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Opportunities for network development in Kazakhstan - WiMax

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Abstract

The purpose of this paper is to discuss Worldwide Interoperability for Microwave Access (Wimax) technology-based network deployment opportunities in Kazakhstan. To be widely adapted and be profitable, even the very promising technology with advantageous features must experience market testing and meet user needs. This project consists of two parts; the first part consists of analysis while the second part focuses on implementation.

In the first part, the telecommunications industry of Kazakhstan is divided into three main segments: fixed communication, mobile communication, and internet & data communication. Some market characteristics are viewed based on data from National Statistics Agency of Kazakhstan, with the role of the segments in the telecommunications industry identified and their future growth discussed. With regards to Broadband Access Services, some user requirements are considered with e-government and e-commerce applications discussed. As a result of market research, a Mobile Wimax is selected for Broadband Access Services implementation for internet & data communication segment.

The second part considers Wimax technology deployment in the access network. Distinctive features such as scalability, range, coverage and QoS; standard specifications, and modulation techniques are explained. The difference between “mobile” and “fixed” Wimax along with their target markets are discussed. Additionally, the approach for estimating user capacity requirements for a metropolitan area is reviewed. Further, a core element of access network Base Station deployments and review of Adaptive Antenna Configurations are provided. A comparative analysis regarding the number of required Base Stations in different implementation scenarios provided by Wimax Forum are reviewed.

Introduction

The telecommunications infrastructure of Kazakhstan and other post-Soviet nations was inherited directly from the Soviet Union, whose infrastructure was problematic. As history shows in Soviet Union, all industries with vital significance for the nation had been under the control of the government and followed a course that the government determined.

Historically, the development of a telecommunications system in the country took the shape of a natural monopoly, where a single carrier owned the majority of the telecommunications network (cables, channels, buildings, and communication installations). The Development of the telecommunications sector is affected by the economical growth and stability, geographical and demographical features, market and user requirements, etc. It is acknowledged that there are also internal political forces; activity of the regulatory body, Agency for Informatization and Communication (AIC), representing government; as well as the Agency for the Regulation of National Monopolies (ARNM), which influences the system. This project, however, focuses on the question of how a Wimax technology can be used for the development of broadband access networks and the telecommunications system.

Market research is formed by comparing data and information about the industry, customers, and existing providers. This research helps the launching of a new product and identifies the population using the services based on a diverse data, such as: age, location, income level, and user requirements. This project also conducts secondary market research as used data is free and easily accessible. While affordability is an advantage, there may also be collateral effects such as biased data, which is hard to validate or materials unspecified to the research area. The primary research is an expensive process and requires focus groups,

surveys, interviews, as well as field tests conducted specifically to research a product[1]. Questions such as the following are addressed:

- What is happening in the market?
- Who are the competitors?"
- What are the trends?
- Which customer needs are important and are currently being met by current services?

The technology of Wimax allows great opportunities for overcoming the provision of wireless broadband access and backhaul networks. With the emergence of mobile Wimax, it provides even more capacity and scalability as well as introduces portability. With appropriate market research and network planning, Wimax operators take the leading positions in the provisioning of broadband access services worldwide. Wimax has different implementation scenarios and a range of applications, including fixed and mobile voice services as well as fixed, portable, and mobile data access. Along with the definition of the Wimax technology during the course of the project, the difference between mobile and fixed Wimax are also discussed.

Network implementation is a complex, long term, and resources demanding process. Initial market research and business sustainability approval are followed by a substantial planning process before actual network design implementation. The network design process undertakes future needs, infrastructure flexibility to support future changes, and balances hardware with budgetary concerns. Regarding the wireless Wimax networks, a number of tools are reviewed including tools for identifying network coverage and capacity for

metropolitan area, frequency band and channel bandwidth considerations, and base-station configurations.

Finally, the project delivers some assumptions on the terms of the network development, goals for mass use, coverage requirements, and other considerations regarding Wimax technology to be adapted in Kazakhstan.

A. General Information

1. Country profile

A former Soviet Union country the Republic of Kazakhstan gained its independence on December 6, 1991. Kazakhstan is the ninth largest country in the world. It is slightly less than four times the size of Texas. The population is 15.34 million. Kazakhstan is located in Central Asia, bordering with China in the northwest, Kyrgyzstan, Uzbekistan, Turkmenistan in the south and Russia in the north and northwest. The capital of Kazakhstan is Astana.

