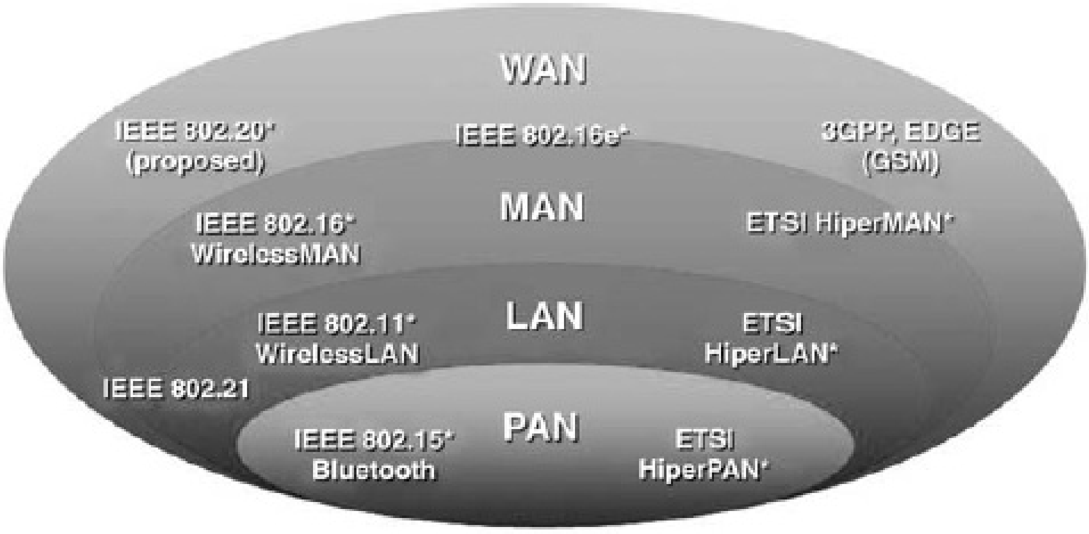

Figure 5. Wireless network standards
Source: Pareek, 2006

As can be seen from the figure, the technologies that are incorporated in the 802.16 standards are covering the two largest geographic areas, the wide are networks (WAN) and metropolitan area networks (MAN). WANs have traditionally been covered by two wireless systems namely nation-wide mobile network systems and satellite systems. In contrast, wireless systems have not found widespread adoption yet in the MAN coverage area of 50 kilometers. On the local area network (LAN) and personal area network (PAN) level several technologies have been successful. WLAN technologies, which underlie WiFi, are delivering data over a range of 150 meters and Bluetooth's technologies are doing this for short ranges of several 10's of meters (OECD 2005, p.7-18).

3.2. Standards

WiMAX is based on the IEEE 802.16 Wireless MAN air interface standard and on the HiperMAN standard developed by the European Telecommunications Standards Institute (ETSI). It originally covered the wireless local loop (WLL) technologies in the 10-66 GHz radio spectrum, which were later extended through amendment projects to include both licensed and unlicensed spectra from 2-11 GHz.[7]

The first standard, IEEE 802.16-2001, was published in April 2002 and it addresses fixed line-of-sight (LOS) connections for the last mile link in the 10-66 GHz frequency bands. However, the IEEE 802.16, which allows non-line-of-sight (NLOS) connectivity, received much more attention when the 802.16a standard for the 2-11 GHz band, including certain license-exempt bands, was ratified in January 2003. This standard positioned WiMAX as the possible dominant fixed wireless broadband technology.

[7] http://www.ieee802.org/16/

3.2.1. IEEE 802.16-2004

The next step was the establishment of a revised standard IEEE 802.16-2004 specifying the air interface of fixed BWA systems supporting multiple services. It was published in October 2004.[8] The medium access control (MAC) supports a primarily point-to-multipoint (PMP) architecture and optionally mesh topology. The MAC is designed to support multiple physical layer (PHY) specification, each suited to a particular operational environment. The PHY is based on single-carrier modulation for the frequencies 10-66 GHz. For frequencies below 11 GHz, where connectivity without LOS must be guaranteed, three alternatives are provided, namely Orthogonal Frequency Division Multiplexing (OFDM), Orthogonal Frequency Division Multiple Access (OFDMA) and single-carrier modulation. The IEEE 802.16-2004 standard consolidates the previous 802.16-2001, 802.16a and 802.16c standards keeping all modes and major features without adding anything. Thus, it provides the full specification for fixed wireless access in the 2-66 GHz frequency bands (IEEE 2004).

The term fixed WiMAX is often used when one refers to this IEEE 802.16-2004 standard, but as discussed above this is not correct strictly spoken since the term WiMAX refers to a certification mark. For marketing reasons and ease of use it is understandable that such a name is used instead of the numerical name.

IEEE 802.16-2004 is a standard for fixed wireless access and is designed to serve as a wireless DSL replacement, which should compete with the incumbent DSL or broadband cable providers or it could serve as basic voice and broadband access in underserved areas where no alternative access technology is available. These areas are, for example, developing countries and rural areas in developed countries where deploying copper wire or cable is not economically feasible.
Another viable solution of 802.16-2004 is for wireless backhaul of WiFi access points or potentially for cellular networks. Finally, in certain configurations, IEEE 802.16-2004 can be used to provide higher data rates and so it could serve as a T1/E1 replacement option for high-value business customers.

3.2.2. IEEE 802.16e-2005

The standard, which is currently attracting most attention from the industry, is the IEEE 802.16e-2005 standard, which was published in February 2006.[9] This version is an amendment to the previous IEEE 802.16-2004. The IEEE 802.16e-2005 offers a key feature that 802.16-2004 lacks, namely portability and eventually full mobility. It uses Scalable Orthogonal Frequency Division Multiplexing Access (SOFDMA), a multi-carrier modulation technique that uses sub-channelization.

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[8] The complete standard is available at http://www.wirelessman.org/pubs/80216-2004.html
IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems

[9] The amendment to IEEE Std 802.16-2004 is available at http://www.wirelessman.org/pubs/80216e.html
Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems- Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands

This standard will allow mobile access via portable devices such as laptops, personal digital assistants (PDA) and mobile phones at vehicular speeds. It should be kept in mind though that a deployment of an 802.16e-based network can also be used to provide fixed services.

The 802.16-2004 and 802.16e-2005 standards have evolved separately, because of the complex design issues of the mobile standard concerning inter-cell handoffs and authentication. This has resulted in the fact that 802.16e-2005 is not backward compatible with 802.16-2004. This could be troublesome for operators who have been planning to deploy an 802.16-2004 network and then in the future want to upgrade to an 802.16e network.

Furthermore, the 802.16 Working Group has been working on an amendment that incorporates mesh-networking capabilities into the standard. The IEEE 802.16f standard was published in December 2005.[10] Currently there are several new amendments under development, for example 802.16g for issues related to handovers.

3.2.3. Wi-Bro

Another interesting technology which should be taken in consideration when discussing WiMAX and the standards on which it is based, is a technology called WiBro (wireless broadband). WiBro is a technology that has been developed by LG Electronics and Samsung in South Korea. WiBro is defined as a 'portable internet service to provide a high data rate wireless internet access with Personal Subscriber Station (PSS) under the stationary or mobile environment, anytime and anywhere'.[11]

The underlying standard has been developed by the 2.3 GHz Portable Internet Project Group (PG302) under the Electronic communication Technology Association (TTA) of Korea. Initially, WiBro was perceived as being a portable solution, even though it could support mobile users, because the technology did not support seamless cell handoffs. However, with its adoption into the IEEE 802.16 set of standards it will support vehicular mobility of around 60 km/h. The harmonization of WiBro with the IEEE 802.16 set of standards was finally agreed upon after much debate. Proponents of WiBro such as Samsung suggested basing IEEE 802.16e on WiBro. Intel, an important driver behind WiMAX, and some other WiMAX supporters opposed this idea, because the WiBro standard used a different frequency band and carrier structure than IEEE 802.16.
An ongoing disagreement could have turned the two technologies into rivals thereby splitting the market, which could hold back an adoption of the technologies. However, both sides have agreed to merge the two technologies together under the IEEE 802.16.

An overview of the discussed standards and its specifications is given in Table 2.

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[10] The amendment to IEEE Std 802.16-2004 is available at http://www.wirelessman.org/pubs/80216f.html Amendment to IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems- Amendment 1: Management Information Base

[11] The definition is taken from the WiBro promotion site http://www.wibro.or.kr/index.htm

Table 2. IEEE 802.16 and WiBro specifications

	IEEE 802.16-2001	IEEE 802.16a amendment	IEEE 802.16e-2005 amendment	WiBro
Completed	December 2001	January 2003	December 2005	December 2004
Spectrum	10-66 GHz	2-11 GHz	Licensed bands 2-6 GHz	2.3-2.4 GHz
Channel conditions	LOS only	LOS, NLOS	LOS, NLOS	LOS, NLOS
Raw bite rate	32-124 Mbps at 28 MHz channelization	Up to 75 Mbps at 20 MHz channelization	Up to 15 Mbps at 5MHz channelization	Downlink 18 Mbps Uplink 6 Mbps
Modulation	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM	QPSK, 16QAM, 64QAM
Multiplexing technique	OFDM	OFDM, OFDMA	SOFDMA	OFDMA
Duplexing	TDD/FDD	TDD/FDD	TDD/FDD	TDD
Channel bandwidth	20, 25 and 28 MHz	1.75-20 MHz	1.75-20 MHz	8.75 MHz
Mobility	Fixed	Fixed, portable	Up to 120 Km/h	Up to 60 Km/h
Typical cell radius	2-5 Km	7-10 km, max range 50 km	2-5 km	Up to 1 km

Compatibility between IEEE 802.16-2004 and 802.16e-2005

The OFDM and SOFDMA modes are not compatible as they are based on two distinct modulation techniques. As a result, a single mode SOFDMA terminal will not work within an OFDM network and vice versa. An important aspect to take into consideration when planning to deploy a WiMAX network.

3.3. WiMAX value chain

The WiMAX value chain is very similar to the general telecommunication industry value chain (Figure 6). An important difference is the driving influence the WiMAX Forum has on this value chain.[12] Although, other technology value chains are pushed also by certain organizations, for example the UMTS Forum for the UMTS industry. The WiMAX Forum does not stand within the industry, but is coordinating the WiMAX industry from higher level. The WiMAX Forum influences all actors of the value chain from the chipmakers to the end-user. It should be clearly understood that the WiMAX Forum consists of these exact same actors.

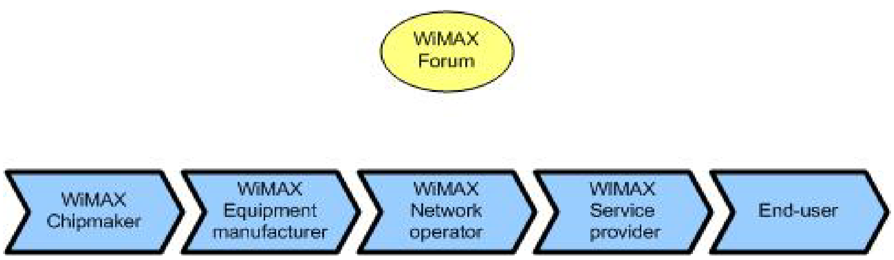


Figure 6. WiMAX value chain

[12] The WiMAX Forum will be discussed in more detail in § 3.4.

Additionally, it should be noted that the WiMAX value chain moves in a direction from left to right. WiMAX chipmakers strongly influence the equipment manufacturers and these influence the network operators and so on. A crucial member of this WiMAX Forum is chipmaker Intel Corporation. Intel really pushes the value chain in order to create a market for its WiMAX chipsets, named Rosedale. Intel shows strong commitment to get WiMAX chipsets integrated in laptops and is developing a dual WiFi/WiMAX chipset for it. Eventually, Intel wants to get its chipsets into mobile devices thereby addressing an enormous market. Intel's strategy goes further than producing the chips and promoting WiMAX via the forum. The venture capitalist Intel Capital, a subsidiary of Intel Corporation, is actively investing in network operators to support their WiMAX network deployment plans. An important example is the US$ 600 million investment in US operator Clearwire to deploy a WiMAX network. In the Netherlands, the WiMAX entrepreneur Enertel Wireless is cooperating with Intel Capital to deploy a WiMAX network. For WiMAX to succeed it is vital that actual WiMAX networks are successfully deployed and commercially available. This can trigger other actors in the value chain such as the operators, service providers and end-users to adapt to WiMAX. By investing in these network operators Intel achieves two goals the realization of a WiMAX network, which can convince other operators to deploy a WiMAX network also, and the sales of its WiMAX chipsets needed for the realization of this network. Thus, WiMAX chipsets sales volume goes up and this can cause an accelerated volume growth when additional networks are deployed.

WiMAX equipment manufacturers also benefit from these investments of for example Intel Capital, because they have to supply the equipment for these networks. Currently, there are about 70 WiMAX equipment manufacturers, of which about 10 offer certified WiMAX equipment.[13] Alvarion is market leader with a large majority market share for fixed WiMAX equipment. However, it is expected that Motorola and Samsung with its WiBro technology will lead the future mobile WiMAX equipment market. Motorola is involved in the major mobile WiMAX deployment plans of among others Clearwire and Sprint-Nextel.

3.4. Architecture PHY and MAC layer

The specifications of the standards are best described by referring to the OSI reference model (Figure 7). The OSI model is usable in the computing and networking industry. It is important to understand what aspects of the WiMAX technology the IEEE specifies. This model divides the features of a protocol into seven different layers. Each separate layer only uses the features of the underlying layer and only exports functionality to the layer above. The interface between the layers thus describes the specifications on how one layer interacts with another layer.
The IEEE standards, as is customary, only specify the two lowest layers, the PHY and MAC layers. The IEEE 802.16-2004 and ETSI HiperMAN standards share the same PHY and MAC layer. In Appendix E, these layers will be explained for the 802.16 standards.

[13] More information can be found in § 3.5.4

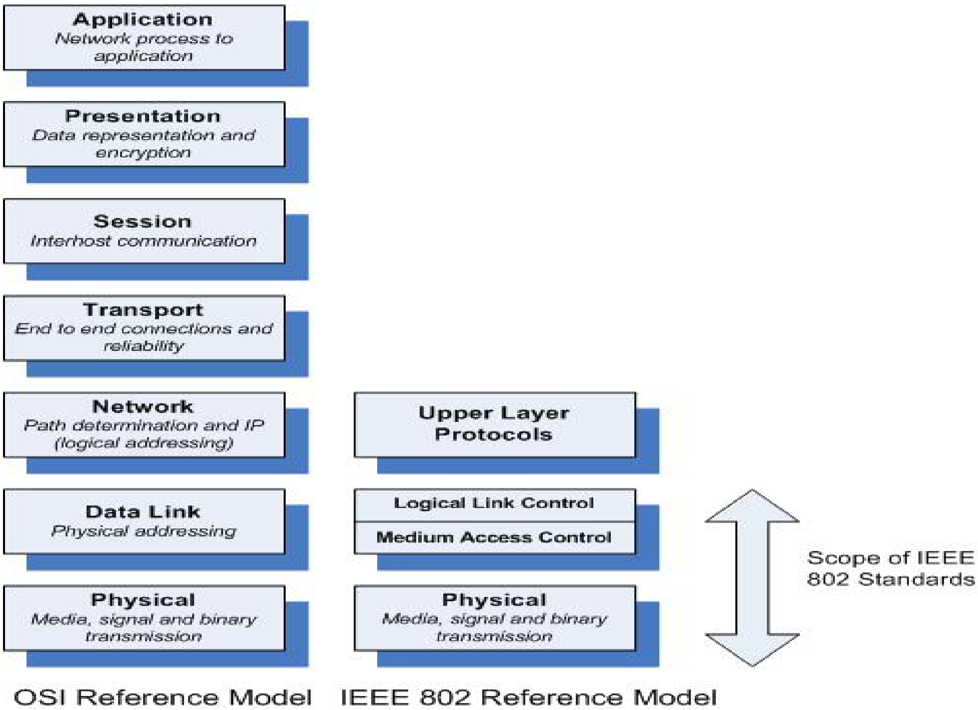


Figure 7. Technical scope of IEEE 802 standard

3.5. WiMAX Forum

The WiMAX Forum is an industry-led, non-profit corporation formed to promote and certify compatibility and interoperability between broadband wireless equipment from different manufactures based on the standards IEEE 802.16 and ETSI HiperMAN. While the IEEE has only specified the PHY and MAC layers leaving many parameters variable, the WiMAX Forum takes this a step further. It has specified certain WiMAX system profiles and test specifications. The objective of these system profiles is to designate which features are obligatory or optional for the different PHY and MAC scenarios that are most likely to occur during network deployments. This allows vendors addressing the same market to deploy systems that are interoperable while not requiring the implementation of every single feature.

The WiMAX Forum was founded in 2001 and currently has more than 350 members including equipment manufacturers, semi-conductor suppliers, operators and content providers. A leading member and important driver behind WiMAX is Intel. Other important members, who are putting their weight behind WiMAX, include wireless equipment maker Alcatel, AT&T, chipmaker Fujitsu, operator Korea Telecom, Motorola and Sprint Nextel.

3.5.1. Why a WiMAX Forum

WiMAX is not the first broadband wireless access system in history that tries to obtain a widespread market adoption. Earlier fixed wireless access technologies like Local Multipoint Distribution Service (LMDS) and Multi-channel Multipoint Distribution Service (MMDS) have made similar attempts, but have seemed to fail in achieving widespread market adoption. The problems with most BWA implementations have been of critical mass and, consequently, cost. Most BWA networks lack all characteristics of a low-cost market namely volume, standardization and interoperability.

These three shortcomings are exactly the aspects in which the WiMAX Forum is trying to foresee. Its efforts should lead to economies of scale, made possible by standards-based, interoperable products and will drive price and performance levels unachievable by proprietary approaches. As a result, operators worldwide will be able to deliver economical broadband data, voice and video services to both residential and business customers'.[14]

3.5.2. System Profiles

Since the IEEE 802.16 standards specify the entire frequency range from 10-66 GHz and the sub-11 GHz bands, there is an enormous amount of options available for numerous deployments. The only way to achieve interoperability and to generate the economies of scale that lead to lower prices and a more appealing technology, is to limit these numerous options to a certain set of system options. Therefore, the WiMAX Forum has devised systems profiles that specify combinations of parameters like operating frequency, modulation scheme and channelization. This choice of profiles is driven by market demand, the availability of spectrum, regulatory constraints, the intended services and vendor interest. For example, the availability of spectrum for BWA in the 3.5 GHz band in several countries motivated the choice for these profiles. The availability of license-exempt spectrum and the demand for fixed services were reasons to create a profile in the 5.8 GHz band. The demand for mobile services and the spectrum availability have made the 2.3 GHz and 2.5GHz bands attractive for the 802.16e profiles. Thus, the WiMAX Forum selected three initial spectrum bands for WiMAX-certified equipment, which include the 2.5 GHz, the 3.5 GHz and the license-exempt 5.8 GHz band.

Fixed WiMAX

Currently, the WiMAX Forum has identified five system profiles for the IEEE 802.16-2004 standard clearly indicating what their focus is. Interestingly, the 20 MHz channel size that was necessary to achieve a throughput speed of 70 Mbit/s is not one of the focus points. The WiMAX Forum has released the initial profiles for fixed and nomadic access in the licensed 3.5 GHz band and in the license-exempt 5.8 GHz band (Table 3).

Table 3. WiMAX Forum certification profiles

Frequency (MHz)	Duplexing	Channels (MHz)	IEEE standard
3400-3600	TDD	3.5	802.16-2004
3400-3600	FDD	3.5	802.16-2004
3400-3600	TDD	7	802.16-2004
3400-3600	FDD	7	802.16-2004
5725-5850	TDD	10	802.16-2004

[14] WiMAX Forum, http://www.WiMAXforum.org/about/WiMAX_Forum_Overview/

The first certification release for 802.16-2004 has been completed for the two 3.5 GHz profiles with a channel bandwidth of 3.5 MHz both TDD and FDD duplexing. Currently, there are certified products in these two profiles commercially available.

Mobile WiMAX

The system profiles for the IEEE 802.16e-2005 standard have been specified for the 2.3 GHz (for WiBro applications), 2.5 GHz, 3.3 GHz and 3.5 GHz frequency band, which are all licensed bands worldwide, with channel bandwidths of 5, 7, 8.75, and 10 MHz channel. However, the initial release of Mobile WiMAX certification profiles will only include TDD. Future releases will consider FDD profiles to address specific market opportunities where local spectrum regulatory requirements either prohibit TDD use or are more suitable for FDD deployments (Table 4).

Table 4. WiMAX Forum certification profiles for mobile WiMAX

Frequency (MHz)	Duplexing	Channels (MHz)	IEEE standard
2300-2400	TDD	5,8.75,10	802.16e-2005
3400-3800	TDD	5,7,10	802.16e-2005
2469-2690	TDD	5, 10	802.16e-2005
3300-3400	TDD	5,7	802.16e-2005
2305-2320, 2345-2360	TDD	3.5,5,10	802.16e-2005

The first certification for 802.16e-2005 will commence in Q4 2006 with the following profiles; 2.3 GHz band, 8.75 MHz channel size and TDD duplexing. This corresponds with the WiBro specifications.

The positioning of WiBro in mobile WiMAX is as follows. The WiBro profiles and test specifications have been fully harmonized with the system profiles for the 802.16e-2005 standard. This makes WiBro an integral part of mobile WiMAX and it uses the 802.16e-2005 as its base standard. WiBro can be seen as a service name for offering mobile WiMAX in Korea. Since the second half of 2006 such WiBro services are offered in the form of PCMCIA-cards for laptops. However, at the moment this is not an official certified mobile WiMAX system, but a mobile pre-WiMAX system. Certified mobile WiMAX products are expected to be available only from H1 2007.

3.5.3. WiMAX Test Laboratory

The testing for the fixed WiMAX equipment (based on the IEEE 802.16-2004 standard) is done by an authorized independent laboratory. The WiMAX Forum selected Cetecom Laboratories in Spain to be its official main certification laboratory. Cetecom will thus test and certify the equipment products of WiMAX Forum member companies to ensure they conform to the system profiles and specifications. Systems conforming to the test specifications will receive a WiMAX Certified label.

In January 2006, the first round of commercial fixed wireless broadband systems received this WiMAX Certified label. This is about half a year later than was originally planned by the WiMAX Forum. This delay could appear to be crucial for the success of fixed WiMAX when operators decide to skip this fixed WiMAX step and directly move to mobile WiMAX deployments. On the other hand, one should realize that the markets for fixed and mobile WiMAX could be two separated markets with different business cases and different market players.

The testing for the mobile WiMAX equipment (based on the IEEE 802.16e-2005 standard) has not started yet, but the WiMAX Forum has selected Electronic communication Technology Association's (TTA) IT Testing and Certification Laboratory in Korea as a second test laboratory for mobile WiMAX next to Cetecom Laboratories. It is expected that the test procedure will start in Q4 2006 and that the first commercial mobile WiMAX products will be certified by Q1 2007.

It is important to note that globally many operators in the past have appeared to be claiming to offer WiMAX services over their WiMAX network, but before 2006 this was impossible. The operators should have referred to it as pre-WiMAX networks, equipment or services.

3.5.4. WiMAX Forum Certified Products

There are currently eleven equipment manufacturers, who are offering certified fixed WiMAX products, both base stations and subscriber station. These are Airspan, Alvarion, Aperto Networks, Axxcelera Broadband Wireless, Proxim Wireless Corporation, Redline Communications, Selex Communications, Sequans Communications, Siemes SPA, SR Telecom and Wavesat Wireless. In Figure 8 three examples of such certified fixed WiMAX subscriber stations are shown.

Figure 8. Certified fixed WiMAX subscriber stations

Most subscriber stations are outdoor CPE devices. This means that a professionally installed outdoor antenna is necessary. This makes a network deployment more costly than when a self-installable CPE is used. In time the functionality of the subscriber stations will increase, from outdoor CPE to indoor CPE to PCMCIA cards for laptops. In Figure 9 the commercial availability of certified fixed and mobile WiMAX products is shown. Currently, there is one self-installable indoor CPE available. However, it is expected that the actual availability of mobile WiMAX will be at a later date than the roadmap of the WiMAX Forum shows us. The certified fixed WiMAX products came six months later on the market than the WiMAX Forum had initially planned, because of delays at the Cetecom Laboratories.

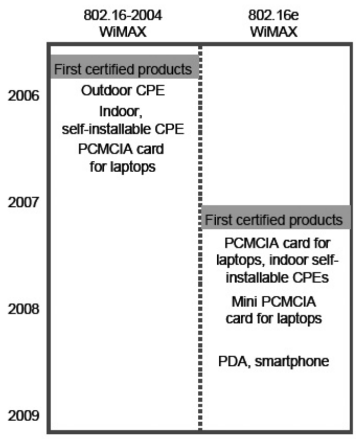


Figure 9. Expected commercial availability of WiMAX products
Source: WiMAX Forum, 2006

The figure shows that the first certified mobile WiMAX products are expected to be available in the first half of 2007 as PCMCIA cards for laptops and these will support any type of access, from fixed to mobile. Towards the end of 2007 mini PCMCIA cards should be available for laptops with built-in WiMAX functionality. The last stage in the development of the mobile WiMAX products will be the availability of PDAs and smartphones somewhere in 2008.

Not all equipment manufacturers of fixed WiMAX products will also offer mobile WiMAX products in the future. Two noted manufacturers of certified mobile WiMAX products will be Samsung and Motorola.

3.6. WiMAX Regulation

One of the challenges for a successful introduction of WiMAX lies in the regulatory field. The regulatory implications requiring attention of the regulators and the WiMAX Forum include spectrum management and allocation, type of usage allowed (fixed or mobile), power restrictions and global harmonization.

3.6.1. Global spectrum harmonization

In order to address a worldwide WiMAX market it is highly important to achieve a high degree of spectrum harmonization on a global level. This will minimize the number of equipment variants and thereby increase economy of scale benefits. When a globally recognized frequency band for WiMAX deployments cannot be secured then the economies of scale will be reduced and the network costs will increase.

3.6.2. Spectrum

Much of the success of WiMAX is dependent on the ability of operators to find appropriate and available spectrum. The IEEE 802.16 work group has tried to address these issues by making the channel bandwidth small ranging from 1.75 MHz to 20 MHz (Table 2). This flexibility makes it easier to find available spectrum among existing allocations. In contrast, WiFi demands channel sizes of 20-22 MHz.

Allocation

There are two main types of spectrum allocation: licensed and unlicensed. The licensed frequencies are generally obtained through an auction, as is the case in most EU countries or via a contest, which is common for example in Japan. Licensed spectrum requires an authorization from the regulators, which gives the exclusive right to an operator to use that specific frequency at a particular location or within a defined geographic area. For this license, a certain fee has to be paid by the operator, which could be very large amount like in the case of the Universal Mobile Telephone System (UMTS) auctions in the UK and Germany where million of euros were paid. However, such high auction fees are not expected for the WiMAX licenses. In the Netherlands, fees for licenses for fixed wireless broadband applications have been relatively low.

Licensed

The World Radiocommunications Conference (WRC) in 2000 appointed the 2.5 GHz to 2.69 GHz band for IMT-2000 cellular technologies and most national regulators of OECD countries have adopted this. Keeping in mind that the 2.5 GHz band is one of the selected spectrum bands by the WiMAX Forum, this means that currently this band cannot be used for WiMAX applications. Some exceptions are the United States and Mexico, which have allocated the 2.5 GHz band for fixed and mobile broadband services.

Another initial key WiMAX frequency is the 3.5 GHz band. This band is available in many OECD countries for fixed wireless access (FWA). This band offers great potential for various fixed WiMAX applications, but not for mobile applications. However, regulators are starting to revise their positions to include portable access in a first step and will eventually allow full mobility in the 3.5 GHz band.

Unlicensed

The unlicensed frequencies allow several operators to share the same frequency band without prior authorization of the regulator or paying a fee for it. However, license-exempt transmissions are still subject to rules and constraints. For example, the equipment must use mitigation techniques like Transmitter Power Control (TPC) and Dynamic Frequency Selection (DFS) to prevent interfering with other licensed uses.
Although the use of license-exempt bands may be an inexpensive and fast to deploy solution, it is not without risk since operators have to tolerate interference from other non-licensed usage. This can result in a decrease in service stability and quality.

In 2003, the WRC has allocated the 5150-5350 MHz and 5470-5725 MHz bands to the mobile service for implementation of wireless access systems, including Radio Local

Area Networks (RLAN).[15] This newly allocated 5470-5725 MHz band adds a significant amount of license-exempt bandwidth, which could very well be suitable for WiMAX applications. However, the high frequency ranges make it more suited for fixed applications than for mobile applications, because for a mobile network many more base stations are required for a good coverage, including indoors.

3.7. Deployment scenarios

The 802.16 standard will support the industry to provide solutions across multiple broadband segments. WiMAX was initially developed as a wireless last-mile access technology competing with DSL, cable and T1 technologies. However, the development of the IEEE 802.16e-2005 standard adds a completely new mobile dimension to the application options for WiMAX. The appeal of mobile WiMAX goes further than just mobile usage. It is important to keep in mind that it supports multiple usage scenarios, including fixed, portable and mobile access, using the same network infrastructure.

WiMAX is credited to support many types of wireless broadband applications including but not limited to high-bandwidth MANs, cellular backhaul, clustered Wi-Fi hotspots backhaul, last-mile broadband, mobile phone replacements for various wireless service applications like ATM's, vehicular data and voice, security and surveillance applications, wireless VoIP and video streaming. Today, these applications are, if available, served by expensive, proprietary systems for broadband access. In areas, where no fixed broadband infrastructure exists, such as developing countries, WiMAX can provide a fast to deploy and cost effective solution (Figure 10).

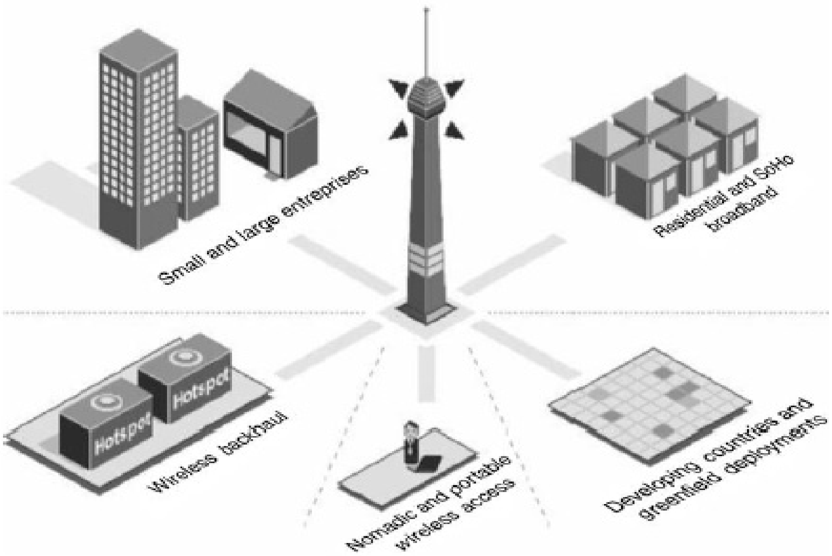


Figure 10. WiMAX applications
Source: Pareek, 2006

[15] World Radiocommunications Conference, Resolution 229 (WRC-03)

The above-mentioned applications for WiMAX can generally be grouped into three deployment scenarios;

1. Wireless access fixed or mobile
2. Backhaul WiFi hotspot or cellular
3. Metropolitan area networks

WiMAX was designed to provide low-cost, flexible, high-quality BWA that makes use of certified, standardized and interoperable equipments from multiple vendors.

3.8. Performance comparison of technologies

When comparing WiMAX with other technologies it is important to keep in mind what type of usage model WiMAX is used for (Figure 11). Fixed and mobile WiMAX have different application areas and depending on these areas a performance analysis comparing other technologies, competing or complementing, is executed.

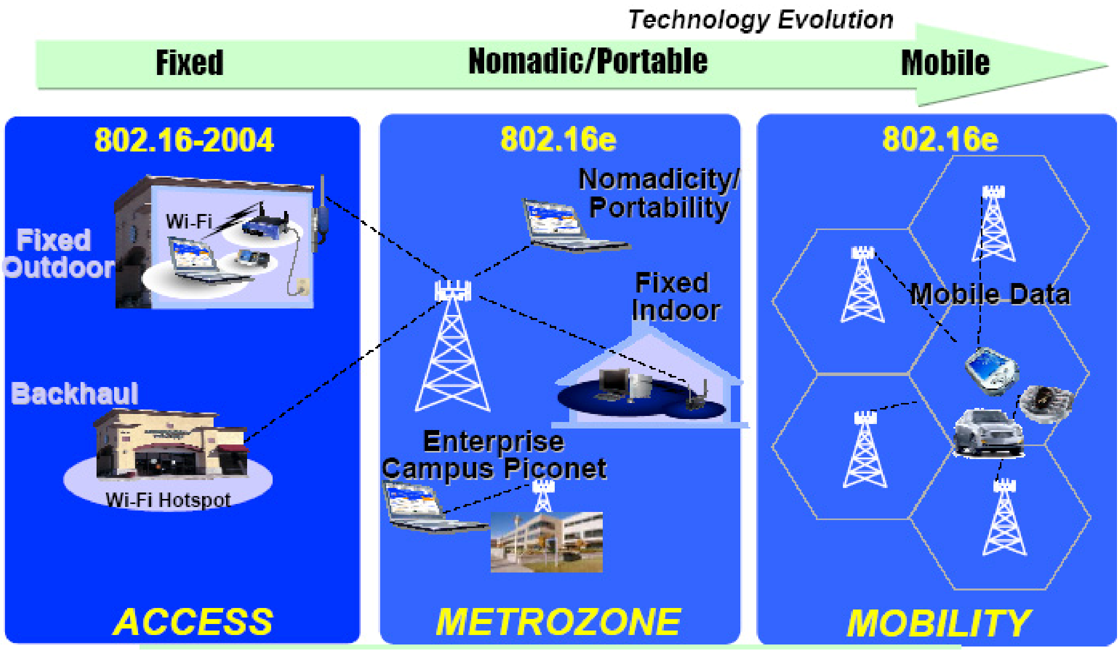


Figure 11. WiMAX usage scenarios
Source: ITU-T, 2006

In case of a fixed access usage, fixed WiMAX can compete with DSL. Fixed WiMAX is expected to initially offer 40 Mbit/s per wireless channel. Depending on the specific technical configuration chosen, this is enough to support tens of businesses with T-1 speed connectivity and hundreds of residences with DSL speed.

In case of a mobility usage model, mobile WiMAX should be compared with 3.5G technologies, such as HSDPA/HSUPA (HSPA) and CDMA2000-EVDO. A study executed by the WiMAX Forum shows the following results when comparing the throughput of these different technologies (Figure 12). It can be observed from the figure that mobile WiMAX especially with the use of multiple antenna technology MIMO has a much larger throughput, 14 Mbit/s, than for example HSDPA.[16]

In the same study, the spectral efficiency of mobile WiMAX, HSPA and EVDO is compared (Figure 13). Mobile WiMAX with MIMO is significantly more efficient than HSDPA. Considering the fact, that spectrum is a scarce resource and the demand for broadband rises this is a great advantage of WiMAX. The reason with the spectral efficiency is among others the underlying technology that mobile WiMAX uses, namely OFDMA. OFDMA is especially for the downlink a very spectrum efficient technology.

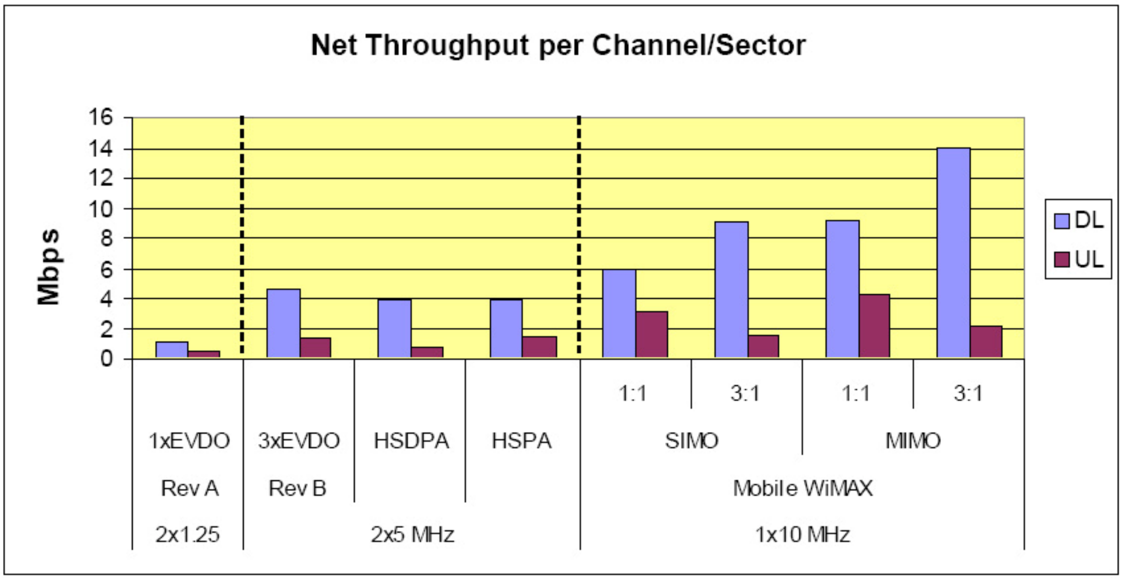


Figure 12. Sector throughput comparison
Source: WiMAX Forum, 2006

[16] The exact simulation parameters of the comparison are available at WiMAX Forum (2006). "Mobile WiMAX - Part 2: A Comparative Analysis ".

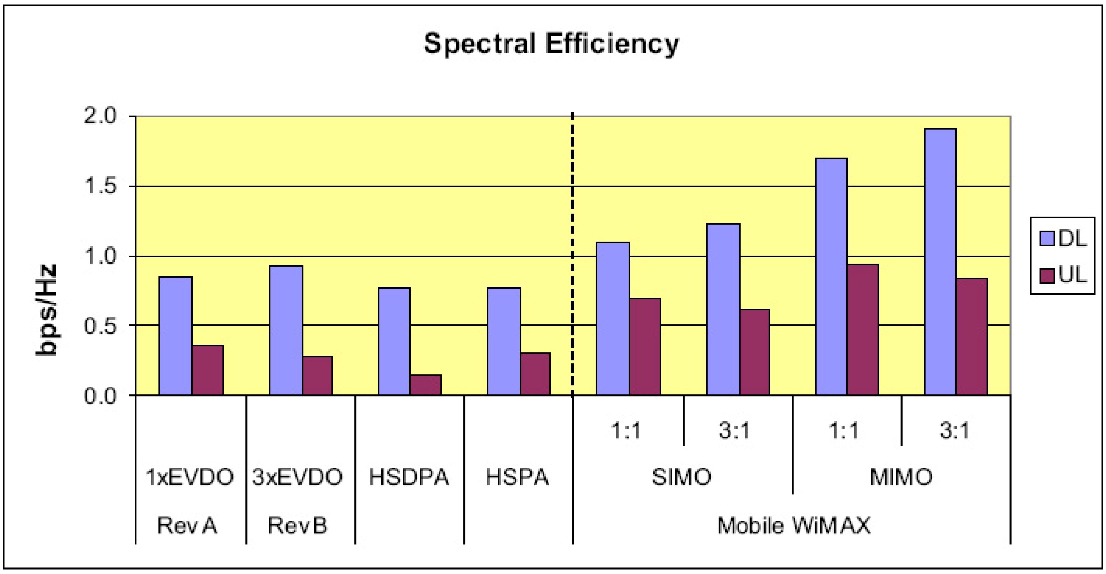


Figure 13. Spectral efficiency comparison
Source: WiMAX Forum, 2006

Having analyzed the performance differences of the various technologies, it is worth mentioning that these technologies do not necessarily have to compete against each other. These technologies can have a complementary role. It highly depends on the deployment situation and on the networks already in place of the operator. Fixed WiMAX could serve as the wireless extension to DSL, but also as a competitor. Mobile WiMAX could serve as a backhaul technology complementing a 3G/3.5G network. In areas where such networks are available, it does not seem to be feasible business case to rollout a nation-wide mobile WiMAX.

3.9. WiMAX Costs

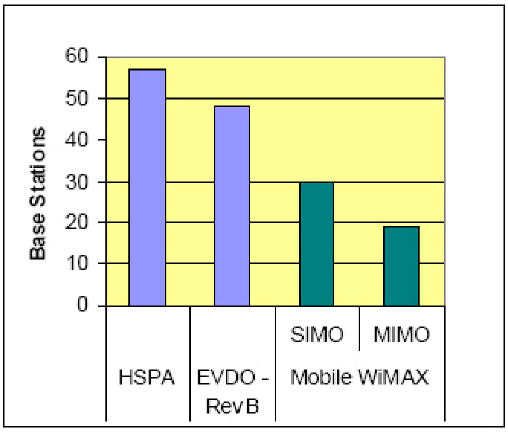
In analyzing the typical costs of WiMAX deployments, it must be noted that reliable and complete data was difficult to obtain due to the novelty of the subject and the limited financial resources. Research reports are written either by the biased WiMAX Forum (or derived from it) or by very costly independent research companies, such as Skylight Research or Maravedis.

3.9.1. WiMAX base stations

In general, the cost-efficiency of WiMAX is caused by the throughput and spectral efficiency advantages of WiMAX resulting in the fewer base stations needed to achieve a desired data density. The use of fewer base stations reduce the CAPEX of a network given a certain capacity and also reduces OPEX, because of the reduced maintenance costs. Additionally, the use of wireless eliminates the costly trenching and cabling of new wire/fiber lines in case of DSL/fiber deployments.

However, the cost of a base station also needs to be low and therefore a global market needs to be reached resulting in economy of scale benefits. A task held in high esteem by the WiMAX Forum.

A study executed by the WiMAX Forum shows the following results in respect to the number of base stations necessary for mobile WiMAX deployments in comparison with 3.5G networks (Figure 14). It shows the number of base stations needed in order to achieve a downlink data density of 215 kbyte/s/km² over a 129 km² coverage area. It can be observed that mobile WiMAX together with the use of multiple antenna technology MIMO requires around 19 base stations. Compared with the about 57 required base stations for HSPA (HSDPA/HSUPA) this is a significant difference. One third of the number of required base stations for HSPA deployment is needed for a mobile WiMAX deployment using MIMO. The price of a HSPA base station and a WiMAX base station is expected to be in the same order, because the materials used for and the production complexity of the base stations is expected to be very similar. This results in the WiMAX network deployment costs, as far as the base stations are concerned, to be about 1/3 the costs of a HSPA network deployment.



- WiMAX Frequency = 2500 MHz
- HSPA, EVDO Frequency = 2000 MHz
- Occupied Spectrum = 10 MHz
- Frequency Reuse = (c,1,3)
- Coverage Area = 129 sq-km
- DL/UL Traffic Ratio = 2:1
- DL Data Density = 215 kbytes/sec/sq-km
- Monthly Capacity ~23 Gigabytes/sq-km

Figure 14. Number of required base stations
Source: WiMAX Forum, 2006

For fixed WiMAX deployments to achieve the same data density less base stations are needed due to possible optimum position of installing the fixed antenna on the rooftop and the lack of building penetration loss. For mobile WiMAX indoor coverage is required resulting in more base stations.

3.9.2. WiMAX CPE

The cost-efficiency of a WiMAX network deployment also needs to express itself in low priced WiMAX CPEs. As long as the CPEs are expensive it will be difficult for WiMAX to reach mass market adoption, because especially the customer is not willing to pay a high price for their WiMAX CPEs. In comparison, the mass market adoption of 2G technologies only occurred when operators offered their customers nearly free of cost 2G handsets. According to Sky Light Research, it is expected that WiMAX CPEs costs will rapidly decrease in the coming years (Figure 15).

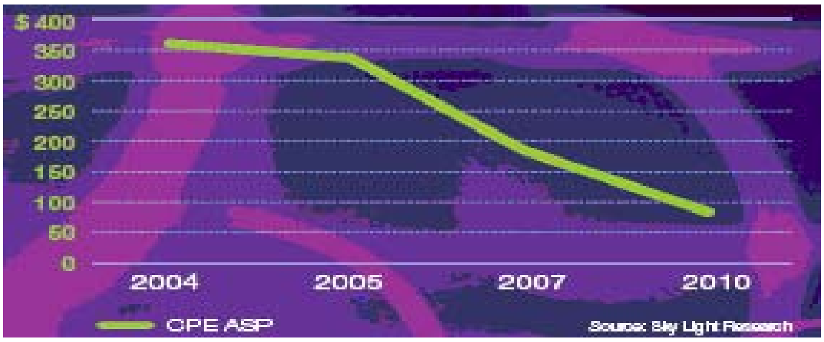


Figure 15. WiMAX CPE pricing potential
Source: Sky Light Research, 2006

It is important to understand that as volume increases, CPE pricing will decrease. However, volume does not increase if CPE costs remain high and CPE costs do not decrease if the volume is low. A crucial question is how this cycle can be broken.

3.9.3. Volume

There are various market forecasts by commercial research companies such as Sky Light Research, Rethink Research and Gartner. The predictions are varying from time to time, but the more recent forecast show increasingly higher numbers on WiMAX equipment spending. In 2004, Sky Light Research forecasted worldwide WiMAX equipment sales of US$ 1.6 billion by 2009. In 2006, In-Stat research predicts WiMAX equipment sales of US$ 3.2 billion by 2010. However, it states that this is highly depending on the CPE price. If the price becomes US$ 100 or lower by 2010 than WiMAX equipment sales can become as much as US$ 3.2 billion. If the CPE price remains higher than WiMAX equipment sales will be only US$ 2.1 billion. Rethink Research does a very different forecast. It predicts that global WiMAX infrastructure spending will rise from US$ 655 million in 2006 to US$ 7.36 billion in 2009. This research is based on the intended spending plans of more than 200 service providers around the world.

The forecasts seem promising, but how can these volumes be reached. An important advantage of WiMAX is that it is based on the international IEEE 802.16 standards. The WiMAX Forum is constantly promoting a globally harmonized spectrum for WiMAX deployments. It is cooperating with and influencing the national governments to manage their spectrum in a globally coordinated way and to make free spectrum for wireless broadband applications. This has been realized to a great success. The US, Mexico and Japan for example will use the 2.5 GHz band for mobile wireless broadband applications while Europe is aiming at the 3.5 GHz band.
Additionally, the WiMAX Forum is making strong efforts to ensure that WiMAX products of different equipment manufacturers are interoperable and compatible. However, fixed and mobile WiMAX products will not be compatible.