Kazakhstan's economy is larger than those of all the other Central Asian states combined, largely due to the country's vast natural resources and a recent history of political stability. However, "the country has embarked upon an industrial policy designed to diversify the economy away from overdependence on the oil sector by developing its manufacturing potential. The policy aims to reduce the influence of foreign investment and foreign personnel. Aided by strong growth and foreign exchange earnings, Kazakhstan aspires to become a regional financial center and has created a banking system comparable to those in Central Europe"[2].

The scientific base and culture of Kazakhstan was inherited from the Soviet regime, after the Soviet Union's collapse. Kazakhstan wants to meet its development goals largely by recruiting, educating and retaining qualified young people in key fields of Science and Technology. Currently Kazakhstan has an excellent Bolashak (meaning *future* in Kazakh) Program, under which 3,000 Kazakhstani students at a given time are given opportunities to study at leading universities in several foreign countries.

Since 1991, after claiming its independence Kazakhstan has become "a leader in economic reform, implementing bold programs that have attracted investment, created jobs, and established a vibrant banking system in Central Asia"[3]. As a result of the country's economical growth potential, today many foreign investors have expressed interest in developing technology sectors in Kazakhstan. In the Internet Technology sector there are companies such as Microsoft, Oracle, EMC, Cisco, etc. Main vendors of telecommunications equipment in the country are Ericsson, Alcatel-Lucent, Nortel, Huawei, Cisco, etc.

Kazakhstan is a cosmopolitan country as many nations were forcibly moved to these places during the Stalin's regime. Ethnic Kazakhs are half of the population; also, there are many other large ethnic groups such as Russian, Ukrainian, Uzbek, German, Tatar, Uygur, etc. Most people are Muslims and Russian Orthodox. Kazakhstan has two official languages Kazakh and Russian. Kazakh is a state language and Russian is designated as "the language of interethnic communication". The literacy rate is 99.5 %.[4]

2. Government

In conformity with the constitution, the Republic of Kazakhstan "proclaims itself as a democratic, secular and social state whose highest values are the individual, his life, rights and freedom" [5]. Kazakhstan is a unitary state with a presidential form of government. The president is the head of state and the commander of the armed forces. The head of the government is the prime minister and is responsible for the cabinet of ministers.

The bicameral Parliament consists of the Senate (47 seats, 7 members are appointed by the president other members are elected by local assemblies; to serve six-year terms) and Mazhilis (107 seats; 9 out of the 107 Mazhilis members are elected from the Assembly of the

People of Kazakhstan, which represents the country's ethnic minorities; members are popularly elected to serve five-year term)[6].

3. Population and environment

During its first decade of independence Kazakhstan has experienced a decline in population due to immigration to historic homelands in the CIS and western countries. Recently the government has developed good social benefits and credits to ethnic Kazakhs living in foreign countries provided they return to their homelands. This entailed the resettlement of *oralmans* (returnees) from China, Uzbekistan, Kyrgyzstan, Mongolia, etc. As mentioned before the population of Kazakhstan is 15.3 million. For a large territory of 2.7 million square kilometers the population density is low. Also, due to the various geographical and economical development in different regions of Kazakhstan the population density is uneven. The highest population density, almost half of the urban population, is concentrated in the south (Almaty, Shymkent Taraz and Kyzylorda). This region's climate is favorable for agriculture and livestock breeding. The next by its population density is north of the country (Astana, Karaganda and Kostanay), explained by the industrial character of the region[7].

The contamination of the environment is becoming a serious issue. There are issues such as land and soil degradation in the northern part caused by overuse of agricultural chemicals. As a result of improper use of water resources there is an issue of Aral Sea disappearance. Although several years have passed since the last nuclear explosion in the Semey firing test ground, the region and people still experience the irrevocable consequences. The land of the western part of Kazakhstan is unsuitable for agriculture due to saline soil. These are a few of today's important environmental issues.