These three aspects make it in theory possible to reach a global market, but how will volume increase when equipment costs are high. If there is anybody in the electronic communication industry who can break this cycle then it must be Intel. Intel’s strategy will be crucial in achieving high WiMAX sales volumes and mass-market adoption of WiMAX. Large investments need to be made in deploying initial WiMAX networks to increase the number of WiMAX networks commercially available. This is exactly what Intel and others are doing. Intel Capital is heavily investing in numerous WiMAX network deployments around the world. This increases WiMAX equipment sales volumes and in addition can stimulate other operators to deploy WiMAX networks.

An extremely important moment for the success of WiMAX is the recent decision of US operator Sprint Nextel, a board member of the WiMAX Forum, to deploy a nation-wide mobile WiMAX network in cooperation with Intel, Motorola and Samsung. The investment size is enormous, US$ 1 billion in 2007 and US$ 1.5-2 billion in 2008. The impact of this on the mobile WiMAX industry will be very significant. This might even be called a breaking point for the future success of mobile WiMAX. It has become more likely that other operators will follow Sprint Nextel example of deploying such large-scale mobile WiMAX network. WiMAX equipment sales volume will increase and equipment costs will probably decrease. However, this is just an initial step and it is still remains to be seen if WiMAX equipment prices will sufficiently decrease to become adopted by the mass-market. The drive of Intel to incorporate WiMAX chipsets in laptops, in a similar way Wi-Fi chipsets are now incorporated, certainly will help to reach the desired volumes.

3.10. Conclusion

This conclusion gives an answer to the first research question: ‘What are the advantages and disadvantages of WiMAX compared to other communication technologies?’
The spectral efficiency and throughput performance of WiMAX compared with other wireless technologies like HSDPA is significant. Spectral efficiency is on the long run greatly important since spectrum is scarce. The cost-efficiency of WiMAX network deployments is another important advantage. As shown in Figure 14 less base stations are needed for the deployment of a WiMAX network due to the spectral efficiency and throughput performance. However, it is important that the price of the WiMAX equipment, including the CPEs, will decrease. Additionally, the high costs of trenching when rolling out a wired line network, such as DSL and cable, is avoided, because WiMAX is wireless. The various levels of quality of service (QoS) and the support of the IP protocol are two other attractive advantages of WiMAX. The industry movement towards NGNs and all-IP networks makes WiMAX a suitable technology in this development path. One of the most important advantages of WiMAX is the fact that WiMAX is based on a truly international standard of the IEEE. The WiMAX Forum is committing important global industry players to WiMAX in order to drive its success.

The disadvantages of WiMAX are the immaturity of the technology and the limited product availability of mostly mobile WiMAX. Other issues are the insecurities around full mobility capabilities of mobile WiMAX. Additionally, WiMAX is a very new technology and operational difficulties while deploying a network are bound to occur.

4. WiMAX in the Netherlands

In this chapter the industry environment and external environment of the electronic communication industry in the Netherlands will be examined briefly in order to obtain an understanding of the WIMAX in the Netherlands. The chapter gives an answer the second research question: 'What are the key issues concerning WiMAX for operators in the Netherlands?'

In Figure 16 the framework of analysis for the Dutch internal and external electronic communication industry is shown. The aim is to present a brief analysis of the Dutch situation. The focus will be on the external environment and on the incumbent rivalry in the Netherlands. Therefore, the suppliers, buyers, new entrants and complementors will not be analyzed for the Dutch situation. Important is to understand for which segments of operators WiMAX could be an interesting opportunity.

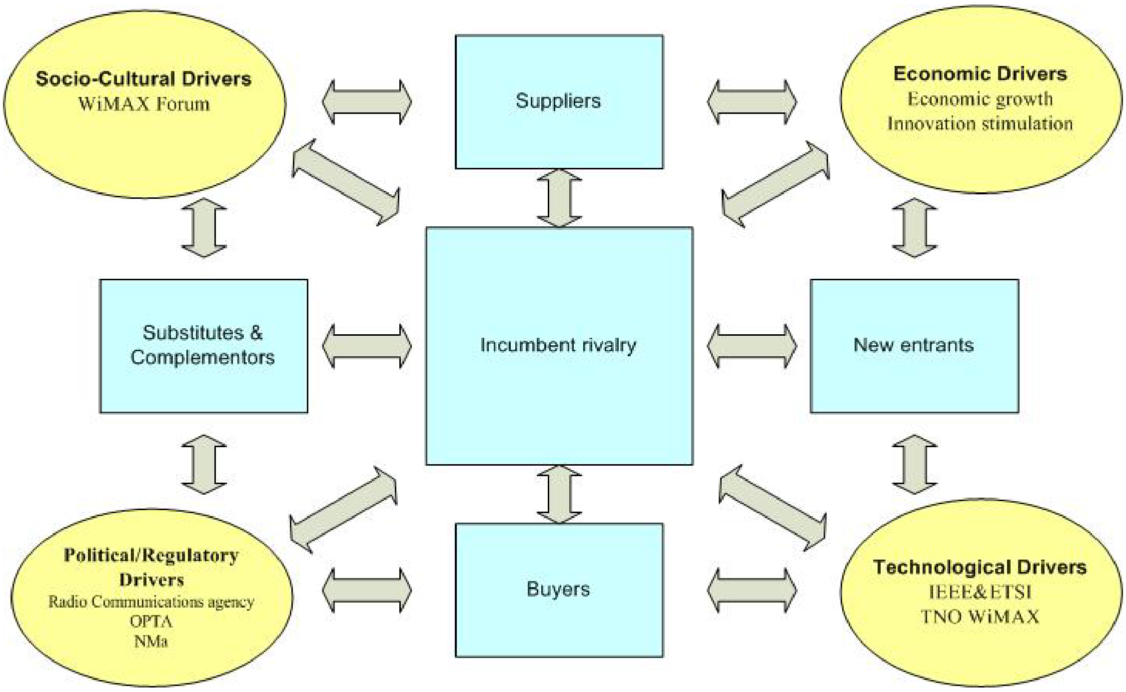


Figure 16. Framework of Analysis overview of the Netherlands

This chapter consists of an introduction to basic statistics of the Netherlands, a brief presentation of the socio-economic background of the Netherlands, an analysis of the external environment of the Dutch electronic communication industry, an overview of the Dutch incumbent rivals and its segments and ends with a conclusion.

Basic statistics of the Netherlands
The Netherlands has a country size of 42,000 km² and a population of 16,258,000 inhabitants. The population density is very high 481 inhabitants per km² of land. The GDP per capita is € 30,055 and the growth rate is around 2% of real GDP (OECD 2005).

4.1. External environment of the Dutch electronic communication industry

In this paragraph, the external environment of the electronic communication industry in the Netherlands is analyzed. As discussed earlier, the electronic communication industry can be characterized by a high degree of technology innovation and government regulation. Therefore, it is expected that the political and regulatory drivers and the technological drivers are the most important drivers in this analysis.

4.1.1. Political and regulatory drivers

The main institutions that supervise the electronic communication industry in the Netherlands are the Ministry of Economic Affairs, which supervises the Directorate General of Energy and Electronic communication (DGET)[17], the regulatory authority Onafhankelijke Post en Telecommunicatie Authoriteit (OPTA) and the national competition authority Nederlandse Mededingingsauthoriteit (NMa). DGTP is responsible for the policy formation and implementation. In the case of wireless communication, an important task of DGET, more specific the Radiocommunications Agency, is the frequency policy.

The management of the spectrum is globally coordinated by the following institutions on three levels:

- ITU at a global level
- European Conference of Postal and Electronic communication Administrations (CEPT) at a European level
- DGET at a national level in the Netherlands

Frequency management is regularly changing, because of trends in the electronic communication industry such as fast technological developments, convergence of broadcasting, internet and electronic communication, strong demand for radio services that requires more efficient use and inventive sharing techniques of the spectrum, and globalization of the industry, which requires harmonization of the spectrum.
The two key elements of these institutional activities are global spectrum harmonization and flexibility by reducing constraints on the use of spectrum and barriers to access spectrum.
The decisions of the higher-level institutions have a binding character for the lower level institutions. Every three years the World Radio Conference is held at which decisions and recommendations for changes of spectrum management are formulated.

[17] Since January 2006 DGTP became part of the new Directorate General Energy and Telecommunication (DGET).

The frequency policy of the Radiocommunications Agency in the Netherlands is in essence technology and application neutral. Operators can obtain licenses by means of a beauty contest or auction or it can be directly distributed in a first come first serve or privileged way. If the spectrum is scarce or the demand for it is high then often an auction mechanism is used. The policy allows secondary trading of the license between operators.

Frequency opportunities for WiMAX

It is important now to understand what the possibilities for WiMAX in the Netherlands are considering the availability of spectrum. As previously mentioned, the WiMAX Forum has devised system profiles, based on a market driven approach, specifying the operating frequency and other parameters. For fixed WiMAX the initial focus is on the 3.5 GHz and 5.8 GHz frequencies and for mobile WiMAX on the 2.3 GHz, 2.5 GHz and the 3.4-3.8 GHz frequency bands.

2.5 GHz

The Dutch Radiocommunications Agency has, based on the decision of CEPT, assigned approximately 144 MHz in the 2.5 GHz band (2520-2670 MHz) for FWA applications (CEPT 2004). It is specified for a channel bandwidth of 1.75 MHz and for FDD as duplexing method[18]. There is one license issued for this spectrum and it is valid until January 2008.

After January 2008, it has been assigned to IMT-2000 applications, such as UMTS and the likes. Meaning that in the Netherlands neither fixed nor mobile WiMAX application are an option in this band. However, in an interview with DGET it was indicated that there is a discussion going at European level by the Joint Project Team on BWA (JPT-BWA) to broaden the application area of this 2.5 GHz band to include usage for any type of mobile communication (Anker 2006). As of August 2006, there is no official word to be found on the developments in the matter after consulting the meeting documents of CEPT[19].

3.5 GHz

Currently, there is 80 MHz of spectrum available in the 3.5 GHz band (3500-3580 MHz) for FWA in the form of one license[20]. It is specified for channel bandwidths of 1,75 and 5 MHz and for FDD as duplexing method.
Both licenses (2.5 and 3,5 GHz) have large amounts of spectrum, 144 MHz and 80 MHz respectively, and it is expected that in the future these will be divided into several separate licenses.

The recent development considering the changes in the allocation of the 3.4-3.8 GHz bands is of crucial importance. In June 2006, the JPT-BWA of CEPT has formulated a draft decision that establishes conditions for BWA usage in the 3.4-3.8 GHz bands, which

[18] National Frequency Plan 2005, p.43; www.agentschap-telecom.nl/nfr
[19] The progress on the discussion of changes in frequency management on European level can be found in the meeting documents of the European Radio Office (ERO) division of CEPT; www.ero.dk
[20] National Frequency Plan 2005, p.44; www.agentschap-telecom.nl/nfr

were so far limited to fixed FWA applications. The usage modes include fixed, nomadic and mobile (CEPT 2006).
This enormous amount of spectrum availability would greatly increase the possibilities for both fixed and mobile WiMAX in the Netherlands while providing harmonization with other European countries.

However, the final decision in this matter will be taken at its best somewhere in the beginning of 2007. After which the Dutch Radiocommunications Agency has to implement it and has to prepare the licensing process, most probably by means of an auction. This process can easily take one year.

Conclusion, an operator interested in such license can only obtain it in the beginning of 2008 (Anker 2006).

5.8 GHz
In the Netherlands, the 5.8 GHz band (5725-5875 MHz) is currently used for fixed satellite communication for business users and for radio systems of the Ministry of Defense[21]. These radio systems of the Defense Ministry have priority above other communication systems. However, there is clear demand from the industry globally to use this 5.8 GHz band for FWA in lightly licensed or license exempt mode. With the help of technologies as Dynamic Frequency Selection (DFS) designed for spectrum sharing, this frequency band can be shared between multiple technologies.
The JPT-BWA has formulated a draft recommendation on sharing this band, both ensuring the existing systems and creating possibilities for future FWA systems to capitalize on the industry developments (CEPT 2006). However, concerns at the Defense Ministry remain. The final decision is expected to be taken at the end of 2006.

4.1.2. Economic drivers

The influence of the external economic environment on the Dutch electronic communication industry will only be briefly discussed, because a more elaborate discussion of the Dutch economy does not fit within the scope of this research project.

In 2006 the Dutch economy is recovering after a long period of downturn. The economic growth has been little since the beginning of the century and was inhibited by weak domestic and external demand and rising oil prices.
Competitiveness is now improving and exports stimulate the economy. Corporate earnings are growing fast, real GDP accelerated in the second quarter and unemployment has slightly declined in the third quarter of 2005. This all and many other factors could result in an economic growth of more than 2% in 2006 (OECD 2005).

Another point worth mentioning concerns innovation. Innovation activity supported by the Dutch government should make the Netherlands more attractive for both domestic and inward R&D spending. One of the most important indicators for innovation is

[21] National Frequency Plan 2005, p.45; www.agentschap-telecom.nl/nfr

business R&D intensity. In the Netherlands, this is only 1% of GDP, while the OECD average is 1.5%.

It is assumed that the increasing economic growth will have positive effect, or at least no negative effect, on consumer spending and demand for communication services, including WiMAX services. Further, it is assumed that the stimulation of innovation and R&D spending will have a positive effect on the communication industry, including the WiMAX industry. Vice versa, this is equally true. Since wireless services, especially wireless broadband, are critical for the development of the communications industry and its infrastructure, and consequently for the health of the Dutch economy (Pareek 2006). Consequently it is a mutual dependent relation.

4.1.3. Socio-cultural drivers

Important socio-cultural drivers trying to change the state of the electronic communication industry, globally and in the Netherlands, by promoting a wide spread diffusion of WiMAX are community groups and the media. The WiMAX Forum can be characterized as a kind of community group with very tight relations to the industry environment. It is the leading driver to make WiMAX successful in the electronic communication industry. It does not merely influence the industry, but is on an operational level actively leading the introduction of WiMAX into the industry. However, it could also be argued that the WiMAX Forum is an actor in the industry environment, because it also consists of these industry actors. The WiMAX Forum is actually the key representative or agent driving the technology adoption of WiMAX into the electronic communication industry.

The WiMAX Forum activities have already been discussed in Chapter 3, but an additional task worth mentioning concerns the media. In promoting the uptake of WiMAX it is actively influencing the media and the media in its turn influences the industry environment. A true hype around WiMAX and its ‘endless’ possibilities has been observed. WiMAX was supposed to bring wireless broadband communication at speeds of 70 Mbit/s with a range of 50km. This has most certainly contributed to the popularity or fame of WiMAX, but has also created a lot of confusion in the industry.

Another driver for change of the state of the electronic communication industry is the public and governmental opinion on health issues relating to radiation of wireless communication systems. In the case of UMTS, municipalities or housing corporations in the Netherlands have inhibited the roll out of UMTS base stations, because of protests of its inhabitants or insecurity on the possible radiation dangers. This was greatly stimulated by the results of a report by the Netherlands Organization for applied scientific research TNO indicating that radiation negatively influences the health of people. However, the results of a Swiss contra-research by the universities of Bern and Zurich indicate that there is no such relation between radiation and health.
Additionally, a Dutch lobbyist group called StopUMTS puts great effort in convincing that UMTS radiation is dangerous for the people’s health.
In a similar way, municipalities, housing corporations or lobbyist groups can delay or inhibit the roll-out of future WiMAX networks. However, now the radiation debate

concerning WiMAX is outside the public opinion in the Netherlands. This could change when large deployments of WiMAX networks are taking place.

4.1.4. Technological drivers

The key driver for change in the state of the electronic communication industry is the introduction of new innovative technologies and communication standards. This technological development in the electronic communication industry is at the center of this research project, the introduction of WiMAX into the electronic communication industry in the Netherlands.

In the Netherlands the research institute TNO is an important driver for technological development. Currently, TNO Information and Electronic communication is actively involved in WiMAX and it has put up the WiMAX Expert Centre. It offers operators interested in WiMAX a range of services from consultancy on WiMAX, through WiMAX network design, to assistance with the deployment of a WiMAX network.

On an international level, the standardization bodies IEEE and ETSI are crucial external actors for a technology to become widely adopted. Standardization is necessary for a variety of reasons, including economies of scale and global harmonization, for the WiMAX technology to be widely adopted. The activities of the IEEE 802.16 working group on wireless MAN has been discussed in Chapter 3.

4.2. Industry environment of the Dutch electronic communication industry

After having analyzed the external environment of the Dutch electronic communication industry by means of a PEST analysis, the industry environment of the Netherlands will be analyzed. This paragraph gives a brief overview of the operators in the Dutch electronic communication industry. The dynamics of this industry became apparent during this research project, because the industry structure is in nearly constant change due to mergers and (foreign) investments.[22] Through active M&A activities of for example KPN that incorporated mobile operator Telfort and fixed line operator Enertel, the industry is restructuring. However, KPN was not allowed by NMa to acquire Enertel Wireless because of market dominance and competition issues. Enertel Wireless, the wireless subsidiary of Enertel, and its WLL license in the 3.5 GHz band is cooperating now with investor Intel Capital under the name WorldMax. Additionally, cable operator Casema acquired the 2.6 GHz WLL license of Versatel and is deploying a certified fixed WiMAX now.

4.2.1. Incumbent rivalry

The central square of Figure 16 representing the internal rivalry between incumbents is also analyzed from the perspective of the Dutch operator. It should be kept in mind that the service provider and the network operator can be the same actor. As for WiMAX in

[22] In the case of Enertel/WorldMax, Intel Capital is investing for a mobile WiMAX network deployment.

the Netherlands, this is the case; both Enertel/WorldMax and Casema are both operator and network operator.

The Dutch electronic communication industry is very competitive and since the telecom liberalization process started many new players, national and international have entered the market. For example, only in the mobile voice segment of the market already more than six players each try to take their share. Figure 17 shows an overview of the Dutch electronic communication industry. As can be seen from the image the same players may operate in different segments of the electronic communication industry. For example KPN is active in almost all segments, except cable and analogue TV. This image clearly shows the degree of competitiveness in the Netherlands.

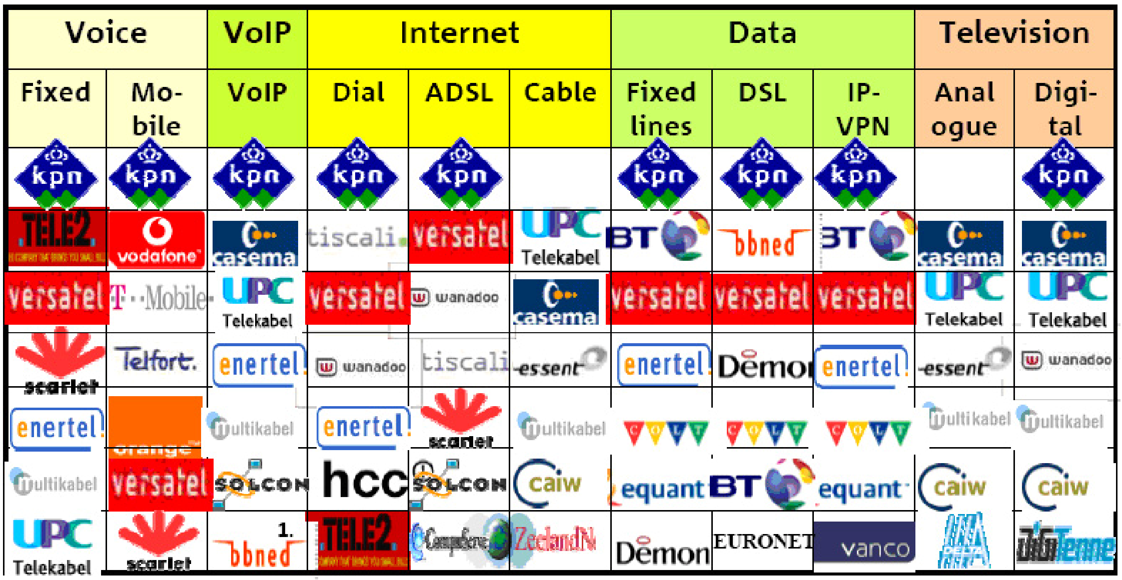


Figure 17. The Dutch electronic communication industry
Source: KPN, 2005

When examining the competitiveness of the Dutch industry and realizing the amount of electronic communication networks already available in the Netherlands, the inevitable question comes up of where fixed or mobile WiMAX could fit into this picture. In order to get better understanding of this, the following four different operators/operators segments have been distinguished; wired line operators, cellular and mobile operators, WISP and new entrants. It should be kept in mind however that such distinction is not completely strict and actors can operate in different segments.

Broadband market
The broadband penetration rate in the Netherlands is one of the highest in the world (Figure 1) with DSL and cable being the most important technologies. This extremely high rate and the demographic situation of the Netherlands, makes it difficult for fixed WiMAX to get a significant market share. The population of the Netherlands is well

spread throughout the country and there are no large rural or underserved areas, only some small-localized areas with very few inhabitants. The city of Wassenaar close to The Hague for example has no DSL, which is also the case in the North Eastern part of the Netherlands. This spread of underserved areas makes it very difficult for fixed WiMAX to support feasible business case.

4.2.2. Type of operator segments and its issues

Wired line operators

Wired line operators include cable operators, DSL operators and other fixed line operators. Although the fixed voice market segment in the Netherlands consists of several different players like KPN, Tele2, Scarlet, Versatel, etc. and despite regulation, the incumbent KPN still appears to be dominating the local loop. However, the basic voice revenues for KPN and other fixed voice operators, are declining caused by the growth of residential broadband services and mobile telephony.

Therefore, WiMAX is an opportunity for wired line operators to extend its services and to add value. Wired line operators can extend their fixed network with fixed WiMAX to be able to offer the business or residential customer the wireless last mile or to reach the rural areas in for example North East Groningen, where previously it was not feasible to deploy a wired line network. However, the potential customer base in those areas is very limited, possibly making a feasible business case impossible. The Dutch government, like other governments all over the world, is prioritizing broadband as a key political objective for all inhabitants to overcome the broadband gap between urban and rural areas also know as the 'digital divide'.

Wired line operators can also get into mobile WiMAX in order to get a foothold in the cellular market. In the Netherlands cable operator Casema and fixed line operator Enertel have deployed regional fixed WiMAX networks for business consumers. However, both operators have their eye on mobile WiMAX to either extend their services and to offer personal broadband thereby getting a share of the cellular market.

Cellular operators

The continuing ambition of cellular operators is to make their networks faster in order to increase their revenue by new Internet access, multimedia and data-based broadband services in addition to voice service. In the Netherlands cellular operators like KPN Mobile, Vodafone and T-Mobile are preparing the transition from 3G to 4G and are upgrading their 3G UMTS network to a 3.5G High Speed Download Packet Access (HSDPA) network. T-mobile is the first to offer HSDPA services, currently only for laptop use, and KPN and Vodafone will start offering it at the end of 2006. Therefore, their focus is on the cellular technologies and to upgrade it.

The high-speed data demand is causing current cellular networks to congest. Here WiMAX can still play a role in enabling cellular operators to cost-effectively increase backhaul capacity by using WiMAX as an overlay network. This overlay approach will enable cellular operators to add the capacity required to support their new bandwidth demanding mobile services and to avoid network congestion. However, the 3G networks in the Netherlands are not intensively used and congestion is not an issue. At the moment, neither KPN, T-Mobile nor Vodafone are actively involved in such overlay approach.

Both KPN and T-Mobile have a license for the 26GHz band, which is a suitable frequency for wireless PTP backhaul. T-Mobile has decided to use a proprietary technology of Ericson and not WiMAX.