4. Government policies

Kazakhstan has several short term government programs and strategies directed to develop different branches of economy. Among these the most important program is the long term strategy the “Kazakhstan 2030”. This plan concentrates the attention of the state on a pretty narrow range of priorities, thus, urging the Government to settle these tasks and strategies[8]. (Kazakhstan 2030). There are 7 priorities specified in this strategy such as: National Security; Domestic Political Stability; Development of Open Market Economy; Health & Education; Power Resources; Transport and Communication; and Professional State.

An issue of Communications and Telecommunication Networks is given special importance since they are “considered to be vitally important and necessary prerequisites for modern business development”[7]. The strategy notes the importance of information technology development in health care, education and environmental protection. The program expects development of the independent and effective telecommunications network, competitive in future with the similar infrastructure of the world developed economies. It is admitted that underdevelopment of this sector will cause serious economical problems.

5. Wars and conflicts

Since its independence Kazakhstan has been acting as a peaceful country as it is stated in the constitution. Neither has Kazakhstan taken activity in any international conflict, nor has it been an epicenter of any conflict or government revolution. Kazakhstan has commenced demarcation of its boundaries with neighboring Russia, Uzbekistan, Kyrgyzstan, China, and Turkmenistan. No resolution has been made on a seabed boundary of the littoral states in the Caspian Sea; however, there are treaties ratifying equidistant seabed.

6. Economy

The second largest of the former Soviet republics in territory, Kazakhstan, possesses supplies of metal and plentiful supplies of minerals including enormous fossil fuel reserves. “Kazakhstan's share in world output of commercial minerals and products of procession thereof (according to estimates of the Union Bank of Switzerland amounts to the following: Beryllium - 24%, Zink - 7%, Tantalum - 33%, Titanium - 26%, Chromite - 27%, Copper - 3%, Barite - 7%, Molybdenum - 3%, Lead - 7%, Bauxites - 1%, Uranium -14%, Manganese - 5%, Silver - 6%, Iron ore - 2%, Tungsten - 12%, Gold - 1%”[9].

The agriculture sector features livestock and grain. Extracting and processing natural resources is the basis of the industrial sector. Four years after the collapse of the Soviet Union the economy experienced contraction due to a low demand in Kazakhstan’s traditional heavy industry products. Economic reforms and privatization carried out by the government resulted in shifting of assets into the private sector. Not only the country’s booming energy sector, but also economical reform, good harvests, and foreign investments allowed double digit growth of Gross Domestic Product (GDP) in the period from 2000-07[210].

In the next few years Kazakhstan has an ambitious program to increase its technological competitiveness in the global marketplace. The government of Kazakhstan has concluded “that the countries long-term economic well-being will depend in large measure on how wisely its financial resources are invested in the development of non-oil sectors of the economy and in promotion of sustainable, broad based economic growth.” There is a need in transition “from producing and exporting primarily unprocessed raw material to producing more knowledge-intensive, value-added goods and materials”[11].

B. Status of telecommunications system in the country

Today the development of telecommunications systems in a country is of great significance as it is the conditional factor for integration with the world community. Kazakhstan's telecommunications market is dynamically developing. For the last three years the average annual increase of income from telecommunications services was 28%, which can be compared with the developing dynamics of such fields of economy as gas and oil production services 35%[12]. Despite the high growth of the index, which is higher than the world's average growth index, numerous indexes representing the growth in this sector of the economy in the Republic of Kazakhstan does not comply with the overall economical situation in the country. For instance, the share of the telecommunications market of Kazakhstan hardly exceeds the amount of 0.1% of the telecommunications market of the world[13].

At the same time the share of "telecommunications" field in Gross Domestic Product (GDP) of Kazakhstan in 2006 formed 1.8%. Russia's share in GDP was 3.5%[14], whereas, the development model of telecommunications market in these countries is similar.

Table 1 Income from telecommunications services and growth, 2005-2007

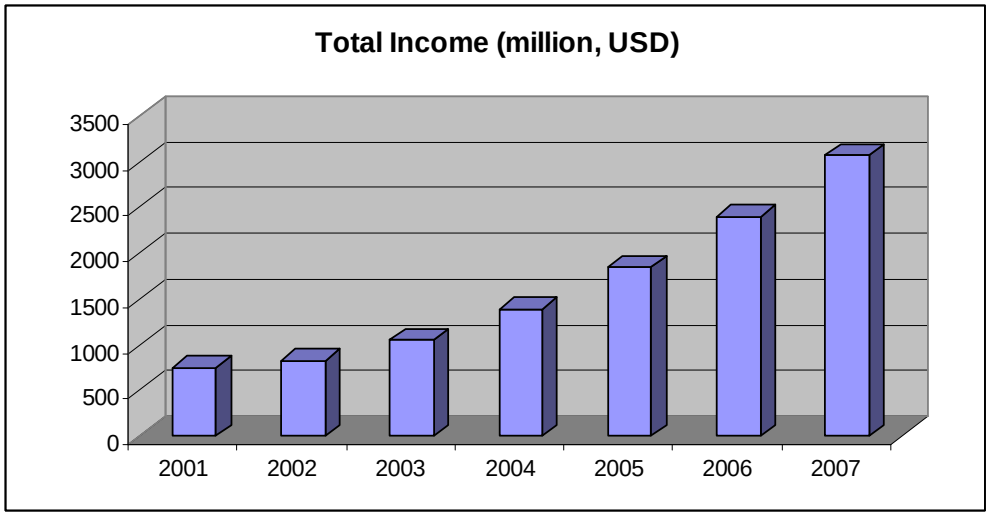
	million USD				
	2005	**2006**	**2007**	**2005/2006 (+ %)**	**2006/2007 (+ %)**
Total	1789.89	2324.00	2981.76	29.84	28.30
Intercity and International traffic	368.56	424.09	446.49	15.06	5.28
local telephone services	145.31	167.46	190.75	15.24	13.91
data transfer services	26.60	36.83	47.01	38.43	27.66
Internet access services	80.51	121.49	184.91	50.91	52.19
Mobile telephone services	778.34	1153.04	1621.57	48.14	40.63
Cable television	64.02	73.54	92.15	14.87	25.32
other telecommunications services	298.86	347.56	398.88	16.29	14.77

Source: The Agency of Statistics of Kazakhstan for the years cited (www.stat.kz)

In money terms the volume of the telecommunications market in 2007 reached 357 billion Kazakhstan Tenge (KZT) or $2.98 billion USD[15], while Russia's – 1,035 trillion Russian Rubles (RUR) or $44.55 billion[16]. The following figures are indicative: the net income of Verizon Communications Inc. for 2007 totaled $5.5 billion[17] which is almost twice the income from the whole telecommunications market of Kazakhstan.

According to the statistics agency of Kazakhstan in 2008 the volume of national telecommunications market can amount to $ 3.81 billion. At the same time, for 2008-2009 it is forecasted that the rate of growth of the telecommunications market in financial terms will be reduced, since the Government of Kazakhstan is making efforts on reducing tariffs to fixed, mobile communication and Internet data services. This short-term government policy will reduce the rate of growth in income of players in the telecommunications market. However, this policy will not directly affect the increase in customer base and consumption of telecommunications services.

Figure 1 Growth dynamics of the telecommunications market of Republic of Kazakhstan



Source: The Agency of Statistics of Kazakhstan (www.stat.kz)

Some of the features that influences the development of the telecommunications market in Kazakhstan are geographical and demographical, or namely the large territory of the country and the low density of population. By territory Kazakhstan is the ninth largest country in the world after Argentina and Brazil, while it is 60th by population. Thus, the density of population is very low, approximately 5.5 person/sq. meter, which is 1.5 times smaller than Russia's figure and dozens of times lower than that of European countries. The large territory in aggregate with the low population, high number of rural population (40%) and high coefficient of family size (on average - 3.5 person/family and 4 persons/ family in rural areas) partly explains the low penetration of telecommunications services in the country. For instance, fixed telephone services penetration in households is 62% in Russia and 97% in Germany[18].