Wireless internet operator

WiMAX gives wireless internet operators (WISP) the opportunity to offer their wireless services on a broader metropolitan scale. WISPs can either extend their existing wireless LANs, most probably consisting of WiFi hotspots, or they can deploy a stationary WiMAX network for large area coverage, known as hot zones. KPN and T-Mobile are the biggest hot-spot owners in the Netherlands and WiMAX is a good opportunity to connect their hot-spots. However, neither operators have a license for such WiMAX usage.

WiFi hotspots are being installed at a rapid pace, but the biggest obstacle for continued hotspot growth is the availability of high-capacity, cost-effective backhaul solutions. Nowadays, WiFi operators have to make use of expensive T1 or DSL lines. Proprietary wireless backhaul solutions tend to be expensive. If the WiMAX equipment costs, due to economies of scale, will reduce then WiMAX backhaul can significantly reduce hotspot costs and provide nomadic capabilities.

New entrants

WiMAX provides a good opportunity for new operators looking for cost-effective and rapid deployment, making it possible to be competitive with attractively priced services. WiMAX provides a good opportunity for a new entrant to enter the data and VoIP market without depending on incumbent providers. In short, for the new entrant it is possible to control the infrastructure, to deploy cost-effectively and quickly and to easily increase capacity as demand grows. The initial deployment costs can be very low. First a few base stations can be installed and gradually the network can be expanding base station by base station. This makes the entry barrier for the new entrant low.

Those new entrants can include cable operators wanting to compete with electronic communication operators by offering a package of TV, Internet access, wire line phone and mobile voice and data. In the Netherlands, this is exactly what cable operator Casema, with its recently acquired license for FWA applications, seems to be aiming for when making the future transit to mobile WiMAX.

New entrant Enertel/WorldMAX uses fixed WiMAX to offer business users wireless access and has globally one of the first operators to do so.

Conclusion
In order to have a clear understanding of which WiMAX deployment types are of interest for each operator segment of the industry, a matrix of deployment types versus segments has been constructed (Table 5).

Table 5. WiMAX deployment possibilities for operators

Deployment / Segment	Metropolitan area network	Wireless access		Backhaul	
		Fixed	Mobile	Cellular	WiFi hotspot
Wired line operator		x	x		
Cellular operator				x	
WISP	x				x
New entrant	x	x	x		

4.3. WiMAX activities in the Netherlands

4.3.1. Enertel/WorldMAX

Enertel that previously deployed a fixed pre-WiMAX network in the five major cities in the Netherlands, is currently cooperating with Intel Capital under the new name of WorldMax. Worldmax is trying to target the deployment of mobile WiMAX services in the Netherlands. Enertel/WorldMAX has a nationwide license for 80 MHz at 3.5 GHz spectrum until 2015. However, this license can be used for fixed wireless broadband applications only.

"We see the creation of this new wireless operator as an incredible opportunity to provide new services to major cities in the Netherlands," said Cees Meeuwis, Enertel executive chairman. "Worldmax will offer wireless access and services through a wholesale relationship with a number of resale channels in the Dutch market. This wireless broadband access service will uniquely complement the existing fixed-line broadband access services already offered in the Netherlands."[23]

Enertel/WorldMAX offers a 5 Mbit/s wireless LOS connection for business users in five large cities in the Netherlands, Amsterdam, Rotterdam, Utrecht, The Hague and Eindhoven. They are competing against fixed T1/E1 lines by offering a nominal performance increase in terms of data throughput. It is considered as an entry model to get experience with WiMAX and to get a foothold in the market. Now it is a small niche market application. However, since the cooperation with Intel Capital Enertel/WorldMAX has changed its business case to mobile WiMAX deployments. Crucial in both deployments is the cost structure. According to Algra (2006), the most important competition proposition is the cost structure.

[23] http://www.intel.com/pressroom/archive/releases/20060522corp.htm

4.3.2. Casema

Dutch cable operator Casema has purchased a wireless local loop (WLL) license from Versatel as part of plans to extend its national footprint. Versatel was threatened with financial penalties or even having its license revoked for failing to meet the rollout and coverage requirements of the concession, but Casema reports that it has now fulfilled the license conditions. The cable operator plans to start rolling out internet access, telephony and video services and also hopes to test WiMAX with an eye on acquiring a mobile WiMAX license in 2008.

Casema holds a 2.6 GHz license with 144 MHz of bandwidth until 2008 for FWA applications. It is currently rolling out some base stations and focuses on the business customer market; an example is offering a wireless broadband connection to festivals and other events. Such WiMAX network can be put up in a very short timeline. It is competing against fixed T1/E1 lines and wants to offer its current customer the wireless extension. It is a similar business case as Enertel/WorldMAX uses.

However, the focus of Casema is on mobile WiMAX. Therefore, it will most probably not roll-out a large fixed WiMAX network. Mobile WiMAX fits well into Casema's triple/multi play service strategy including the offering of mobile VoIP and IPTV, but before full mobility will be available it will take time. The roll-out of mobile WiMAX will be a phased process eventually leading to mobile WiMAX for handsets. However, many questions concerning the feasibility of this still remain. Insecurities exist concerning the capacity of batteries for the mobile WiMAX handsets and the feasibility of full mobility authentication of WiMAX. The high frequency used and the intended long signal range of WiMAX result in a high power consumption and therefore strong batteries are needed. In comparison, the Japanese handsets that offer mobile digital TV are currently limited to one hour of usage, because of the limited battery capacity. To overcome this problem Japan is actively researching the possibilities of fuel cell batteries for these handsets.

4.4. Conclusion

The structured analysis of the model of Figure 16 provided an insight in the external environment and incumbent rivalry of the Dutch electronic communication industry. This resulted in an understanding of what the key WiMAX issues for operators in the Netherlands are. The broadband environment in the Netherlands is extremely unfavorable for fixed WiMAX deployments. The extremely high rate of broadband penetration and the demographics of the Netherlands make it difficult for fixed WiMAX to get a significant market share. The Dutch 'rural' areas are widely spread. This makes a WiMAX deployment that can serve these underserved broadband areas very expensive and therefore very unlikely.

The regulatory environment of the Netherlands for mobile wireless broadband applications is very promising. An enormous amount of spectrum in the 3.4-3.8 GHz bands will most probably become available. However, it will only be available earliest in the first half of 2008. The availability of certified mobile WiMAX handsets is expected to be in the first half of 2007, but these products are specified for the 2.3 GHz and 2.5 GHz bands. It is uncertain when certified mobile WiMAX products for the 3.5 GHz band will reach the market. However, they should certainly be available by 2008, possibly around the same time as the appropriate licenses will become available.

An issue in the Netherlands is acquiring sufficient sites for WiMAX base stations. This is an issue for any wireless or cellular network in the Netherlands, because of the strong opposition to these placements by lobbyist groups and local governments. The WiMAX operator needs to have a solid strategy for this. Especially, for operators without other wireless networks, such as Casema, this will be a challenge. Also for Enertel/WorldMax, this will be a challenge, because it still needs to acquire a significant number of sites apart from the sites it uses for its fixed WiMAX network.

5. The Japanese electronic communication industry and WiMAX

In this chapter an analysis of the electronic communication industry in Japan and the strategies and experiences on WiMAX is conducted. Again this is done from the viewpoint of an operator. The chapter gives an answer to the third research question; what are the experiences and deployment strategies of WiMAX of operators in Japan?

First, a socio-economic background of Japan is presented, followed by an analysis of the external environment, an analysis of the industry environment and WiMAX players in Japan followed by a conclusion.

The framework of analysis specified for the Japanese situation is shown in Figure 18.

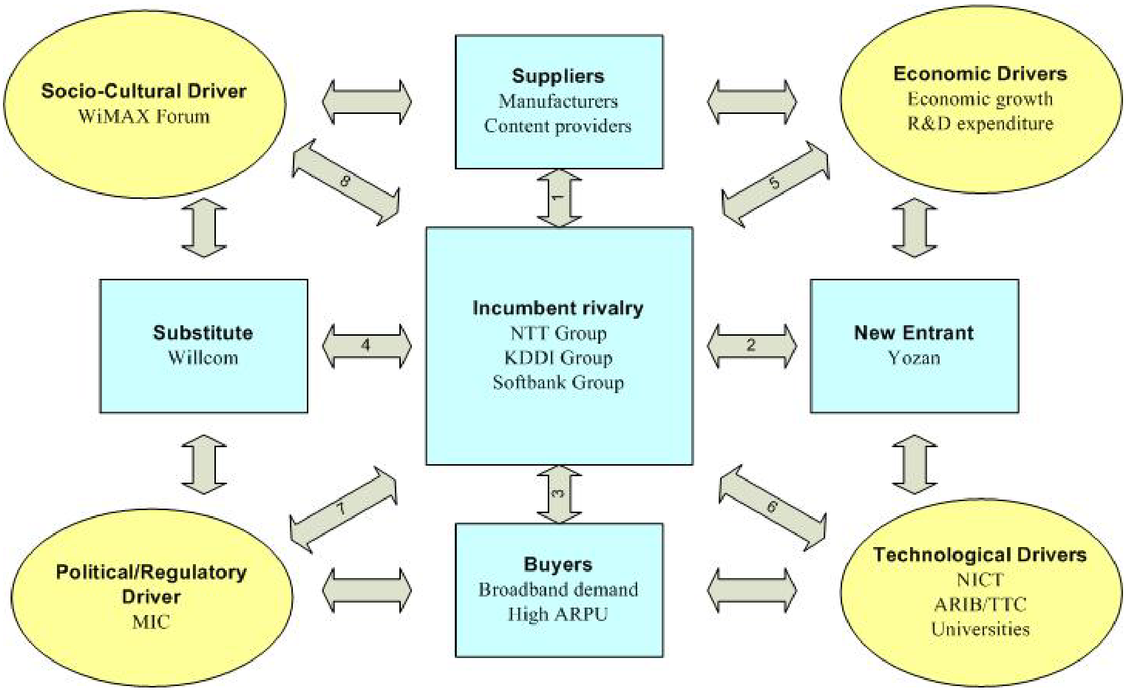


Figure 18. Framework of analysis specified for Japan

Basic statistic of Japan

Japan has a country size of 3,779,000 km2 (about 90 times bigger than the Netherlands) of which 2,511,000 km² is forestland and only 125,000 km² is densely populated. The population has 127,619,000 inhabitants (almost 8 times larger than the Netherlands). The population density is high with the number of inhabitants per km2 of land being 338 (1.5 times smaller than the Netherlands) and 65.2% lives in densely inhabited areas. However, it should be kept in mind that Japan is very mountainous and many areas are not inhabitable as opposed to the Netherlands where nearly every area is inhabitable. The economic growth rate is 1.3% of real GDP (OECD 2005).

In comparison to the Netherland, Japan is also a densely populated country, but the population spread is much less wide. The majority of the inhabitants live in the southern coastal region, roughly between Tokyo (most right) and Fukuoka (most left) indicated by the red areas in Figure 19.

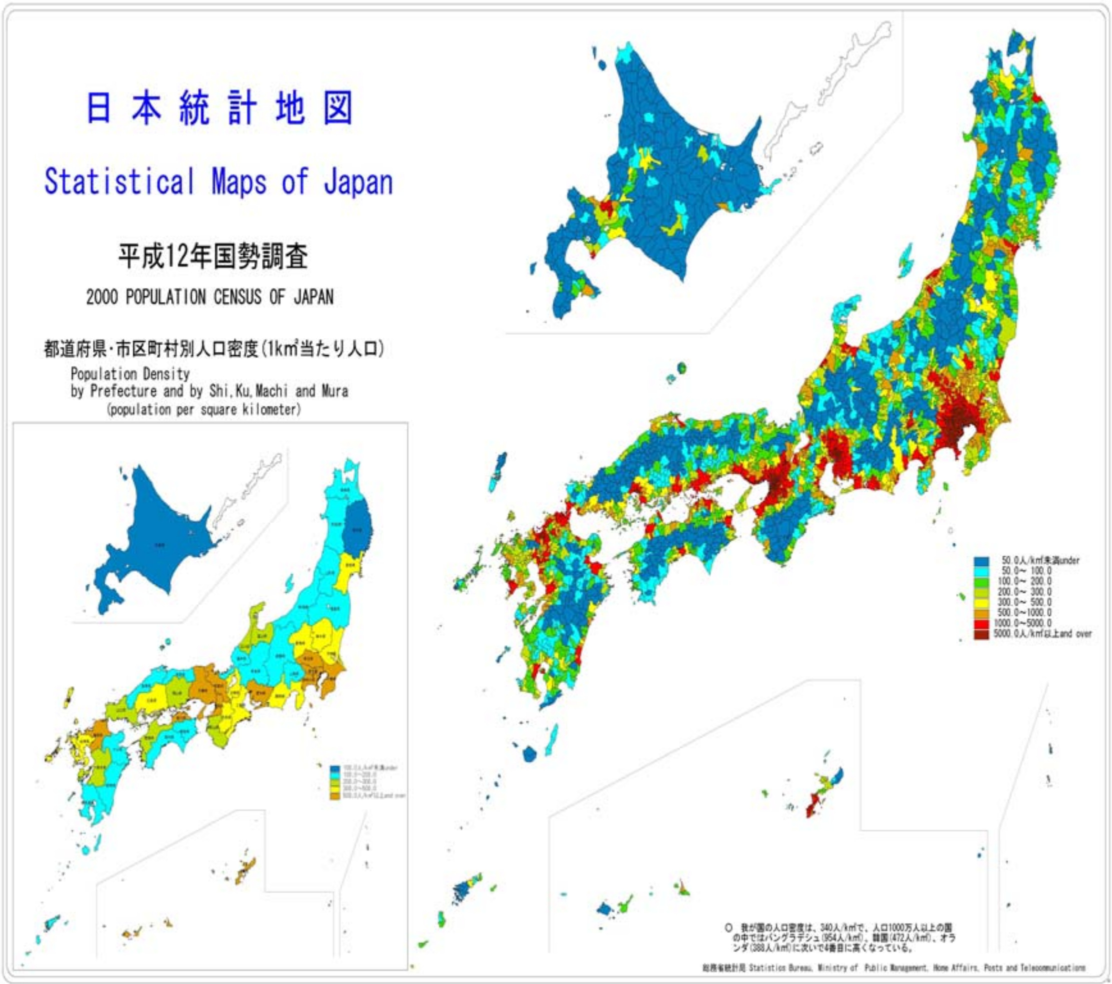


Figure 19. Population density Japan
Source: Ministry of Public Management, Home Affairs and Posts and Telecommunications, 2000

5.1. Socio-economic background Japan

In this section, a brief study of the socio-economic background of Japan is presented. It is not intended to be a complete analysis of the socio-cultural, economic and political situation of the Japanese people, society and industry. Three major differences will be discussed.

5.1.1. Government intervention

A first important aspect to be discussed is the relation of the Japanese government and the industry. Variations in government intervention can be attributed, in part, to differences in the way the markets in various countries are organized, as well as to differences in ideology (Okimoto 1989). Indeed, the industry structure of a country is a central determinant of industrial policy, because this structure provides the framework within which the instruments are designed and applied.

The traditional economic theory's answer to the question of optimal degree of competition has always been simple, namely maximum competition. However, competition may also be excessive. This is a notion that the Japanese government has taken into account. In the period of Japan's most rapid growth during the 1950-1973, the Ministry of International Trade and Industry (MITI) [24] has actively intervened in preventing maximum competition. To promote investment and technical change, instead of permitting maximum competition, MITI has controlled and guided domestic competition in a purposeful way (Amsden and Singh 1994). In general, competition was promoted or limited according to the industry and its life-cycle. Competition was discouraged in young developing industries and in technologically mature industries intense oligopolistic rivalry among competing conglomerates was encouraged.
The emphases on exports and on maintaining oligopolistic rivalry are key distinguishing factors of Japanese industrial policies.

This notion of oligopolistic rivalry raises an interesting question on the validity of Porter's model on industry structure, pursuing maximum competitive rivalry, for the Japanese context.

5.1.2. Industry structure

The previous statement that the industry structure of a country is a central determinant of its industrial policy, is certainly true in the Japanese case. Japan's industry structure allowed for an active government intervention. Especially the existence of what could be called 'extra-market' institutions as *keiretsu* structures, extensive patterns of inter-corporate stockholding, close relations between the banks and the industry, subsidiary and subcontracting networks and specialized trading companies. These allowed MITI to have a direct influence on industry outcome without having to go through the political channels of the parliament (Okimoto 1989).

[24] Since 2001 MITI has been incorporated into the new Ministry of Economics, Trade and Industry (METI)

***Keiretsu* structure**

The *keiretsu* groupings are 'Japanese industrial groupings that bring companies together in loose affiliation based on either prewar conglomerates, financial ties, or vertical integration' (Okimoto 1989, p. 132). Most of the well-known electronics firms in Japan like Fujitsu, Hitachi, NEC are part of a major *keiretsu*. The structure is based on a system of extensive intra-*keiretsu* stockholding, reliance on the main *keiretsu* bank for external indirect financing and stable although not exclusive business transactions. It should be noted that *keiretsu* groupings are not closed, monolithic superstructures tightly controlled by a single holding company, like the prewar conglomerates. It is rather a type of network relation consisting of 'a loosely knit, permeable set of industrial networks, connected through cross-cutting linkages' (Okimoto 1989, p. 133). Although it is strongly cohering.

5.1.3. Theory of Firm

On a corporate and business level, the following discussion points out some interesting differences between firms in Japan and the West. A comparative analysis of the Japanese firm and the Western (particularly Anglo-Saxon) firm is extensively done by Aoki (1990). Aoki describes the so-called J-model as a tool for understanding the working of the Japanese economy and the H-model, the classic agency model of Anglo-Saxon economists.

The essential factors of the agency model of firm are the following: (1) hierarchical decomposition of control originating at stockholders, (2) market-conditioned incentive contracting, (3) the control of the management decision according to the value maximization criterion (Aoki 1990) .

In Japanese firms there are certain essential factors: (1) horizontal coordination among operating units based on knowledge sharing, (2) hierarchy of ranks as primary incentive for employee competition, (3) financial control in a bank-oriented financial system and (4) managerial decisions based on dual influence of financial and employee interests (Aoki 1990).

In other words, Japanese firms appear to be less hierarchical in their coordination on daily operational level, but are more hierarchical in their incentive system based on rank hierarchy instead of a contracting incentive. To keep organizational integrity in the Western context of individualistic values, it is necessary to have contractual agreements on the more hierarchical structuring of internal coordination. In contrast to this clear job demarcation, in Japan horizontal coordination maintains organizational integrity due to dominant social values in Japan like respect for status based on for example age, seniority and level of training.

The corporate management decisions of Japanese firms are not influenced by unilateral control of the interests of ownership (shareholders), but by dual control of financial interest (ownership) and employees' interests. However, the Japanese management is relatively independent of external financial control in their decision-making, in contrast to the control of the shareholder in the Anglo-Saxon context.

This distinction is often referred to as shareholder capitalism of the Anglo-Saxon world, where the interests of the shareholders is of only importance, versus stakeholder capitalism of Japan, Germany and others, for which both the interests of employees, customers and others as well as the interests of shareholders matter. However, there is a tendency of convergence to the Anglo-Saxon model (Dore 2005).

As such, an important characteristic of the Japanese system is traditionally lifetime employment and consequently an inflexible labor market. However, this has slowly changed in the past 15 years since the economic crisis in Japan in the beginning of 1990's when an unprecedented wave of job dismissals took place. A recent indicator could be the increasing popularity of external recruiter/headhunter companies, many of them foreign, in the Japanese market.

5.2. External environment of the Japanese electronic communication industry

5.2.1. Political and regulatory drivers

The main institution that supervises the electronic communication industry in Japan is the Ministry of Internal Affairs and Communications (MIC), which was formerly known as the Ministry of Public Management, Home Affairs, Post and Electronic communication (MPHPT).[25] Unlike most western countries there is no separation between policy-making authorities, regulatory authorities and competition authorities. All these tasks are executed in Japan by MIC.

MIC is actively promoting wireless broadband and has the goal to become a world-leading wireless broadband environment. The radio spectrum use in the world has dramatically expanded over the last two decades. Currently, in Japan there are approximately 103 million radio stations of which about 101 million are mobile handset terminals. This is an increase of about 27 times compared with 20 years ago. Because of this rapid increase MIC is making policies concerning a more effective use of the radio spectrum. Two major aspects of the efforts are in the spectrum reallocation plan and license system policy (MIC 2006).

The policy of MIC is in principle technology neutral, but has an extra condition of maximum frequency efficiency. This concretely means that in the same frequency band different technologies are not promoted, since the larger guard bands needed are 'wasting' spectrum.

Radio Spectrum Reallocation

In order to achieve a true wireless broadband environment, an objective formulated in the 'u-Japan policy', it is very important to enable the use of large amounts of radio spectrum for different communication systems, such as cellular systems, wireless local area

[25] The name of the ministries in Japan seems to be changing rather rapidly, because until 2001 this ministry was called Ministry of Post and Electronic communication (MPT).

network (WLAN) systems and future mobile broadband wireless access (BWA) systems.[26]
In achieving this MIC has formulated the Guidelines for Radio Spectrum Reallocation in which the basic concepts of the radio spectrum reallocation process are described (MIC 2003). The policy of MIC consists of the plan to examine the reallocation of spectrum in order to free an amount of about 330 to 340 MHz of bandwidth. This spectrum will be secured mainly in the 1.7 GHz band for the use of cellular communication systems and in the 2.5 GHz band for the use of mobile broadband wireless access (BWA) systems. within a period of 5 years (MIC 2005).
In this context a benefit system for existing radio spectrum users, whose frequency use will come to an early end, has been introduced to assist them with expenses that normally arise when the said period of use comes to an early end. This should facilitate a quick frequency reallocation process.
An overview of the measures, which MIC is taking to achieve its goal, is shown in Figure 20. Important to note is that MIC has a separate study to promote BWA on a national level, in contrast with the Dutch case where a project team for BWA is operating on a European level (ERO). It is expected that the results and findings of this study group of MIC is more directly influencing the state of the Japanese industry than is the case in the Netherlands.

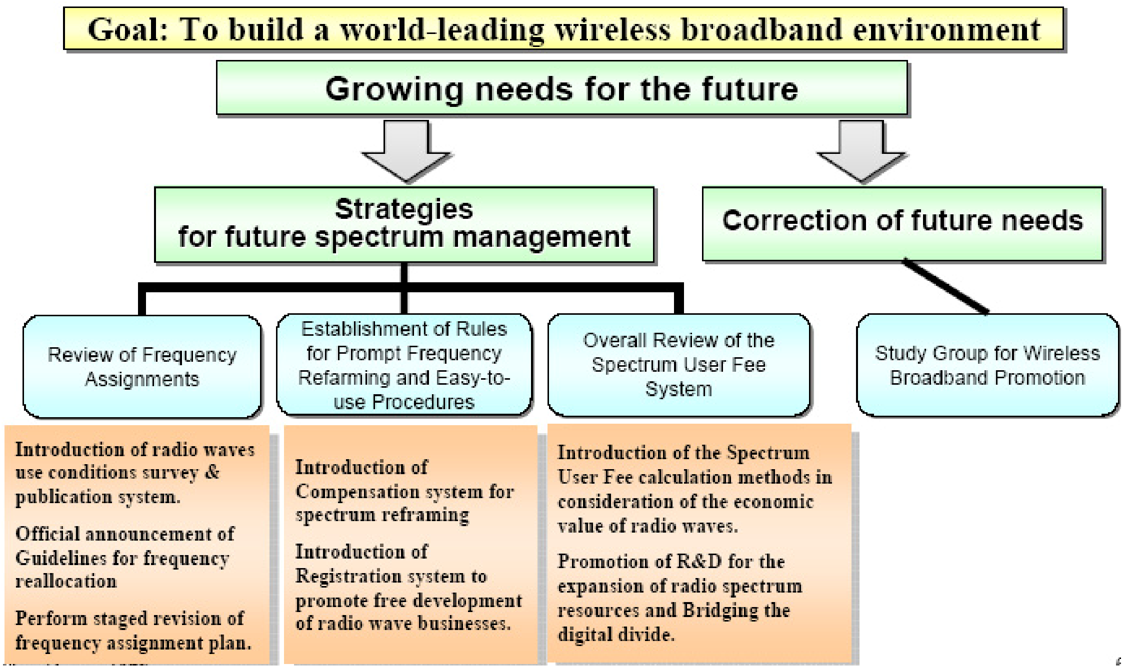


Figure 20. Measures for promotion of efficient use of frequency
Source: MIC, 2005

[26] The 'u-Japan policy' was announced by MIC in December 2004 with the aim of achieving a 'ubiquitous network society' in which 'anything and anyone' can easily access networks and freely transmit information 'from anywhere at any time' by 2010.

Furthermore, the introduction of a registration system in opposition to a licensed system could turn out to be a driving factor for the rapid development of wireless broadband in the electronic communications industry in Japan.

Deregulating the spectrum
MIC has implemented a deregulation policy with regard to wireless systems for shared spectrum use by introducing a post-check registration system. This system will be coexisting next to the existing pre-check licensing system while the spectrum order is maintained. The consequence of this introduction is that it becomes possible to register multiple radio stations with the same mode of use in one time. Previously the radio stations had to be individually licensed based on detailed information. Additionally, individual radio stations can now be freely established using this registration system, while the detailed information on it can be reported subsequently. The aim of this revision is to dramatically accelerate and simplify the procedure for setting up a radio station and it is expected to promote a more flexible use of radio spectrum.

An instant result of the introduction of this post-check registration system has indeed been a development in the industry in the form of the introduction of a new innovative technology. Cellular operator Yozan immediately recognized the opportunity of this registration system and of WiMAX. Yozan is using the 4.9 GHz band for one of the world's first commercial deployment of a fixed pre-WiMAX system.[27] It benefits from the first come first serve principle, which gives Yozan the priority of using the spectrum above other operators. These operators have to make use of carrier sensing mechanisms to avoid interference with Yozan.

License system
The current license selection process is based on a beauty contest, unlike in the Netherlands where often an auction principle is used. For the license a nominal fee has to be paid to MIC. The obvious advantage of this system is the low cost for the operators, which could facilitate innovation and a fast network roll-out, possibly creating end-user benefits. The disadvantage could possibly lie in the degree of objectivity of the decision process. An interesting fact is that no independent telecom regulator exists in Japan. Both the policy making and regulating task are done by MIC.

A license can not freely be traded among operators and it should be giving back to MIC when the new owner plans to use a different business model for it. If the new owner of the spectrum license will offer the same services using the same technology than the license can be traded between operators. A recent example of this is Softbank (a previous wired line only operator) which acquired Vodafone Japan including its mobile license. In order to keep the newly acquired license Softbank will have to continue offering the old Vodafone services using the same technology. However, Softbank had to return its other cellular license, which it had recently acquired, to MIC, because of fair competition issues.

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[27] Airspan and Yozan Announce Expansion of Japan's first WiMAX Network, *Combined WiMAX and Wi-Fi solution will deliver self-installable voice, video and data services*, Press release Mar 11, 2005

Frequency opportunities for WiMAX

It is important to understand what the possibilities for WiMAX in Japan are considering the availability of spectrum. As previously mentioned, the WiMAX Forum has devised system profiles, based on a market driven approach, specifying the operating frequency and other parameters. For fixed WiMAX the initial focus is on the 3.5 GHz and 5.8 GHz frequencies and for mobile WiMAX on the 2.3 GHz, 2.5 GHz and the 3.4-3.8 GHz frequency bands.

The study group for Wireless Broadband Promotion has conducted a preparatory study on the technological aspects of BWA systems and its frequency options. The study group consists of members from various fields both internal industry actors as external actors. The government, the industry and the research centers and universities are joint in this study group.

In the second phase a Ministry Council Committee is formed. The members of this council committee consists of only public associations and institutes like Association of Radio Industries and Businesses (ARIB), Telecommunications Technology Council (TTC), National Institute of Information and Communication Technology (NICT) and university professors. The members should be objective people and therefore members of private organizations are excluded from this council committee.

The final phase of the process consists of another ministerial council, the Radio Regulatory Council. Its task is to make a final decision on the technical regulation and based upon this decision the licensing policy will be formulated. This decision will be made around the middle of 2007, a crucial moment for the success of mobile WiMAX in Japan.

2.5 GHz

The study group of Wireless Broadband Promotion advised to use the 2.5 GHz band for BWA systems and it should consider the following systems IEEE 802.16 (WiMAX), IEEE 802.20 (i-burst and Flash OFDM) and Next Generation PHS. In contrast with the Netherlands where most probably the 3.4-3.8 GHz bands will have opportunities for both fixed and mobile WiMAX

There is 70 MHz (2535-2605 MHZ) available. This excludes the necessary frequency guard band, which is necessary in order to avoid interference between the different systems. The bandwidth of 70 MHz could facilitate two licenses for BWA. This means that only two operators could deploy a BWA system independently or otherwise the operator has to function as a Mobile Virtual Network Operator (MVNO).

Additional spectrum could be available in this 2.5 GHz band. Now satellite systems are operating in this 2.5 GHz band. At 2500-2535 MHz a mobile satellite system is being operated and at 2605-2630 MHz quasi-zenith satellite system would be operating. This quasi-zenith satellite system is mainly being developed in Japan, but private companies withdrew from these projects, because of the weak Japanese economy of last decade. Now only the Japanese government is supporting this project. However, it is expected that also the government will withdraw, making the spectrum available to be assigned to BWA applications and thus creating space for three licenses instead of just two.

Considering the numerous technical proposals for mobile WiMAX systems and the expectation of global adoption, the council regards WiMAX as the most important technology competitor for this spectrum (Nitta 2006).

The coming year will turn out to be a crucial year for the future opportunities of mobile WiMAX in Japan. It is expected that three maybe even four licenses will be available for BWA systems in the 2.5 GHz band. I expect two or three licenses for WiMAX systems and one license for Next Generation PHS.

5.2.2. Economic drivers

The external economic drivers of the Japanese electronic communication industry will only be discussed briefly, because a more elaborate discussion of the Japanese economy does not fit within the scope of this research project.

The Japanese economy is recovering after more than a decade of economic downturn. The economic growth rate has been 1.3 % of real GDP in 2003 and it is expected that the potential growth rate over the period 2004-2010 could be 1.6 % (OECD 2005).

An important economic driver for innovation and industry development is the business R&D intensity. In Japan, the R&D expenditures account for 3% of GDP, the third highest in the OECD region. It is important to note that an exceptionally large share is funded by the industry sectors. This is in sharp contrast with the 1 % of GDP for R&D expenditures in the Netherlands.

It is assumed that the economic growth will have positive effect on consumer spending and demand for communication services, including WiMAX services. It is further assumed that the large R&D spending of the Japanese business industry will have a positive effect on the development and innovation in the electronic communication industry, including the WiMAX industry.

5.2.3. Socio-cultural drivers

The opposition against radiation in relation to health issues has not been observed in Japan as it has in the Netherlands. The Japanese public seems to be less concerned about this or is just indifferent towards it. In the several interviews held with electronic communication specialists in Japan the issue was most often de-emphasized. It was indicated that the signal strength for WiMAX is not higher than for other 3G technologies and therefore health issues will not be a critical aspect for the success or failure of WiMAX in Japan.
However, it has been indicated that the willingness of property owners to approve the placement of new base stations for any mobile or wireless technology is becoming more critical. However, the large operators NTT Docomo and KDDI already have acquired enough sites for base stations. It would thus only be an issue for new entrant operators.

As is the case for the Netherlands, also in Japan the WiMAX Forum is the major driver to make WiMAX successful in the electronic communication industry. It does not merely influence the industry, but is actively leading the introduction of WiMAX into the industry.
One of the major drivers behind this WiMAX Forum is Intel Corporation. Intel's objective is to increase profit by selling large amounts of WiMAX chipsets incorporated in fixed and portable devices and eventually into mobile handsets thereby reaching an enormous customer base. The strategy of Intel is highly significant in the world. Therefore, the success of WiMAX is not only determined by technological issues, but also by Intel's global strategy on WiMAX.
However, the support of the WiMAX Forum and Intel in promoting WiMAX does not guarantee that WiMAX will become a success in Japan. Even an international giant company like Vodafone, being one of the largest telecom operators in the world, did not manage to be successful in Japan (Oobuchi 2006).

5.2.4. Technological drivers

The key driver for change in the state of the electronic communication industry is the introduction of new innovative technologies and communication standards. Important drivers in aiding the introduction of new technologies are the extensive R&D centers in Japan[28], the Japanese standardization bodies and the role of Japanese universities in the electronic communication industry.

National Institute for Information and Communication Technology
Yokosuka Research Park (YRP) is a wireless technology R&D center of the National Institute for Information and Communication Technology (NICT), which is a government 'owned' research institute.YRP houses one of the largest R&D centers in the world for 3G and future 4G technologies. Important to understand is that the Japanese cellular operators play a leading role in these research and development activities. NTT Docomo and KDDI both have large in-house R&D centers. In contrast with Dutch cellular operators, who are much less involved in R&D activities.
In close relation with Japanese equipment manufacturers, NTT Docomo and KDDI are doing extensive research on wireless broadband focusing on WiMAX. NTT Docomo has formed a wireless broadband promotion research program in which they are researching the technological capabilities of mobile WiMAX.
Other important research activities are tests of seamless cell handovers between various technologies as W-CDMA, WiFi and WiMAX.

Standardization bodies
The Japanese standardization bodies Association of Radio Industries and Businesses (ARIB) and Electronic communication Technology Council (TTC) are closely related to the Minister of Internal Affairs and Communications. Their activities focus on spectrum utilization and they are actively participating in the Wireless Broadband Promotion study group and council of MIC.

[28] Keeping in mind that R&D expenditure accounts for 3% of real GDP in Japan

Their standardization activities focus mainly on International Telecommunication Union (ITU) standardization activities and not on IEEE 802.16 standards. However, ARIB has standardized the Personal Handyphone System (PHS), a homegrown Japanese cellular system, under the ITU. Currently, it has proposed Next Generation PHS to the ITU and waits for acceptance. This mobile wireless broadband system is planned to be deployed by Japanese cellular operator Willcom. This will be a strong competitor of mobile WiMAX systems. As mentioned in § 5.2.1, it is expected that Willcom will obtain one of the 2.5 GHz licenses for its Next Generation PHS system.

Universities
The role of Japanese universities in the Japanese electronic communication industry should not be underestimated. Professors of these universities often hold key positions in the standardization bodies like ARIB and TTC and they often chair ministerial study groups and councils, as is the case for the Wireless Broadband Promotion study group and council, which studies mobile WiMAX among others.

5.3. Industry environment of Japan's electronic communication industry

In the previous section, a PEST analysis has been conducted in order to get a better understanding of the external environment of the electronic communication industry in Japan. In this section, an analysis of the industry environment of the Japanese electronic communication industry is executed.
In Figure 4 (Chapter 2) the five elements suppliers, buyers, new entrants, complementors and the incumbent rivals of the industry environment of an industry and its relations with the external environment are shown. The Japanese operators are at the core of this and represent the incumbent rivals in this analysis. It has been observed that in Japan mainly the cellular operators have shown interest using WiMAX, especially mobile WiMAX. These operators are doing research on the possibilities of WiMAX for them and are executing small scale trials. Therefore, the focus of this analysis will be on mobile WiMAX and the Japanese cellular operators.
Before discussing the WiMAX activities and experiences in Japan, first the Japanese electronic communications industry will be presented.

5.3.1. The incumbent rivals

In the past, the formerly state-owned Nippon Telegraph and Telephone Corporation (NTT) had the monopoly for national communications and Kokusai Denshin Denwa Corporation (KDD) had the monopoly for international communications. Since the privatization of NTT the Japanese electronic communication industry has dramatically restructured and currently three dominant operator groups have emerged; the NTT Group, the KDDI Group and the Softbank Group. These industry groups are all active in most or all segments of the electronic communication industry.

NTT Group
The NTT Group is the largest player and consists of several group companies including NTT Communications for long distance/international communication, NTT East and

West offering ADSL and FTTH services and NTT Docomo for cellular communication. The largest investor behind this group is the Japanese government, which gives it a strong foothold in the market.
The NTT Group has a strong presence in the broadband market with both ADSL and FTTH services offering. On November 2, 2004 NTT Group announced a five year plan (2005-2010) to roll out a national optical IP network. It aims to offer 30 million FTTH connections until the year 2010 and plans to invest US$ 24 billion in this period.

NTT Docomo operates both a 2G and 3G network and is the largest cellular operator in Japan, both in terms of revenues and customers. For its 3G network NTT Docomo is using the WCDMA technology. By the end of August 2006 it will launch a HSDPA network initially covering central Tokyo and expanding to 90 % national coverage by the end of 2008. HSDPA enables a theoretical maximum data transmission speed of 14.4 Mbit/s for the downlink, but the first available handset by NEC only handles a maximum of 3.5 Mbit/s.

KDDI Group
The KDDI Group, a merger from KDD, fixed domestic operator DDI and mobile operator AU Corporation among others, is active in the broadband, cellular and fixed line market. The key investors of the KDDI Group are the Toyota Motor Corporation and Kyocera Corporation. KDDI is moving towards an 'all-IP' network and plans to complete this by the end of 2007. KDDI is one of the first in the world to have an 'all-IP' network.

KDDI has been active in the FTTH business and formed an alliance with Tokyo Electric Power Company (TEPCO), which owns fiber optic networks, in order to reduce dependence on the fiber lines of the NTT Group.

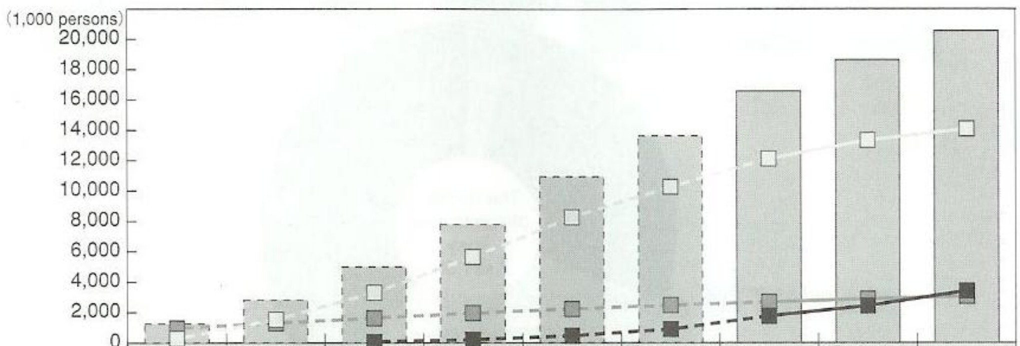
KDDI/au operates a 3G network and a 2G network under the name Tu-Ka and is the second largest cellular operator. KDDI has deployed a 3G network using the 'CDMA2000 1x Evolution-Data Optimized (EV-DO)' system and will expand this system with an 'EV-DO Rev.A' data infrastructure from December 2006. This will increase the uplink speed to maximum 1.8 Mbit/s and the downlink speed to 3.1 Mbit/s. KDDI is the first operator in the world commercially deploying such system.

Softbank Group
The Softbank group is well known in Japan for its aggressive entry strategy in trying to get a large share of the Japanese broadband market. The company had formed a large sales force of young part-timers, who were handing out free ADSL modems to potential customers on the street, a quite peculiar approach in Japan. Softbank dramatically reduced its ADSL access charges forcing NTT and KDDI to follow. This was a driving factor for Japan's broadband market development resulting in the lowest ADSL tariffs in the world. The broadband service ADSL or FTTH is offered under the name Yahoo BB!
At the core of the Softbank Group stands content provider Yahoo Japan, fully independent of Yahoo USA. Yahoo Japan service offerings consist of content, eCommerce, transactions, auctions, etc. Yahoo Japan is held responsible to have

successfully prevented global internet auction house eBay in achieving a strong position in the Japanese market.

Recently, Softbank has extended its operations into the cellular market by acquiring the 2G and 3G mobile networks of Vodafone Japan for US$ 15 billion. Softbank says it will invest US$ 2.13 billion in the nation-wide 3G WCDMA network increasing the number of base stations with 10,000 to 30,000 base stations by March 2007.
Softbank previously obtained a mobile license in the 1.7 GHz band, but now it has to return this license to the MIC. Basically, Softbank has bought time by acquiring the 3G network of Vodafone Japan instead of deploying such network from scratch.

Broadband market
In the last five years, the number of broadband internet access service subscribers has dramatically increased from 1.26 million in June 2001 to 20.6 million in June 2005 (InfoCom Research 2006, p.59). This is largely because of the substantial growth in the ADSL Internet access, which accounts for almost 70 % of all broadband service users in June 2005. However, since 2003 the growth of FTTH has become very prominent and as of June 2005 more than 3 million FTTH users exist (Figure 21).



	June 2001	December 2001	June 2002	December 2002	June 2003	December 2003	June 2004	December 2004	June 2005
FTTH	–	–	69	206	458	894	1,758	2,432	3,410
DSL	291	1,525	3,301	5,646	8,257	10,272	12,119	13,325	14,082
Cable TV	967	1,303	1,626	1,954	2,225	2,475	2,689	2,873	3,062
Total	1,258	2,828	4,996	7,806	10,939	13,641	16,565	18,630	20,554

Figure 21. Broadband internet subscribers in Japan
Source: InfoCom Research, 2006

This trend has continued in 2006 and as of March, Japan has 5.5 million FTTH users. Currently, the growth rate of FTTH users is larger than the decreasing growth rate of ADSL users.

ADSL
The ADSL market in Japan is controlled by three major operators NTT West, NTT East (belonging to the same NTT Group) and Softbank BB of the Softbank Group. In the Eastern area of Japan, NTT East has 38.1% market share and Softbank BB has 31.4%

market share as of March 2006. Combined they have almost 70% of the market. In the Western area of Japan, Softbank BB has 39.1% market share and NTT West has 38%, combined the two operators have more than 75% of the market (InfoCom Research 2006).

FTTH

As for the FTTH market, NTT East and NTT West are together holding the majority of market share, nearly 60% as of December 2004. However, it should be mentioned that operators cooperating with electric power companies, for example KDDI's alliance with TEPCO, have been increasing their share in the FTTH market.

FWA

The only area in which the number of subscribers is decreasing is the FWA area. The number of FWA connections in Japan has decreased in the first quarter of 2006 by 4,000 to 16,000 FWA connections.[29]

Costs

As mentioned earlier the costs for broadband access in Japan are the lowest in the world and the average speed of ADSL access is among the highest globally (Figure 22). The costs for 1 Gbit/s FTTH is around US$ 25/month.

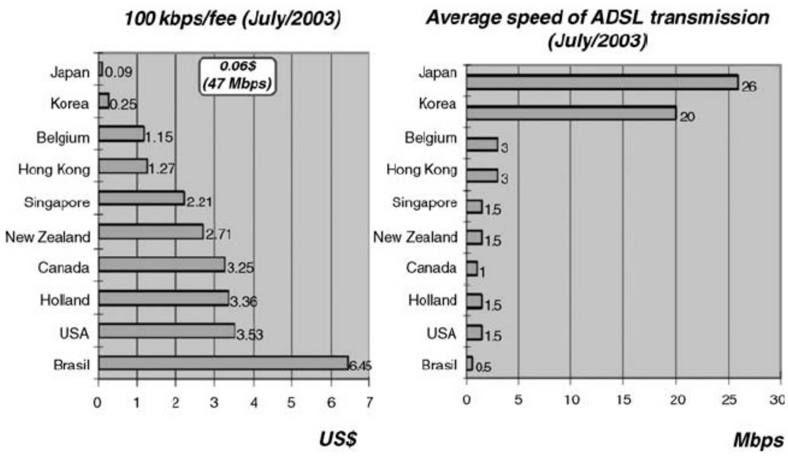


Figure 22. Cost and speed of access for different countries
Source: Pareek, 2006

Cellular market

Three operators NTT Docomo group, KDDI/au group and Vodafone group, acquired by Softbank Group, dominate the cellular market in Japan[30]. At the end of 2004, there were nearly 87 million mobile users in Japan. The NTT Docomo group had a 56.1 % market share against a 22.5 % share of the KDDI/au group and a 17.3 % share of the Vodafone group (Figure 23). The Tu-Ka group is full subsidiary of the KDDI Group and offers 2G

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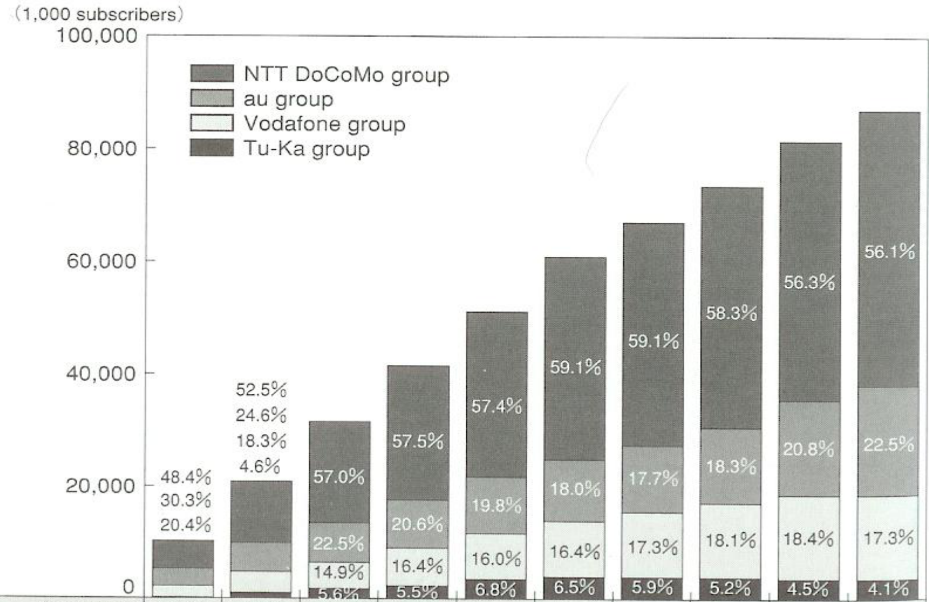
[29] 'Japanese broadband subscriber base still rising', TeleGeography's CommsUpdate, June 2006 at www.telegeography.com

[30] Softbank has re-branded Vodafone to Softbank Mobile.

services. These figures included both 2G and 3G subscribers. Especially the NTT Docomo group has a large 2G subscriber base. It should be noted that mobile number portability is still not possible in Japan largely benefiting the NTT Docomo group. However, as of October 2006 mobile number portability will be possible and market dynamics are expected.



Fiscal year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
NTT DoCoMo group	4,936	10,960	17,982	23,898	29,356	36,026	39,635	42,874	45,927	48,825
au group	3,089	5,146	7,097	8,563	10,125	10,985	11,908	13,468	16,959	19,542
Vodafone group	2,086	3,812	4,696	6,796	8,166	9,977	11,617	13,323	15,002	15,041
Tu-Ka group	93	960	1,750	2,273	3,493	3,954	3,941	3,849	3,632	3,590
Total (1,000 subscribers)	10,204	20,878	31,525	41,530	51,140	60,943	67,101	73,514	81,520	86,998

Figure 23. Number of cellular subscribers and market share
Source: InfoCom Research, 2006

For all groups the number of 2G subscribers is decreasing while the number of 3G subscribers is increasing. As of August 2006, NTT Docomo has more than 27 million 3G W-CDMA subscribers while KDDI/au has more than 23 million 3G CDMA2000 1x subscribers. The Vodafone group is seriously lagging behind in the 3G cellular market with just over 4 million W-CDMA subscribers. The Softbank Group will be determined to bridge this gap possibly aided by the introduction of the mobile number portability.