Table 2 General geographical and demographical characteristics of Kazakhstan compared with other countries, 2005

	Population (mill.)	Area (thous. sq. km.)	Population Density (people/sq.km)	Average annual telecommunications services consumption per capita, USD
Kazakhstan	15.2	2717	5.5	105
Russia	142.7	17045	8.4	250
Europe	727	10000	72.7	343
by countries				
Czech Rep	10.8	78.9	129	539
Hungary	10	93	109	220
France	62.4	547	110	600
UK	60.4	244	247	1826

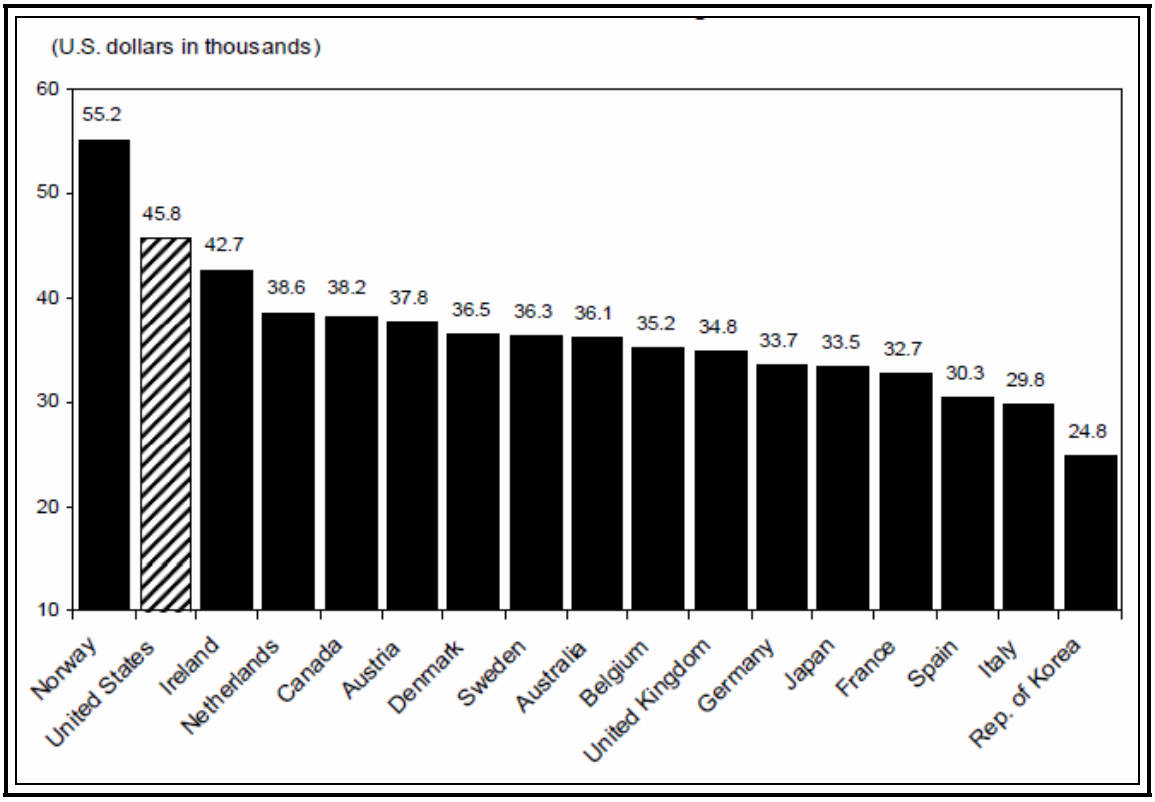
Source: Euromonitor's Global Market Information Database, 2005 (www.portal.euromonitor.com)

It is necessary to emphasize that fixed telephone services penetration is significantly varied between urban and rural areas: in metropolitan areas and large cities from 76% to 87%

of households are equipped with fixed telephone services, while in smaller cities and rural areas only 38-44% of households are equipped with fixed telephone services[19].

The average per capita telecommunications services usage index in the country is not the highest and totals in $105 US dollars annually. For comparison in Russia this index is 250 US dollars in average per capita. One of the main factors defining the development of telecommunications sector is low index of GDP per capita. In 2007 the level of GDP per capita in Kazakhstan amounted to 11,100 US dollars[20], which is several times lower than in some developed countries.

Figure 2 GDP per capita, 2007[21]



Source: U.S. Department of Labor, Bureau of Labor Statistic, 2007

Thus, in Kazakhstan the presence of computers and their connection to Internet services in households stays considerably low. For instance, only 17 % of households are

equipped with a computer, (2/3 of which are in urban areas). To compare in Czech Republic 29 % of households are equipped with computers, in Hungary 32% and in UK 65%. Among all households in Kazakhstan only 5% are connected to the Internet (in Czech Republic 19%, in Hungary 14%, in UK – 56%). On the whole 35% of households, equipped with computers have connection to the Internet. In Czech Republic this figure is 65%, in Hungary – 44% and in UK 86%[22].