5.3.2. Suppliers

One of the most distinguishing aspects of the Japanese cellular industry is that it is operator-led. The operator is at the center of the value web and functions as the spider in this web. It controls the equipment manufacturers and the content providers. This differs from the European case, where also the equipment manufacturers like Nokia and Ericsson have considerable power in the industry.

Equipment manufacturers
Operators and equipment manufacturers work closely together in tightly knit groups and supply the market with handsets and other portable devices. The cellular operator has the ownership of the handset. The Japanese subscriber must first select the operator and then choose the mobile device. The choice of the subscriber is thus limited to the ones offered and branded by the selected operator. The handsets in Japan do not have a separated SIM card, as is the case in Europe, but this is integrated into the handsets. So if a subscriber wants to change operator it also has to get a new handset. As such, the operator in Japan is dominant rather than the equipment manufacturer. This is in opposition to Europe including the Netherlands where the equipment manufacturers Nokia, Motorola and Ericsson have more power in the industry.
This structure also prevents major foreign equipment manufacturers like Nokia and Motorola to get a large market share in the Japanese cellular market.

In the case of mobile WiMAX this raises a critical point. Since the Japanese market is mainly equipped by Japanese manufacturers and because of the strong competition between the cellular operators, there does not seem to be equipment manufacturers available able to produce mobile WiMAX terminals in Japan. The companies NEC, Fujitsu, Matsushita and Hitachi are focusing on 3G/3.5G terminals for HSDPA and CDMA2000 1xEVDO usage. This demands large investments of the manufacturers and reduces their ability to invest in producing WiMAX terminals (Hattori 2006).

Content providers
Another distinguishing aspect is the relation of the operator with the content provider in Japan. The relation is rather tightly controlled by the operator and it can be argued that there are no real free or independent content providers in Japan. In the case of the Softbank Group, this is straightforward; the content provider Yahoo Japan being a fully owned subsidiary of Softbank.
Additionally, the way revenue is shared between the cellular operator and the content provider is a peculiarity of the Japanese cellular market. The majority of the content fees is passed by the operator to the content provider after retaining a commission. However, the content providers do not get any revenue of the traffic that the content sites generate.

5.3.3. Buyers

Buyers' behavior of electronic communication services has not been studied in depth in this research report, because of the pre-mature state of WiMAX networks in Japan, the initial fixed and portable usage scenarios of mobile WiMAX and the complementary role, which WiMAX is most likely going to have in Japan. However, it is worth mentioning a few aspects.

The increasing customer demand for broadband services on a global level is important. This is especially the case in Japan where the mobile data market is highly developed in terms of number of users and revenue. This already causes congestion to occur in the current 3G networks and it will get worse due to the increasing demand for bandwidth.

A second important aspect is the revenue earned of these electronic communication services. Japan has one of the highest ARPUs in the world meaning that the Japanese customer is willing to pay for these services.

Both aspects, the increasing demand for bandwidth and the high APPUs, are positive indicators for the opportunities of WiMAX in Japan.

Furthermore, the movement of cellular customers between the individual industry groups is rather static, because of the lack of mobile number portability. However, in October 2006 number portability will be introduced. As a result, market dynamics are expected.

Services
As was mentioned earlier both the supply-side and the buy-side are of crucial importance for the electronic communication industry to function. A telecommunication infrastructure only becomes beneficial when services are offered that the customer is willing to pay for. In the case of WiMAX, high speed broadband data will initially be the most important service to offer. According to Oobuchi (2006) WiMAX will first be used in Japan to offer broadband data, and later when a nation-wide network is deployed VoIP services can be offered. The offering of IPTV using WiMAX is quite complicated in Japan. The broadcasting industry is a strongly regulated industry in Japan and the national broadcaster NHK has a strong influence on it. Therefore, it is difficult for operators using WiMAX to get involved in this industry (Oobuchi 2006). However, Yozan (§ 5.4.1) is carrying out experiments with NHK to offer live broadcasting services over WiMAX. Currently, Yozan uses its fixed pre-WiMAX network to offer broadband data only (Mochizuki 2006).

Mobile operator KDDI/au (§ 5.4.2) plans to use mobile WiMAX to increase the capacity of its current network in order to offer more bandwidth at cheaper rates to its customers. Thus, KDDI also wants to use WiMAX to offer broadband data. Additionally, KDDI is researching the possibilities of offering VoIP services by using WiMAX. Since WiMAX supports the IP protocol and KDDI is actively moving towards an 'all-IP' network, VoIP seems a promising opportunity for KDDI. However, according to Hattori (2006) VoIP is an immature technology now. If an operator wants to use WiMAX for voice services then a good QoS is required.[31] To guarantee such high QoS level large investments in the WiMAX network needs to be made done, making it expensive to deploy. This largely diminishes the cost-effective competition benefit of WiMAX over other technologies (Hattori 2006).

5.3.4. New entrants

The Japanese electronic communications industry is tightly controlled by the large vertically-integrated incumbent groups, who have a close relations with MIC and R&D centers. This makes it extremely difficult for new entrants to enter the market. However, MIC has recently undertaken several actions to reduce the entry barriers by making spectrum available for new entrants.

[31] In Appendix E, more information on the technical capabilities of WiMAX, including its QoS support, is presented. Especially, the section on the MAC layer of the IEEE 802.16 standard is relevant here.

Two operators eAccess and IPMobile have obtained cellular licenses and are planning to enter the cellular market with 3G/3.5G systems somewhere at the end of 2006 or in 2007. In the context of WiMAX, operator Yozan has a 'registrated' license in the 4.9 GHz band and is deploying fixed WiMAX with future plans to get into the mobile WiMAX business. A more in-depth discussion on Yozan is presented in § 5.4.1.

5.3.5. Substitute

The Personal Handyphone System (PHS) is a communication system developed by the Japanese industry. Currently, only Willcom is active in the PHS market in Japan while the other PHS operators are shutting down their operations.
Willcom is developing a new mobile BWA system called Next Generation PHS and has started a field trial. Willcom's current PHS system has nearly 4.2 million subscribers in August 2006. This PHS system sends data of 1 Mbit/s or more both downlink and uplink using a TDMA/TDD access technology. Willcom offers flat-rate voice and data service.
The Next Generation PHS system should send data of 20 Mbit/s both down- and uplink using OFDMA and TDMA/TDD access technologies. Mobile WiMAX is based on very similar technologies. Both systems can also make use of MIMO and smart antenna technologies. It is positioned as one of the next generation mobile BWA systems in Japan. In designing the Next Generation PHS system a certain synergy between the two systems is desired for reasons like spectrum efficiency (Kinoshita 2006).

Strength of PHS
One of the major strengths of PHS is the fact that it is based on a micro-cell topology creating a huge capacity. The micro-cell network is a network, which exists of cells with a radius of about 2 kilometers in the urban or residential areas. However, in very high dense urban areas, like down-town Tokyo, the size of the cell reduces to 500 meters. For outdoor-coverage not that many base stations are needed, but for indoor-coverage many base stations are needed to be able to offer quality services.
Willcom has deployed around 40,000 base stations in the past 10 years in Tokyo only. Compared with a cellular operator like NTT Docomo, which generally deploys a few 100 base stations in the Tokyo area for its W-CDMA network, the number of base stations Willcom deploys is about a factor 100 larger. This results in a much larger bandwidth capacity for Willcom resulting in less congestion in each cell.

Because base stations of 3G networks of NTT Docomo and KDDI cover a wide area, many users end up sharing the same frequency band. The data rates are decreasing strongly when a network cell contains many users. This limited capacity and the increasing bandwidth demand growth causes congestion in these networks. This problem has to be overcome and WiMAX can possibly provide the solution as overlay network backhauling the extensive traffic.

Weakness of PHS
The difficulty of deploying a micro-cell network is the acquisition and placement agreements of all the sites and the installation of the many base stations making the roll-out process very time consuming and costly. Already in 1995, Willcom started the

deployment of its nation-wide PHS network and it plans to upgrade this network to Next Generation PHS.

Global market

For the success of PHS and Next Generation PHS it is necessary to address a more global market. The Chinese PHS market plays an important role herein. Economy of scale is necessary for the prices of the Next Generation PHS base stations to decrease.
Globally the deployment of PHS systems has about 80 million customers (InfoCom Research 2006). China is by far the biggest market. China Telecom and China Netcom have around 90% of these customers. Other countries where PHS systems have been deployed are Taiwan and Thailand. These markets are also good growth markets for the Next Generation PHS system.

Conclusion

I expect that Willcom will obtain a 2.5 GHz license for its deployment of Next Generation PHS. Willcom will compete with the cellular 3G/3.5G operators and with mobile WiMAX. However, the vertically integrated business model of the Japanese cellular market, does not make it easy for smaller operator to obtain a large market share.

5.4. WiMAX players in Japan

As has been observed in previous paragraph, the Japanese electronic communication industry is a well-developed industry with a high DSL penetration rate, an increasingly growing FTTH penetration and a cellular market of more than 92 million subscribers on a total population of 127 million. When additionally taking into account the geography of Japan, the demography and population density in the coastal area, the Japanese market seems to be saturated. Furthermore, three large incumbent operator groups dominate the electronic communication industry. This oligopolistic rivalry and the vertically integrated industry structure make it extremely difficult for new entrants and substitutes/complementors to get a significant market share.
So, what role can WiMAX as a new technology have in such a highly developed and tightly controlled market? In this paragraph an analysis of the WiMAX activities and experiences of operators and their usage scenarios and deployment plans are executed. It starts briefly with fixed WiMAX before elaborating on mobile WiMAX, the version attracting the most attention by far.

5.4.1. Fixed WiMAX

Currently, there is only one electronic communication operator focusing on the fixed WiMAX technology. This is Yozan, who is deploying a fixed pre-WiMAX network. The roll-out of the fixed pre-WiMAX network is lagging behind mainly because of operational issues. As of August 2006 it has deployed around 300 base stations instead of the planned 3,000 due to December 2005. Yozan has committed itself to increase the number of deployment teams in order to catch up. The deployment plan for Tokyo is to roll-out 3,000 base stations and 30,000 terminals. The total expected CAPEX is around US$ 50 million (Mochizuki 2006).

There are several reasons why Yozan deployed a pre-WiMAX network using the 4.9Ghz band. First of all, the spectrum was not used and Yozan was the first to use it. The licensing falls under the new regulatory registration system (see § 5.1.1). An important aspect of this licensing system is that a second operator using the same spectrum has to make use of carrier sensing technologies to avoid interference with Yozan's operations. Yozan has the first rights of way. Secondly, a license of this 4.9 GHz band is cost free. Thirdly, a large amount of 100 MHz spectrum is available.
Besides these spectral aspects, Yozan already owned BS sites of a PHS network, acquired from Tokyo Electric Power Company (TEPCO), and should therefore be in the position to facilitate a fast roll-out of the fixed WiMAX network.[32]

In the future Yozan clearly wants to obtain a license in the 2.5 GHz band for mobile WiMAX applications. It is important to keep in mind that the 802.16e standard on which mobile WiMAX is based has been designed for portable and mobile access, but it will also support fixed and nomadic access. Yozan is much interested to obtain such license, but according to Mochizuki (2006) it is not absolutely necessary. It can also operate as a MVNO, if for example NTT Docomo and KDDI/au obtain the 2.5 GHz licenses.

Currently, Yozan does not have many customers using their WiMAX services. It says it is now not just concentrating on getting a large customer base, but is merely trying to establish a solid position in the market. Yozan is trying to create this position by establishing good relations with several parties in the industry, for example with TEPCO and NTT Communications both owning fiber optic networks. Additionally, it is now important to get familiar with the technology and its operational issues.

On the longer term Yozan is aiming on a customer base of about 900,000 users of the total broadband users in Tokyo in order to be profitable. This corresponds to about 30 % of the Tokyo broadband market (Mochizuki 2006).

Future for fixed WiMAX

Besides Yozan there is not much interest in the fixed WiMAX standard. This has to do largely with the high DSL penetration and the rapid growth of FTTH networks, which is stimulated by the government. This makes it difficult for fixed WiMAX to get a place in the market. Therefore, most industry attention is directed to mobile WiMAX in Japan.

It is expected though that fixed WiMAX will take its growth in the market again in a later stage of its development in combination with fiber optic networks (Naoe 2006). The goal of MIC in cooperation with the operators is to realize a complete backbone of fiber optics in Japan. In 2010 the realization of such nation wide fiber optic network should become a reality. It is expected that the extensive fiber network will greatly stimulate the customers demand for broadband. The fiber network will not be deployed to the individual homes, because of the high costs, and therefore the last mile could be a good market opportunity for fixed WiMAX.

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[32] Yozan bought the PHS network for a symbolic gift of 1 yen from Tokyo Electric Power Company (TEPCO) and received a business gift of US$ 80 million.

5.4.2. Mobile WiMAX

In Japan, the industry is clearly focusing on mobile WiMAX for future possible mobile BWA deployments. There is a growing interest towards mobile WiMAX. Initially, the major cellular operators, NTT Docomo and KDDI, rolled out mobile WiMAX network trials, but are now followed by Softbank and fixed broadband operator ACCA networks. The most 'aggressive' player on mobile WiMAX is KDDI.

KDDI

KDDI already has invested strongly in its nation-wide CDMA network and has upgraded this to 1x EV-DO. Therefore, KDDI will not deploy a nation-wide WiMAX network. Mobile WiMAX is expected to be a part of an overlay system and will be complementary to the 3G cellular system of KDDI. The addition of mobile WiMAX is to achieve higher data rates in areas where a lot of congestion exists. Thus, it will be primarily applicable in high dense urban areas where the demand for broadband is high and increasing.
The setup of the network must be a dual mode type and thus the terminals must be dual mode as well, but how is still largely uncertain (Nohara 2006).

Currently, KDDI is conducting mobile WiMAX trials to evaluate the technological capabilities of mobile WiMAX. Based on the results of the trials and studies a better decision can be made on how to use mobile WiMAX. At this moment it is not precisely known how to deploy and commercialize mobile WiMAX.

The main goal of incorporating mobile WiMAX into KDDI's future all IP-network is to be able to offer data transmission at cheaper rates. The general trend of growing traffic demand of users and their unwillingness to pay for the higher bills demands a lower bit rate price (Nohara 2006).
KDDI also wants to offer VoIP services and this should be seen in the context of KDDI's overall strive to do 'everything over IP' in the future. A good balance needs to be found between the offering of cellular voice services and VoIP services and their respective revenues. This is a difficult task and is yet unclear, but the global tendency is towards VoIP.

Trial experiences

KDDI developed an IEEE 802.16e-based mobile WiMAX system and has conducted field trials in Osaka since July 2005. In the trial, three 802.16e access points are collocated on existing 3G cellular base stations and a test terminal receiver is used on-board a vehicle in the form of card for a laptop. However, in the future it is also intended to build handsets with mobile WiMAX.
The transmitting frequency that is used is in the 2.0 GHz band, because KDDI already has a license for the use of this frequency. The parameters measured are the receiving power and the throughput while moving at a speed of less than 60km/h. Testing higher speeds is not possible in the trial setup, because the trial is not executed on a highway but in a residential area.
According to Nohara (2006), mobile WiMAX is capable of broadband transmission even at speeds of 120km/h. The expected capabilities of mobile WiMAX, from the

fundamental propagation to the applications such as VoIP and video streaming, successfully confirmed through the trials.
It is yet unclear when the first commercial trials can start.

NTT Docomo
Like KDDI, cellular operator NTT Docomo is also interested in mobile WiMAX. In the YRP R&D center NTT Docomo is operating a Wireless Broadband Promotion program and is currently executing a year-long trial with mobile WiMAX using the 2.5 GHz band in Tokyo. It is one of the most important projects of Docomo's R&D activities, emphasizing the focus on mobile WiMAX.
The trial is analyzing how mobile WiMAX can play a role in its existing network. NTT Docomo says not to be committed to WiMAX, but takes a technology neutral standpoint. Important for NTT Docomo, is to evaluate the capabilities of mobile WiMAX. When this is clear they will develop a business plan (Hiramoto 2006).
According to Hiramoto (2006), the main problems with mobile WiMAX are authentication issues like seamless cell handovers.

It has not been indicated which usage scenario NTT Docomo initially will use for mobile WiMAX deployments. I expect that NTT Docomo will use mobile WiMAX as an overlay network backhauling excessive traffic to solve congestion problems in its W-CDMA/HSDPA network.

Softbank Group
Softbank will start mobile WiMAX trials in Tokyo from September 2006 and has selected Motorola, one of the largest mobile WiMAX equipment manufacturer, for deploying five WiMAX access points and 25 prototype WiMAX mobile handheld devices. The trial will evaluate the effectiveness of mobile WiMAX as a BWA technology and its potential to be integrated into Softbank's service offering. It is not clear for which usage scenario's Softbank is intended to use mobile WiMAX. It could be as the wireless extension of its ADSL network or as a complementary technology for its newly acquired 3G network in a similar as KDDI and NTT Docomo.

The trial will focus on performance capabilities as throughput, range and speed of network handovers between access points of mobile WiMAX in the 2.5 GHz band.[33] Additionally, it will test MIMO capabilities of Motorola's WiMAX products.
Motorola focuses its business directly on mobile WiMAX equipment and skipped producing fixed WiMAX equipment altogether. Considering the vertically integrated structure of the Japanese cellular market, it is peculiar of Softbank to select a foreign equipment manufacturer. The obvious reason must be the fact the Japanese equipment manufacturers do not have the resources or interest to actively produce WiMAX equipment, as mentioned earlier in § 5.2.2.

A critical point is to be made considering the investment possibilities of Softbank a future WiMAX network. The large investments in its ADSL network, the high leasing costs of

[33] The band to become commercially available for BWA deployment in the middle of 2007

fiber lines from NTT Communication and the costs for the acquisition of Vodafone has limited Softbank financial resources. It is therefore unlikely that Softbank will deploy a mobile WiMAX network in the near future.

ACCA Networks
The only non-cellular operator actively interested in mobile WiMAX is ACCA Networks, a large DSL and fiber operator. In June 2006, the mobile WiMAX trial network will be deployed using equipment of Alcatel operating in the 2.5 GHz band.
For ACCA mobile WiMAX can serve as the wireless extension of its DSL services. The trial will validate the integration of mobile WiMAX services in its existing DSL offering, with the first applications being video streaming, high-speed Internet access and VoIP.

However, obtaining one of the three/four 2.5 GHz licenses in mid 2007 will be a difficult task considering the competition. I expect that ACCA will have to operate as an MVNO.

5.5. Conclusion

This conclusion gives an answer to the third research question 'what are the experiences and deployment strategies on WiMAX of operators in Japan'.

5.5.1. Industry structure

Three major industry groups dominate the Japanese electronic communication industry: NTT Group, KDDI Group and Softbank Group. These groups are all active in both the cellular market and the broadband market together holding a more the 2/3 market share depending on the market. Therefore, the Japanese electronic communication industry is characterized as an oligopolistic industry.
The oligopolistic rivalry between the industry groups is very competitive. In the case of the broadband market, this resulted in the lowest costs for bandwidth in the world. This contradicts the general notion in the Netherlands and the West of oligopolistic markets being non-competitive and keeping prices high for the consumer. The traditional economic theory's answer to the question of optimal degree of competition has always been simple, namely maximum competition.

The relation between the individual groups and their suppliers, both content providers and equipment manufacturers, is tight (relation 1 in Figure 18). The operator is dominant in this relation. This operator-led approach is the most distinguishing aspect of the Japanese electronic communication industry with respect to the European case, where also the equipment manufacturers like Ericsson, Nokia and Motorola have significant power.

In the case of the cellular market, also the relation between the individual groups and their buyers is rather tight due to the lack of mobile number portability (relation 3 in Figure 18).

The operator groups have large in-house R&D centers on wireless technologies hosted in Yokosuka Research Park of the National Institute for Information and Communication

Technology. Thus, the relation between the incumbent operator groups and the research institutes, being one of the technological drivers, is a close relation (relation 6 in Figure 18).

The role of the Japanese government in the form of MIC is of crucial importance in the electronic communication industry. MIC has a directive role and has formulated the 'u-Japan' policy. The goals specified in the policy are to be achieved in close cooperation with the industry. The relation between MIC and the operator groups is tight (relation 7 in Figure 18).
The results of the Study Group for Wireless Broadband Promotion of MIC are a product of a cooperative process of the industry, the government and the research institutes and universities. There is no clear distinction to be made between the working arena of the actors of this triangle relation. The operators participate in the research institutes together with the government and the research institutes and universities take place in governmental advisory groups. This creates consensus on the direction the industry should follow. This view was exemplified during the interview with NTT Docomo when it was stated that NTT Docomo shares the views of the Study Group for Wireless Broadband Promotion (Hiramoto 2006). The goal is to 'build a world leading wireless broadband environment' and this will be achieved.

Considering the above-mentioned three tight relations (relation 1, 6, 7 in Figure 18) the Japanese electronic communication industry is characterized as highly vertically integrated.

5.5.2. WiMAX experiences and opportunities in Japan

It has been observed that the Japanese electronic communication industry is interested in mobile WiMAX. Fixed WiMAX is not considered to be feasible in Japan, because of the high DSL penetration rate and the strong growth of the FTTH penetration rate. Additionally, the large majority of the population is located in the southern coastal area roughly between Tokyo and Fukuoka and has access to high speed and cheap fixed broadband. The remaining minority of the population living in the mountainous inland area of Japan do not seem to provide a feasible business case for fixed WiMAX.

The three large industry group, NTT Docomo, KDDI and Softbank, are all actively researching the possibilities of mobile WiMAX and are all doing outdoor WiMAX trials. The goal is to evaluate the performance capabilities of mobile WiMAX and how mobile WiMAX can fit into their existing networks and service portfolio. Mobile WiMAX will have a complementary role in Japan as an overlay network and no nation-wide independent mobile WiMAX networks are expected in Japan.
A critical issue is the spectrum availability for mobile WiMAX. An amount of 95 MHz of spectrum in the 2.5 GHz band will most probably be secured for mobile BWA applications. There will be three or possibly even four licenses available in the middle of 2007 following the final decision of the Ministry Council. This will be a crucial moment for the future of mobile WiMAX in Japan. The limited availability of licenses will make it difficult for new entrants to enter the market and get a large market share.

I expect that NTT Docomo and KDDI will get a license for mobile WiMAX and Willcom for its Next Generation PHS system. Mobile WiMAX and Next Generation PHS should not be seen as competitors in Japan, because of mobile WiMAX's complementary role in opposition to Next Generation PHS's independent role. Next Generation PHS will directly compete with the 3G/3.5G networks of NTT Docomo, KDDI and Softbank. In the case of a fourth license, I expect Softbank to obtain this license.
Other operators, as Yozan and ACCA Networks, can operate as MVNOs in order to offer WiMAX services.

The competitive oligopolistic rivalry, the vertical-integrate structure and the limited availability of licenses determine the mobile WiMAX development path in the electronic communication industry. This vertically integrated structure could be compared with the *keiretsu* structure. Although many additional relations, for example the industry group and the banks, has not been researched in this project.