Let us examine the structure of Kazakhstan's telecommunications system according to income from different services.

According to the data from the Statistics Agency of Kazakhstan in 2004 the shares of income from fixed telephones and mobile communication were almost the same – 36% and 37 % respectively. However, in 2007 the largest part of the income from telecommunications services came from mobile telephone services and amounted in 1.62 billion USD, which is a 54 % share of total income[23]. The second largest segment of income is fixed telephone services with 632 million USD or a 21 % share. Internet access and data transfer services forms only 7 % of total income from telecommunications services. As a result of rapid development of new means of communications the share of income from fixed telephone services changes very slightly compared to mobile telephone services and Internet data transfer services. In other words, in later 4-5 years while consumers spent almost the same amount of money on fixed telephone services, their expenses on Internet access and especially mobile communication increased considerably.

Table 3 Income from telecommunications services

million USD

	2001	2002	2003	2004	2005	2006	2007
Total	715.73	789.33	1003.92	1341.25	1789.89	2324.00	2981.76
Intercity and International traffic from fixed telephones	279.71	294.48	350.01	390.11	368.56	424.09	446.49
Local fixed telephone services	164.74	156.40	110.25	122.87	145.31	167.46	190.75
Data transfer services	18.56	33.82	41.39	38.78	26.60	36.83	47.01
Internet access services	27.24	31.13	26.01	52.36	80.51	121.49	184.91
Mobile telephone services	166.88	194.83	301.61	486.37	778.34	1153.04	1621.57
Cable television	30.34	35.87	41.93	55.60	64.02	73.54	92.15
Other services	28.26	42.81	99.51	156.34	298.86	347.56	398.88

Source: The Agency of Statistics of Kazakhstan, Telecommunications (www.stat.kz)

Thus, from the table above we can define the most important three sectors of the telecommunications market of Kazakhstan - fixed communication, mobile communication and Internet & data transfer services. Since data transfer and Internet access are inseparable and develop together we will consider them as one.

1. Fixed telephone services market

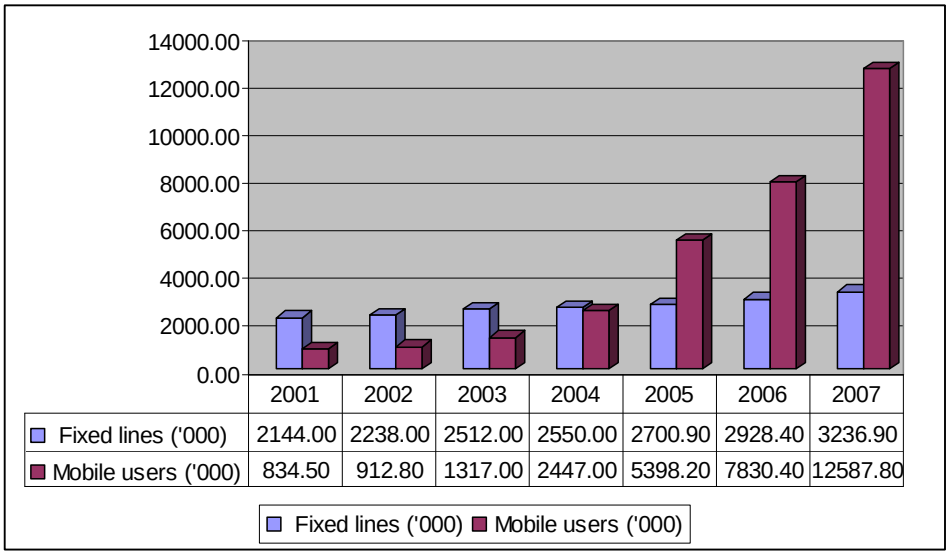
The following segment is presented by local telephone services, intercity, international communication as well as by transmission lines interconnecting mobile operators' networks and outgoing calls to mobile networks. In 2005 the average expense on every single fixed telephone line was 11 USD for individuals and 93 USD for enterprises. The increase in income from 2005 to 2007 is mainly the result of the increase in local services and intercity communication. In the period of 2004-2005 there was no growth in income of international communication services. The growth was expected by the government, as a result of market liberalization and reduction of tariffs on fixed

communication. Although, the international traffic (the number of minutes) increased compared to previous years the income from international calls services in 2005 decreased (table 3).