6. Conclusions and Recommendations

In the Chapters 3, 4 and 5 the research sub-questions were answered, combining these results the main research question will be addressed in this chapter. This final conclusion gives an answer to the main research question: What are the opportunities of WiMAX for operators in the Dutch electronic communication industry based on the WiMAX experiences of Japanese operators?

6.1. Conclusions

- Concentration and vertical integration are the two dimensions of the Japanese electronic communication industry, which are the important determinants of the industry development in Japan. The concentrated nature of the Japanese industry is observed both in the broadband and cellular market. This oligopolistic rivalry of the electronic communication industry is very competitive among the three industry groups NTT Group, KDDI Group and Softbank Group, making it difficult for new entrants to enter the market and get market share.
  The operators have close relationships with their suppliers (equipment manufacturers and content providers), the Ministry of Internal Affairs and Communications and the research institutes. In the industry environment, the incumbent operators have the highest power in the value web and determine the direction of the industry development. Of the external environment, MIC has a key role in guiding the direction of the development of the electronic communication industry. This vertically integrated structure causes the industry to have a focused approach to which direction the industry is developing. The promotion of mobile wireless broadband lies within this focus so it is expected that mobile wireless broadband will have a stable place within the future electronic communication industry in Japan.

  In contrast with Japan, neither the broadband market nor the cellular market is concentrated in the Dutch electronic communication industry. Many different national and international players exist in the industry including many MVNOs in the cellular market (MVNOs have captured 14.8% of this market). This maximum competitive rivalry makes it easier for a new entrant to enter the market, but also makes it easier to exit the market forced by the intense competition.
  The relation of the Dutch operators with the government is of a more distant nature than in Japan and the Dutch industry environment is determining the direction of the industry development.

- The fixed broadband markets in Japan and the Netherlands both have very high penetration rates. The broadband services are competitively priced and of high quality. Therefore, I do not consider the Dutch or the Japanese market to have a profitable opportunity for the deployment of fixed WiMAX, apart from a very small niche market in for example the shipping industry or events and festival industry.

  The cellular market in Japan is very well developed with millions of users and high APPUs. The congestion, which occurs in the 3G networks, drives the industry to actively research new technologies to solve this problem. WiMAX fits well into this context.

- In Japan, all the three industry groups, NTT Group, KDDI Group and Softbank Group, are interested in mobile WiMAX. From the four formulated types of industry segments (wired line operator, cellular operator, WISP and new entrant), the cellular operators focus on mobile WiMAX in Japan although it has to be kept in mind that they each belong to their parent group.

  In the Netherlands, several types of industry segments have interest in mobile WiMAX, such as wired line operator Casema and new entrant Enertel/WorldMAX. Casema and Enertel/WorldMAX are the only Dutch operators that currently have concrete plans with mobile WiMAX. In contrast with Japan, no cellular operator in the Netherlands is currently focusing on WiMAX. The Dutch cellular operators are busy upgrading their 3G networks to HSDPA networks. These networks are not used intensively yet and congestion is not a problem for Dutch cellular operators. Therefore, using WiMAX as a backhaul technology or overlay technology is not a necessity yet, but this could change in the future when the 3.5G networks in the Netherlands will be congested.

  Currently Enertel/WorldMAX and Casema actually deployed networks using fixed WiMAX. Although I did not have access to the financial information, I do not expect them they have been receiving large revenues for these fixed WiMAX services, especially Casema. The main benefit for them is the exposure to the fixed WiMAX technology and the operational issues concerning the roll-out of such network. However, mobile and fixed WiMAX are different technologies and therefore the benefit of the exposure may be limited.

  Considering this operator focus difference, the deployment scenarios for WiMAX in the Netherlands will greatly differ from those in Japan. It was expected when the research started that Dutch operators could learn from the deployment experiences of fixed WiMAX networks in Japan, especially of Yozan. However, Yozan's fixed WiMAX network roll-out is seriously lagging behind and its revenue model does not seem too promising either. The focus in Japan has already shifted to mobile WiMAX.

- Japanese operators have large in-house R&D centers where they actively research the benefits and characteristics of new technologies, such as WiMAX. In a coordinated way operators, equipment manufacturers, MIC and standardization bodies and universities cooperate in the research institutes. Yokosuka Research Park is one of the most notable research centers for wireless technologies and WiMAX takes currently an important position in the research activities.
  All the three large cellular operators, NTT Docomo, KDDI and Softbank, are intensively doing real-life trials with small mobile WiMAX network deployments.

  In contrast, the Dutch operators have no in-house R&D centers and do not have WiMAX research programs. They also do not seem to be involved in actual real-life WiMAX trials. Their approach seems to be a 'learning by doing' approach. When rolling out the network they might experience the operational problems. Such approach was mistakenly taken by Yozan, when deploying its fixed pre-WiMAX network, and is now crucially lagging behind its roll-out plan. This is greatly decreasing its WiMAX opportunities, because mobile WiMAX is around the corner now making fixed WiMAX dispensable.

- The role of mobile WiMAX in Japan is clearly a complementary one. WiMAX will be used by the cellular operators as an overlay network to their 3G/3.5G networks backhauling excessive traffic. This makes the future mobile WiMAX market a certain one although not a very large one.

  The role of mobile WiMAX in the Netherlands is a more insecure one. Although the Dutch market is more open for new entrants or existing operators extending their services with WiMAX, the direction of where the industry is going with mobile WiMAX is more unclear. Since the cellular operators are just focusing on 3G/3.5G, I am under the impression that the biggest opportunity for mobile WiMAX is for wired line operators. Mobile WiMAX should be used as the mobile extension of their future triple/multi play services.

- The biggest constraint in Japan for the future development of mobile WiMAX in Japan is in the regulatory field. The limited amount of spectrum assigned to mobile BWA application, maximum 95 MHz, does not allow many operators to obtain a license apart from the three incumbent industry groups. Additionally, a part of that spectrum will most probably be used by Willcom's Next Generation PHS system. Besides Willcom, I expect NTT Docomo and KDDI to get a mobile BWA license and possibly Softbank if a fourth license will become available.
  This is the determining factor why mobile WiMAX, for now at least, will have a limited, but certain, role in the electronic communication industry in Japan.

  This spectrum limitation is not an issue in the Netherlands, because of the plans on European level to allocate the 3.4-3.8 GHz band to BWA applications although it will take at least 2 more years before this spectrum comes available. In contrast with Japan, where the 2.5 GHz band will become available in the middle of 2007. However, this does not have to be a key issue since certified mobile WiMAX products will be available in the second half of 2007 according to the WiMAX Forum. However, I expect that the certification process will be delayed again, just as the certification process of fixed WiMAX products was delayed about six months, to somewhere in 2008.

- On a global level, I am positive about the future of WiMAX. The support and commitment to WiMAX by leading players in the electronic communication industry, such as Intel, Motorola, Alvarion, Samsung and many operator like Sprint Nextel, KDDI, KT Telecom and BT Telecom are important drivers for the success of WiMAX. The recent deal Sprint Nextel made with Motorola and Samsung to invest US$ 3 billion to deploy a mobile WiMAX network is an important driver for the future of mobile WiMAX.

  The efforts of the WiMAX Forum have been substantial ones. The standardization and certification process is certainly a milestone for WiMAX. However, large equipment volumes resulting in decreasing equipment prices have not been reached yet.

Another important issue is that spectrum is being secured globally. In Europe, the 3.5 GHz band is becoming available for BWA deployments, while in Japan and the US the 2.5 GHz band will become available for BWA applications.

At the moment, mobile WiMAX products are not widely available and only at the end of 2007 or in 2008 will mobile WiMAX network deployments become a more concrete reality.

6.2. Recommendations

The opportunity of WiMAX in the Netherlands is limited, for now. Fixed WiMAX deployments will not be very feasible, although some small niche markets could be addressed. Mobile WiMAX offers more opportunities. Mostly for wired line operators who can use mobile WiMAX to extend their services with the mobile wireless end. However, operators should be aware of the insecurities that surround full mobility WiMAX. It should be noted that mobile WiMAX can be used for not only mobile applications, but also fixed applications.
At the moment, there does not seem to be a need for cellular operators to get involved with WiMAX. However, on the long run if their 3.5G networks will be congested and if they want to improve the cost per bit ratio they should consider WiMAX. Any operator, who is actively upgrading its network to an all IP should definitely consider WiMAX for the future. WiMAX fits well into the development towards 4G networks. When WiMAX equipment sales volumes increase and equipment costs decrease, WiMAX will become an even more interesting opportunity for operators in the Netherlands.

The operators in the Netherlands who decide to deploy a WiMAX network should wait for certified mobile WiMAX products. They should acquire a 3.5 GHz license in 2008 and should start acquiring base stations sites as soon as possible. This will be a challenging exercise. Before deploying its WiMAX network, the operators should definitely do trials with WiMAX, like the operators in Japan do, in order to understand its capabilities and where it can fit into the operator's existing network. WiMAX is a new technology so operational and technological difficulties are bound to exist. Therefore, the operator should prepare well.

7. Reflection

In this chapter, a reflection is given on the theory and analytical framework that has been used in order to analyze the opportunities of WiMAX and the electronic communication industry in the Netherlands and Japan. It aims to answer the presented questions of § 2.4. Since the model (Figure 4) has its roots in Western strategic management theory, it is questionable if this model can equally be used for a non-Western context, in this case the Japanese environment. Additionally, a few suggestions for further research are presented.

7.1. Capabilities of the framework of analysis

The model distinguishes the external environment from the industry environment. It can be debated whether the firm is leading the industry or the industry environment is leading the industry (industry leadership perspective versus the industry dynamics perspective). In Japan, the industry environment and the external environment are more tightly related to each other than is the case in the Netherlands. The Dutch government has a more neutral non-directive approach and does not seem to drive the path of industry development.[34]

In Japan, there is a strong presence of individual relations between actors of the industry, the government and the universities/research centers. These embedded relational ties, which could be traced to university background of the individual, can have significant influence on the industry development path.[35] For example, decisions on which technology to adopt could be influenced by these embedded relational ties.

It can be argued that the Japanese Ministry of Internal Affairs and Communication is besides the policy maker and regulatory also an industry player in driving the industry towards its desired direction. The path of the industry development is directed by MIC in cooperation with the incumbent rivals, most notable NTT Docomo.[36] The policy on wireless broadband is formed in cooperation with the industry players by means of for example study groups. In a cooperative way the policy goals are determined. Therefore, MIC should be placed in the industry environment, removing it from the external environment. The oval 'Political/regulatory driver' of Figure 18, representing MIC, should be a square representing the industry environment. In other words, the industry environment represented by the Five Forces model of Porter should be extended with a sixth force, MIC. This 'Six Forces' model better represents the structure of the Japanese electronic communication industry. Therefore, it is advice to use this 'Six Forces' model when analyzing the Japanese electronic communication industry. Obviously, many fundamental behavioral differences between the government and the industry actors can be observed. One of them is profit realization. However, it takes too far the further discuss this in the context of this research project.

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[34] It must be noted that I have not explicitly researched the relation of the Dutch government with the industry. It is merely an impression.

[35] I have understood that there are two distinctive 'camps' coming from the two (former) public top universities, Tokyo University and Kyoto University.

[36] NTT Docomo is the former national operator of Japan and the Japanese government is still its largest investor.

Although the relations between the government, universities/research centers and the industry players are much tighter than in the Netherlands and although the Japanese government has a driving influence on the path of the industry development, I think the framework of analysis can still be used in the Japanese context when analyzing the industry structure and external environment. It is a useful descriptive tool to obtain an understanding of the industry and the environment in a structured way. The difference is the strength or tightness of the relational arrows between the external environment and the industry environment. However, it is more a static tool than a dynamic one.

Secondly, it is questionable if the semi-dynamic model (Figure 4) is suitable for the electronic communication industry. This industry is characterized as highly dynamic, because of among others the rapid technology development. Technological innovation is the key driver in changing the state and direction of the electronic communication industry. Porter's Five Forces model underestimates the power of technological innovation to change the industry structure. The technology adoption life cycle model (Appendix D) can be useful to understand better the path of the industry development. When combined with the model, this would certainly improve the dynamics of the model.

Before further discussing this matter, it is important to understand what the fundamental difference is between the static approach and the dynamic approach. As described by Lemstra: "The major distinction between the static and the dynamic views in economics is in the role of innovation. In the static view innovation is an exogenous factor, in the dynamic view innovation is endogenous." (2006, p 114). The model of Figure 4 presents innovation as an exogenous factor represented by the technological driver of the external environment. By incorporating innovation endogenously in the industry structure dynamics is introduced. A relevant concept to mention in this context is 'creative destruction', introduced by Schumpeter, which can be described as the process of industrial transformation that accompanies radical innovation. The concept of creative destruction can be used to explain many of the dynamics of industrial change. This has further inspired theories such as the endogenous growth theory. This theory was formulated as a reaction to neo-classical growth models in which the long-run rate of growth is exogenously determined and based on factors such as an assumed rate of technological innovation and an assumed rate of labor force growth. However, this does not explain the origin of growth. Endogenous growth theory does not assume such rates, but endogenously incorporates technological innovation within the model. When a radical technological change occurs then the relation between the institutional arrangements and the industry environment should be dynamic in order to maintain a fit between the two and to rapidly reach an optimal degree of coherence. The degree of coherence determines the performance of the industry.

Having briefly reviewed the dynamic approach on industry development, should it be advised to use such dynamic approach in the context of this study? During the short period of study of six months the conditions were relatively stable. The technological innovative force of WiMAX and the necessary institutional arrangements have not radically changed the degree of coherence between the technological and institutional arrangements. The framework of analysis is an useful tool to analyze the electronic communication industry assuming the conditions to be stable for the period of study. Therefore, I conclude that under these relatively stable conditions the use of the static or semi-dynamic model (Figure 4) is suitable for the purpose of this research.

7.2. Future research

Although the static or semi-dynamic framework used in this research was appropriate for the objective of the research within its short time frame. However, it has merely a descriptive function. An interesting research could be how technological innovation in the electronic communication industry influences the performance of the industry considering innovation as an endogenous factor of the industry.

This research deliberately focuses on the supply-side of the electronic communication industry. However, the demand-side is equally important. Services for WiMAX should be explicitly researched. The technological capabilities of WiMAX should be analyzed in order to determine if WiMAX is suitable for services such as IPTV, streaming video and VoIP.

Considering the advanced state of mobile WiMAX deployments and operations in Korea (Wi-Bro), I advice my successor to do field research in Korea. This research can benefit from the availability of operational Wi-Bro networks providing the possibility of acquiring concrete data on for example actual throughput rates, total deployment costs and user experiences. Unfortunately, the availability of this concrete data was lacking in my research.

References

Algra, K. (2006). Interview on Enertel's WiMAX business strategy. M. R. Meijering. Enertel, Rotterdam.

Amsden, A. H. and A. Singh (1994). "The optimal degree of competition and dynamic efficiency in Japan and Korea." European Economic Review 38: 941-951.

Anker, P. (2006). Interview on spectrum policy in the Netherlands. M. R. Meijering. DGET, The Hague.

Aoki, M. (1990). "Toward an Economic Model of the Japanese Firm." Journal of Economic Literature 28(1): 1-27.

Barney, J. B. (1991). "Firm Resources and Sustained Competitive advantage." Journal of Management 17(1): 99-120.

CEPT (2004). Harmonization of the frequency usage within the additional frequency band of 2500-2690 MHz to be made available for IMT-2000/UMTS systems in Europe.

CEPT (2006). Final Report from CEPT in response to the EC Mandate to identify the conditions relating to the provision of harmonized radio frequency bands in the European Union for Broadband Wireless Access applications.

De Man, A. P. (1994). "1980, 1985, 1990: A Porter Exegesis." Scandinavian Journal of Management 10(4): 437-450.

De Wit, B. and R. Meyer (2004). Strategy Process, Content, Context. an international perspective London, Thomson Learning.

Dore, R. (2005). "Deviant or Different? Corporate Governance in Japan and Germany." 13(3): 437-446.

European Commission (2004). Facing the Challenge: The Lisbon strategy for growth and employment.

Frankfort-Nachmias, C. and D. Nachmias (1992). Research Methods in the Social Sciences. London, St. Martin's Press, Inc.

Hattori, T. (2006). Interview on WiMAX opportunities in Japan. M. R. Meijering. Sophia University, Tokyo.

Hiramoto, Y. (2006). Interview on NTT Docomo's mobile WiMAX experiences. M. R. Meijering. NTT Docomo R&D Center, Yokosuka.

Hoymann, C. (2005). "Analysis and performance evaluation of the OFDM-based metropolitan area network IEEE 802.16." Computer Networks 49: 1-23.
IEEE (2004). IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems.

InfoCom Research (2006). Information & Communications in Japan 2006. Tokyo, Japan.

Intven, H. and Tétrault (2000). Overview of Telecommunications Regulation. Washington, World Bank: 1-26.

Kinoshita, R. (2006). Interview on Next Generation PHS and Willcom. M. R. Meijering. Willcom Inc, Tokyo.

Lemstra, W. (2005). Economics of Infrastructures. SPM2220. Retrieved November 28, 2005. http://blackboard.icto.tudelft.nl

Lemstra, W. (2006). The internet bubble: The impact on the development path of the telecommunication sector. Eemnes, the Netherlands, Industry-Insights BV.

MIC (2003). Guidelines for Radio Spectrum Reallocation. Japan, Ministry of Internal Affairs and Communications.

MIC (2005). Information and Communications in Japan, Stirring of u-Japan, Ministry of Internal Affairs and Communications Ministry of Internal Affairs and Communications.

MIC (2006). Policies on Next-Generation Mobile Communications. Japan, Ministry of Internal Affairs and Communications.

Ministry of Economic Affairs (2004). Breedband nota: Een kwestie van tempo en betere benutting. The Netherlands.

Mochizuki, L. (2006). Interview on Yozan's business strategy. M. R. Meijering. Tokyo.

Moore, G. A. (2000). Living on the Fault Line: Managing for Shareholders Value in the Age of the Internet. New York, Harper Business.

Nalebuff, B. and A. Bradenburger (1996). Co-opetition: A revolutionary mindset that combines competition and cooperation in the market place New York, Doubleday Press.

Naoe, S. (2006). Interview on WiMAX opportunities in Japan. M. R. Meijering. Chuo University, Tokyo.

Nitta, T. (2006). Interview on frequency policy concerning Broadband Wireless Access systems in Japan. M. R. Meijering. Ministry of Internal Affairs and Communications, Tokyo.

Nohara, M. (2006). Interview on KDDI's mobile WiMAX activities. M. R. Meijering. KDDI, Tokyo.

OECD (2003). ICT and Economic Growth. Evidence from OECD countries, industries and firms.

OECD (2005). Economic Survey The Netherlands.

OECD (2005). Economic Surveys Japan.

OECD (2005). The implications of WiMAX for competition and regulation, OECD, Directorate for Science, Technology and Industry.

Okimoto, D. I. (1989). Between MITI and the Market: Japanese industrial policy for high technology. Stanford, Stanford University Press.

Oobuchi, Y. (2006). Interview on WiMAX opportunities in Japan. M. R. Meijering. Ric Telecom, Tokyo.

Pareek, D. (2006). The Business of WiMax. West Sussex, John Wiley & Sons, LTD.

Porter, M. (1980). Competitive Strategy. Techniques for Analyzing Industries and Competitors. New York, Free Press.

Reve, T. (1990). The Firm as a Nexus of Internal and External Contracts London, Sage.

Rogers, E. (1983). Diffusion of Innovation. New York, Free Press.

Sampler, J. L. (1998). "Redefining Industry Structure for the Information Age." Strategic Management Journal 19(4): 343-355.

Steinbock, D. (2003). "Globalization of wireless value system: From geographic to strategic advantages." Telecommunications Policy 27: 207-235.

Ubacht, J. (2005). Beleid, Economie en Recht op het I-domein. SPM3420. Retrieved November 28, 2005. http://blackboard.icto.tudelft.nl.

Van de Kar, E. A. M. (2004). Designing Mobile Information Services: An Approach for Organisations in a Value Network. Delft, Delft University of Technology.

Verschuren, P. and H. Doorewaard (2000). Het ontwerpen van een onderzoek. Utrecht, Lemma BV.

Waldman, D. E. and E. J. Jensen (2001). Industrial Organization; Theory and Practice, Addison Wesley Longman, Inc.

WiMAX Forum (2006). "Mobile WiMAX - Part 2: A Comparative Analysis ".

Annex

A. Interview Protocol

This is the general interview protocol that has been used for the personal interviews in both the Netherlands and Japan. Depending on the situation, certain questions were more relevant than others were. Therefore, not all questions have been asked in all interviews. Additionally, in some interviews not all questions were answered, because of confidentiality reasons or inability to answer due to the maturity of the WiMAX industry. Especially the questions concerning investments were avoided by the respondents.

Technology WiMAX

1. How do you position the fixed and the mobile WiMAX standard with respect to other technologies?

2. What are the technological strengths of this WiMAX standard with respect to these other technologies?

3. What are the technological weaknesses of this WiMAX standard with respect to these other technologies?

4. I have identified three basic deployment options for WiMAX, namely for WLL access, backhaul (Wifi/WiMAX or cellular/WiMAX) or mobile.

4a. Do you agree with this division? If not, what are other deployment options?

4b. What do you consider to be the most important opportunities for this WiMAX standard in the Netherlands/Japan?

4c. What type of business model do you consider to be most valuable for the fixed/mobile WiMAX standard?

5. What do you consider to be the most important threats for this WiMAX standard in the Netherlands/Japan?

6. In the past, there have already been two other generations of fixed wireless technologies, namely LMDS and MMDS. Both have had limited success.

6a. In what is the fixed WiMAX standard comparable with these two technologies?

6b. In what does the fixed WiMAX standard differ from these two technologies?

6c. Can a different development with the fixed WiMAX standard be expected?

WiMAX forum

The WiMAX Forum claims the following benefits of a standard for operators.[37]

- Common Platform drives down costs, fosters healthy competition and encourages innovation
- Enables a relatively low initial CAPEX investment and incremental expenditures that reflect growth

[37] http://www.WiMAXforum.org/technology/benefits/

- No more commitments to a single vendor, a typical by-product of the proprietary technology model
- Wireless systems significantly reduce operator investment risk
- Global interoperability

7. What is your perception on this? Is this already the reality for the WiMAX standard?

The Dutch/Japanese context

8. Which regulatory factors do you consider to be of critical importance for the success or failure of this WiMAX standard in the Netherlands/Japan?

9. Which technological factors do you consider to be of critical importance for the success or failure of this WiMAX standard in the Netherlands/Japan?

10. Which economical or marketing factors do you consider to be of critical importance for the success or failure of this WiMAX standard in the Netherlands/Japan?

11. Which social factors do you consider to be of critical importance for the success or failure of this WiMAX standard in the Netherlands/Japan?