In order to enter the World Trade Organization (WTO), from 2003-2005 the government carried out measures to rebalance the tariffs of fixed communications services. As a result, under the pressure of the government, the main provider of fixed communications services in Kazakhstan Kazakhtelecom reduced the prices for international calls by 33%[24]. At the same time the tariffs on local services were increased by 20 %. The government expected growth in this market; however, time showed that the international communications services did not provide enough flexibility to cover the losses followed by the tariffs rebalancing. There were some reasons for that: the number of households willing to make international calls is not large. According to the Statistics Agency of Kazakhstan only 22 % of households in Kazakhstan wish to make international calls, where half of the households are already using international call services.

The possibilities for growth in local telephone services are limited as well. By the end of 2007 total number of fixed landlines reached 3.236 million lines (figure 4), where the market capacity (or the maximum possible number of landlines) is 4.7 million telephone lines. Thus, the maximum possible growth is approximately 1.2 million fixed telephone lines.

Figure 4 Growth dynamics of mobile and fixed telephone users



	2001	2002	2003	2004	2005	2006	2007
Fixed lines ('000)	2144.00	2238.00	2512.00	2550.00	2700.90	2928.40	3236.90
Mobile users ('000)	834.50	912.80	1317.00	2447.00	5398.20	7830.40	12587.80

Source: The Agency of Statistics of Kazakhstan (www.stat.kz)

There is no doubt, despite the reforms of 2003-2005 carried out by the government of Kazakhstan to demonopolize the market; there is still one central and powerful operator. The main provider of fixed local communication services in Kazakhstan remains Kazakhtelecom whose share among all provided telecommunications services is 48% (mobile, internet and fixed), and 96 % of all fixed communication. The most important improvement of the reform is that Kazakhtelecom is no longer a single operator in provision of international and intercity communication[25]. Today six new operators hold licenses for provision of international and intercity communication: Astel, ARNA, Nursat, TNS Plus, KazTranscom and Transtelecom. The last two are the branches of KazMunaiGaz (KMG) and KazTemirZhol (KTZ). KMG is the largest national oil company and KazTransCom mainly provides telecommunications services for KMG and in some regions for individuals. Transtelecom provides telecommunications services only for KTZ, which is the national railway transportation

company. Since both KazMunaiGaz and KazTemirZhol are owned by the government, the KazTransCom and Transtelecom are also indirectly owned by the government.

Legally the reform gave the opportunity for new operators to provide these services; however, they do not have enough resources for equal competition.

The main issue is that none of these new companies have a network as broadly developed as Kazakhtelecom's. All of them do not have many options: either to build their own network, which is completely unattractive due to significant expenses, or to rent channels from Kazakhtelecom. In its terms Kazakhtelecom resists in order not to lose its international traffic. The main customers of Kazakhtelecom's competitors are corporate enterprises, since new operators have high borders for entrance in the market for mass usage. As a result, all new operators in any event depend on Kazakhtelecom. In the view of developed countries there is a lack of competition in this market.

None of the new operators have made any attempts to provide services for rural areas, due to economical unprofitableness and yet 40% of country's population lives in the rural areas. Telecommunication services in rural areas are provided only by the national operator Kazakhtelecom. In 2007 Kazakhtelecom supplied with telephone access all of the settlements in the country exceeding 50 people[26].

Recently, the regulatory body, Agency for Informatization and Communication (AIC) has promoted a proposal to separate Kazakhtelecom on the basis of its functionality[27].