Deployment strategy

12. Which companies in the Netherlands/Japan are focusing their business on the fixed/mobile WiMAX standard?

Spectrum

13. Which frequency band is most interesting for fixed/mobile WiMAX deployment in the Netherlands/Japan?

Geographic area

14. Which geographic area is most interesting for fixed/mobile WiMAX deployment in the Netherlands/Japan?

Customer segment

15. Which customer segment is most interesting for fixed/mobile WiMAX deployment in the Netherlands/Japan?

Market

16. In which type of market should fixed/mobile WiMAX try to get a market share?

17. What is the size of this market in the Netherlands/Japan?

18. What expected market share can fixed/mobile WiMAX take in this previously mentioned market?

Services

19. What type of services should be offered when using fixed/mobile WiMAX?

Revenue

20. What type of revenue model should be using when offering WiMAX services?

21. What is the expected revenue for offering fixed/mobile WiMAX services?

Competitive environment

22. Against which technologies will fixed/mobile WiMAX compete in the Netherlands/Japan?

23. Which companies in the Netherlands/Japan are competitors of companies offering fixed/mobile WiMAX services?

WiMAX technology variant

24. Do you have future plans to offer services based on the mobile WiMAX standard? If yes, when?

Open question

25. What are the most important uncertainties or insecurities concerning the deployment of the WiMAX standard?

26. Are there any questions, which have not been mentioned in this interview, but are of importance?

B. Causal diagram of WiMAX factors

The causal diagram is used to give a structured insight into the relevant factors concerning WiMAX deployment (Figure 24). The ovals in the diagram represent the different factors. The central red oval is the main factor of this diagram and represents the question: What are the opportunities of WiMAX? The directed links represent the influence of one factor upon another. A positive link from factor A to B means if more A than more B or if less A than less B. An example of the diagram is the following. If the factor 'Expected revenue' is high than also the factor 'WiMAX opportunities' is high, meaning that deploying WiMAX could be a feasible business opportunity. A negative link from factor A to B means if more A than less B or if less A than more B. The frames 'Technological capabilities' and 'Regulatory environment' group several factors together to make it more orderly.

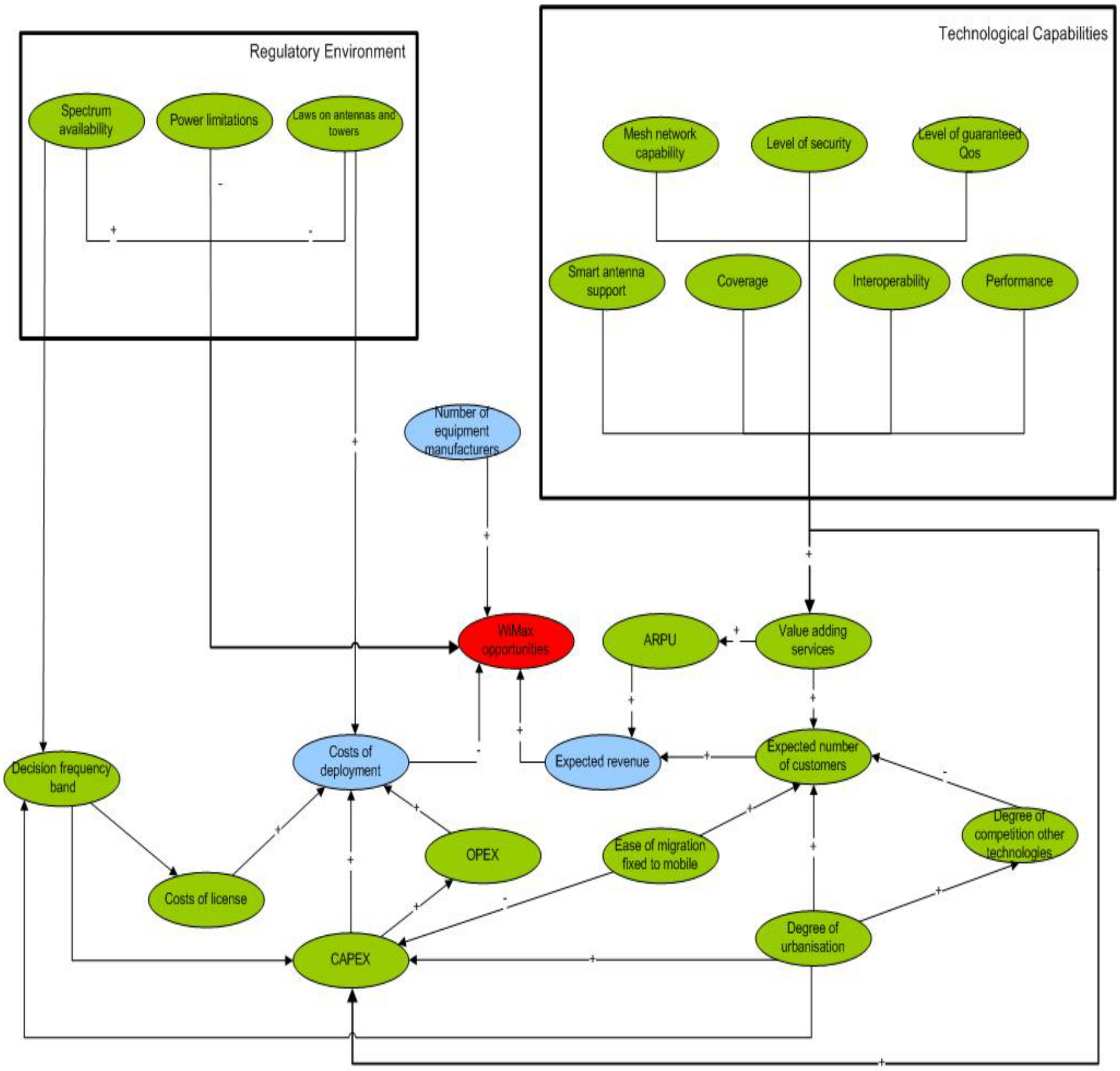

Figure 24. Causal diagram of WiMAX factors

The two blue factors ‘costs of deployment’ and ‘expected revenue’ are important factors which directly influence the decision of the operator to deploy WiMAX or not. The ‘expected revenue’ is positively influenced by the ‘ARPU’ and the ‘expected number of customers. These are both positively influence by the ‘Value adding service’. The underlying thought here is that customers are more interested in using the new WiMAX technology if more advanced and value adding services are offered, for example VoIP or IPTV. The seven factors of the technological capabilities frame all influence this ‘value adding services’ factor and the ‘CAPEX’ factor. The ‘degree of competition other technologies’ signifies the level of competition of operators using other technologies like DSL or cable which WiMAX operators could be facing in a certain area. For example, highly populated areas in the Netherlands have very high DSL or cable penetration rate deployed by numerous of operators. Here competition is expected to fierce.
Another important factor is the ‘degree of urbanisation’ which positively influences the ‘expected number of customers’ and the ‘degree of competition other technologies’. This refers to the deployment area, urban, sub-urban or rural. It is assumed that an urban area is likely to have more ‘expected number of customers’ since the population density is higher. On the other hand in an urban area it is also likely that there are more operators operating. This increases the degree of competition and has again a negative influence on the ‘expected number of customers’.
The factor ‘ease of migration fixed to mobile’ refers to the fact that there are two versions of WiMAX, fixed and mobile. The fixed WiMAX version is designed for fixed and nomadic access. The mobile WiMAX version adds portable and mobile access to this. The underlying techniques of these two versions are different. In order for the fixed and mobile WiMAX versions to be interoperable a supporting migration path needs to be designed. The ease of migration negatively influences the ‘CAPEX’ factor. This means the capital expense is typically lower when the migration path is easier. For example, instead of replacing the base stations the operator may perform a software upgrade.
Another factor worth to point out is ‘decision frequency band’. Since WiMAX may operate in the licensed and unlicensed spectrum, a decision by the operator has to be made. This decision is influenced by the ‘spectrum availability’ and the ‘degree of urbanisation’. An operator who operates in the unlicensed spectrum runs the risk of interference problems, especially in an urban area with a high population density. This decision directly influences the ‘costs of license’ and the investments, which have to be made for the WiMAX network, the ‘CAPEX’.
The factors within the ‘regulatory environment’ frame define the regulatory context in which a WiMAX operator can operate. For example, if there is only very little spectrum available for WiMAX deployment than this complicates the WiMAX business opportunity for an operator.
The last factor, which asks for some explanation, is the ‘number of equipment manufacturers’. It positively influences the feasibility of WiMAX deployment. If a large number of equipment manufactures produce the necessary equipment for a WiMAX network infrastructure than more deployment choice and options are available which could stimulate the dynamics of the WiMAX market, create economics of scale and therefore make WiMAX deployment more feasible. A clear advantage for operators is the desired interoperability of WiMAX equipment of the various manufacturers.

C. Value Network

The concept of the 'value network' represents all the different important actors in an industry and the mutual dependent relations between them. In a value network the actors, their roles and their way of interaction change (Van de Kar 2004).
The concept of a value network can be used to gain a better understanding of the relevant actors of the WiMAX industry and its interdependent relations. In Figure 25, a general and simplified value network is shown of the WiMAX industry.
It should be noted that the operator and the network operator could be the same actor. The strict boundaries between these actors are in general in the communication industry increasingly diminishing. According to my experience, this is especially true for the WiMAX industry. There seems to be no actor, who is currently offering WiMAX services without also operating the network. However, this could change when the industry is becoming more mature.
The actor 'WiMAX Forum' has a mutual relation with all the other actors in the value network, but also consists of these same actors. In short, the WiMAX Forum is an industry led non-profit organization for the promotion of WiMAX.

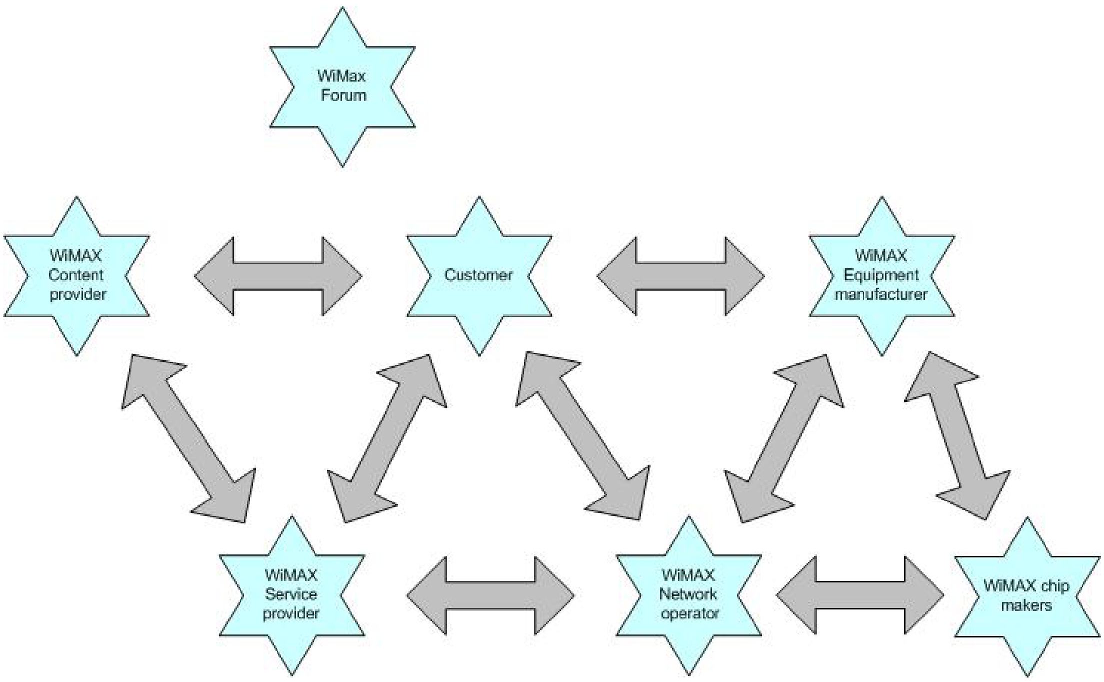

Figure 25. Value network for WiMAX industry

D. Technology adoption life cycle

Of the drivers of the external environment, socio-cultural, economical, political/regulatory and technological, it can be argued that the technological driver in the form of the adoption of a new disruptive technology is the most prominent (Moore 2000). Such a technological driver can greatly change the state and direction of the industry.

In the context of this research project, such a technological driver is the introduction of WiMAX in the industry. Therefore, of the four drivers of the external environment the technological driver will be of key importance. A useful tool in understanding the development of this technological driver is the technology adoption life cycle.

According to Moore (2000) the adoption of a new technology goes through a number of phases. The technology adoption life cycle, which is based on Roger's diffusion of innovation theory (1983), has the following strategic segments; technology enthusiasts, visionaries, pragmatists, conservatives and skeptics. The technology adoption life cycle is shaped like a bell and the various segments represent the predicted percentage to adopt one of the above-mentioned strategic options. The standard technology adoption life cycle is shown in Figure 26.

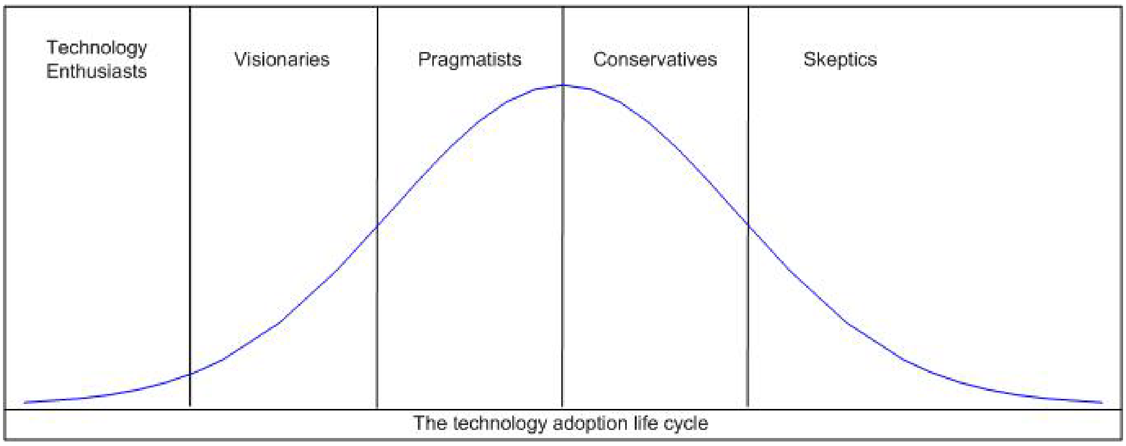

Figure 26. The technology adoption life cycle

Technology enthusiast strategy
This strategy will adopt the technology immediately after its availability. It is used to examine the characteristics and capabilities of the technology.

Visionary strategy
This strategy is used for obtaining a dramatic competitive advantage by adopting the new technology. By being first to the market and deploying the new technological system, it is expected to take the lead over the competition. It is a strongly differentiating strategy.

Pragmatist strategy
This strategy adopts the new technology when everybody in the industry environment is also adopting the technology. The technology must been proven by concrete examples of successful deployments before it will be adopted. Once the initial value of the new technology has been proven then the technology will be adopted.

Conservative strategy
This strategy will use the old technology as long as possible, because it is familiar and it has been paid for. In the long run the organization will change to the technology, which by then knows wide spread adoption.

Skeptic strategy
This strategy will not adopt the new technology at all, because it simply does not believe in the benefits and its possibility of achieving mass-market adoption.

E. The PHY and MAC layer of the IEEE 802.16 standards

The PHY Layer of IEEE 802.16

The IEEE 802.16 standard was designed to develop as a set of air interfaces based on a common MAC layer protocol, but with several PHY layer specifications depending on the spectrum of use and the associated regulations specified by the different National Regulatory Authorities (NRA). In the following three important aspects of the PHY layer are being discussed; multiplexing, duplexing and channel bandwidth.

Multiplexing

The PHY layer contains several forms of modulation and multiplexing to support different frequency range and application. Two multi-carrier multiplexing techniques are supported in the 802.16-2004 standards: OFDM with 256 carriers and OFDMA with 2048 carriers.

OFDM is a modulation technique that subdivides the bandwidth into multiple frequency sub-carriers. The input data stream is divided into several parallel sub-streams of reduced data rate and each sub-stream is modulated and transmitted on a separate orthogonal sub-carrier.

The benefits of OFDM are high spectrum efficiency, resistance against multi-path interference and ease of filtering out noise. Additionally, the downlink and uplink data rates can be altered by allocating either more or fewer carriers depending on the need. However, strict frequency synchronization is demanded and an imperfect synchronization results in severely reduced performance.

OFDMA is a multiplexing technique that provides multiplexing operation of data streams from multiple users onto the downlink sub-channels and uplink multiple access by means of uplink sub-channels. In short, OFDMA is the multi-user version of OFDM.

The benefits are an even higher spectral efficiency, because of the simultaneous transmission from several users, and it supports high rate applications since more than one sub-carrier can be assigned to one user. A disadvantage is that multi-user interference is introduced when imperfect frequency synchronization occurs (Hoymann 2005).

Channel bandwidth

The IEEE 82.16e-2005 standard is based on scalable OFDMA (SOFDMA). SOFDMA supports a wide range of channel bandwidths ranging from 1.75 MHZ to 20 MHz to flexibly support the need for various spectrum allocation and usage model requirements. This flexibility is needed because the channel bandwidth is highly dependent on the spectrum allocated by the regulators. It supports features especially suited for high-speed mobile operation, for example downlink and uplink sub-channelization and fixed sub-carrier spacing.

Duplexing
The 806.16 standards support two duplexing options and an additional one for the 802.16e-2005 standard. Both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) are supported and additionally for the 80216e standard half Frequency Division Duplex (HFDD).

TDD is a technique that uses a single channel for its traffic while the downlink and uplink are assigned to different time slots. TDD has a strong advantage where the traffic demand allows for an asymmetric down- and uplink data speed. If the amount of downlink data increases then more bandwidth can be allocated for the downlink and vice versa.
TDD also provides an advantage where a regulator allocates the spectrum in an adjacent block. Band separation for TDD is not needed and therefore the whole spectrum allocation is used efficiently both uplink and downlink.
Furthermore, TDD assures channel reciprocity for better support of link adaptation (e.g. beamforming), Multiple Input Multiple Output (MIMO) and other advanced antenna technologies.

FDD is a technique that uses two different channels for its uplink and downlink traffic. Resulting in the fact that FDD is more efficient than TDD in the case of symmetric traffic, because no switching overhead between the uplink and the downlink is existing.
Another advantage of FDD is generally easier radio planning, because no strict time synchronization is necessary, which makes a system more complex and therefore costly.
HFDD, a half-duplex system, does not simultaneously transmit and receive. It allows communications in both directions, but only one direction at a time. In Table 6 an overview is shown.

Table 6. Comparison Time Division Duplex and Frequency Division Duplex

	TDD	FDD
UL/DL isolation	Guard time	Guard band
Spectrum efficiency	More efficient (smaller GB)	Less efficient (larger GB)
UL/DL channel	Reciprocal (supports MIMO,beamforming)	Non-reciprocal
Suitable for	Packet base data traffic	Symmetric traffic like voice

TDD is the preferred duplexing mode for broadband services for the following reasons:

- TDD supports asymmetric downlink/uplink traffic. Since traffic is becoming more and more dominated by data, downlink traffic will generally be more dominant causing traffic to become asymmetric. Since the FDD downlink/uplink is always fixed and has generally equal downlink/uplink bandwidths, one of the channels will be underutilized resulting in a decrease in overall spectral efficiency.
- TDD requires only a single channel, unlike FDD that requires a pair of channels. This provides a greater flexibility for adaptation to the varied global spectrum allocations.
- TDD supports advanced antenna technologies like beamforming and MIMO.

The MAC Layer for IEEE 802.16

The Medium Access Control (MAC) layer of the IEEE 802.16 standard was designed for PMP broadband wireless access applications, is quality of service (QoS) sensitive and connection-oriented. It supports higher layer or transport protocols such as ATM, Ethernet or Internet Protocol (IP), and is designed to easily accommodate future protocols that have not yet been developed. The allocation of bandwidth by the base station (BS) goes according to requests of the subscriber stations (SS). The design addresses the need for very high bit rates for both the downlink as the uplink. The MAC can accommodate continuous and burst traffic in order to support the diversity of services required by the multiple end users. These services are for example legacy time division multiplex (TDM) voice and data, IP connectivity, VoIP and streaming audio and video.
The 802.16 MAC is adaptable and flexible and it supports several multiplexing and duplexing methods (Table 2). The 802.16 MAC layer consists of three sublayers, namely the service-specific convergence sublayer (SSCS), the common part sublayer (CPS) and the privacy sublayer. The SSCS is used to map the traffic specific for the transport layer to a MAC that is flexible enough to efficiently carry that traffic type.
Furthermore, the 802.16 MAC is based on collision sense multiple access with collision avoidance (CSMA/CA). This uses a carrier-sensing scheme. A data station that wants to transmit sends a jam signal. After waiting a sufficient time, so that the stations have all received the jam signal, the data station starts to transmit. The MAC layer incorporates several features supporting a wide variety of application at different mobility rates. Several important features are the following:

- Four service classes; unsolicited grant service (UGS) for VoIP applications, real-time polling service (rtPS) for streaming audio and video, non-real-time polling service (nrtPS) for file transfer protocol (FTP) and best effort (BE) for data transfer and web browsing applications
- Header suppression, packing and fragmentation for efficient use of spectrum
- Privacy key management (PKM) for MAC layer security
- Broadcast and multicast support
- High-speed handover and mobility management primitives
- Three power management levels for efficient use of battery capacity; normal operation, sleep mode and idle mode with paging support

An overview of the features of the IEEE 802.16 MAC layer is shown below (Table 7).

Table 7. IEEE 802.16 MAC layer features

Feature	Benefits
TDM/TDMA scheduled downlink/uplink frames	• Efficient bandwidth usage
Scalable from 1 to hundreds of subscribers	• Allows cost-effectieve deployments by supporting enough subscribers to deliver a robust business case
Connection-oriented	• Per connection QoS • Faster packet routing and forwarding
QoS support UGS, rtPS, nrtPS, BE	• Low latency for delay sensitive services (TDM voice, VoIP) • Optimal transport for VBR traffic (streaming video) • Data prioritization
Automatic retransmision request (ARQ)	• Improves end to end performace by hiding RF layer induced errors from upper layer protocols
Support for adaptive modulation	• Enables highest data rates allowed by channel conditions, improving system capacity
Security and encryption	• Protects user privacy
Automatic power control	• Enables cellular deployments by minimizing self interference

F. MIC's requirements and basic principles for technical study of BWA systems

To qualify as a BWA system for the use of the 2.5GHz spectrum band in the form of a license for it. The different BWA systems must satisfy the following three technical requirement issues. These requirements have been formulated by MIC in order to most efficiently use the spectrum with the end result of provide the maximum benefit for the end-users.

1. Requirement on frequency band use
2. Requirement on system capacity
3. Requirement on penetration

From the viewpoint of frequency efficient use the first requirement states that a TDD system should be adopted, taking into account the fact that only unpaired band (2535-2695MHz) can be prepared for BWA.

The second requirement consists of three parts. The first is that the forward link peak data rate should be higher than 3G/3.5G. When considering a peak data rate of HSDPA of 14.4Mbit/s/5MHz, it should be more than 20-30Mbit/s/10MHz.
Secondly, the reverse link peak data rate should be higher than 3G/3.5G. When considering the peak data rate of HSDPA of 5.7Mbit/s/5MHz, it should be more than 10Mbit/s/10MHz.
Thirdly, the frequency efficiency should be higher than 3G/3.5G. When considering the average throughput of HSDPA of 0.6-0.8 bps/Hz than it should be more than 0.8bps/Hz.

The third requirement focuses on penetration. The applicable BWA systems should be standardized or on the process of standardization by global standardization bodies, so that it can be expected that they become globally penetrating systems and that also the operators can select their network equipment from worldwide manufacturers.

In conclusion the study items of the Council Committee are twofold. Firstly, the technical study of each BWA system. Basically, based on the results of the technical proposals of BWA systems invited by the Study Group for Wireless Broadband Promotion, the Committee Council should study the BWA systems IEEE 802.16 (WiMAX), IEEE 802.20 (i-burst and Flash OFDM) and next generation PHS. Secondly, the examination of technical requirements for implementation of each system, such as frequency guard bandwidth between BWA systems and adjustment system and the frequency guard bandwidth between one BWA system.