Table 4 Communication facilities and services

	2001	2002	2003	2004	2005	2006	2007
Intercity, International outgoing traffic (million min.)	1187.90	1380.50	1724.80	1925.60	2286.40	2602.80	3025.90
Fixed telephone lines ('000)	2144.00	2238.00	2512.00	2550.00	2700.90	2928.40	3236.90
Fixed telephone lines used by individuals ('000)	1758.00	1901.00	2083.00	2150.00	2330.20	2495.10	2757.30
Mobile telephone users ('000)	834.50	912.80	1317.00	2447.00	5398.20	7830.40	12587.80
Mobile telephone users (%)	5.61	6.14	8.83	16.30	35.64	50.82	81.29
Internet Users ('000)	91.70	133.70	185.00	203.00	301.60	310.80	381.20
Internet Users (%)	0.62	0.90	1.24	1.35	1.99	2.02	2.46

Source: The Agency of Statistics of Kazakhstan, Telecommunications (www.stat.kz)

i. Voice over Internet Protocol (VoIP) in Kazakhstan

A reasonable alternative for high tariffs of national operator on international and intercity calls became calls by means of VoIP technology. Numerous companies provide IP-telephony services. Despite the significant cheapness of VoIP compared to tariffs of fixed operators, the service is not widely used. Only 14 % of all international calls are made by VoIP technology[28]. While sometimes poor voice quality could be a reason for not choosing VoIP, another possible reason could be inconvenience caused by the dialing process: access number + pin number + destination number (up to 22 digits).

The usage of IP-telephony for international calls was one of the main advantages, which allowed the new mobile operator Neo (working on Global System for Mobile (GSM) standard) to enter the most competitive market in the country - mobile communications. Neo created a pricing policy of 0.26 USD per minute to any part of the world allowing a competitive business model (see table 5). The dialing process is also easier compared to VoIP cards, users need to dial only the destination number.

Table 5 Comparison of tariffs on 1 min international calls to Germany

Operator	USD/min
Kazakhtelecom (Fixed)	0.82
Ducat (fixed)	1.37
NEO (mobile GSM)	0.26
Kcell (mobile GSM)	1.11
Dalacom (mobile CDMA)	0.83
KazTranscom (fixed)	N/A
VoIP	
NetCard (Ducat)	0.31
Call Card	0.25
i-Card	0.28
Tarlan (Kazakhtelecom)	0.23

Although, fixed communication has slower penetration and overall limited market capacity (as previously mentioned only 1.2 million telephone lines for possible growth) for the majority of the time it is the preferable choice due to unlimited talking time with a comparably lower monthly price. None of today's mobile operators provides the same voice quality as can be provided by fixed telephone lines. On the other hand, the emergence of operators providing services of international call exchanges reduces the profit of traditional fixed operators. In several countries more and more people make their choices in favor of mobile phones. For instance, according to the survey carried out by the US Center of Health Statistics in 2007, among 13, 000 respondents, 16% of households are not equipped with fixed telephones and another 13% have a telephone but rarely use it. Thus, almost 29% of households have no need in fixed telephone. Currently, the situation in Kazakhstan is slightly similar since the number of mobile users is as twice as the number of fixed telephones.

2. Mobile communication services market

This sector of communication is generally presented by cellular communication, which in 2007 formed 97 % of the whole mobile communication market. The sector of

mobile communications is the most dynamically developing sector of telecommunications market of Kazakhstan.

In 2007 the income from this sector increased by 40 %, and the total number of mobile subscribers has doubled since 2005 resulting in 12.5 million users. According to world practices, there are two critical threshold values in analyzing mobile services penetration. After reaching 20 % penetration there is a boost in growth of subscriber base. In a short period of time, three to five years, the penetration can reach 50-60%. The second critical period is the 70% threshold. According to the specialists in mobile communication 70% penetration is a saturation point. After passing a 70% penetration threshold the growth in customer base distinctly slows down[20].

According to the Statistics Agency of Kazakhstan the penetration of mobile services in 2007 reached 60-65% in the country, and 82% in rural areas. Thus, this market in large cities is over the satiation point and mobile operators are headed to cover urban areas, highways and railways connecting cities as future growth for subscriber base could be reached through urban area users.

One of the distinctive features of the mobile communication market development in Kazakhstan is that at initial stages the market developed as a monopoly. From 1994 to 1998 the single holder of licenses for mobile communication services was Altel. In 1998 the government of Kazakhstan arranged a legal tender for licenses in provision of mobile operating services. As a result, another two mobile operators GSM-Kazakhstan and Kar-Tel (now Beeline) emerged in February 1999.

Currently there are six operators of mobile communication services. Three of them are operating in GSM standard and another three in Code Division Multiple Access (CDMA)

standard. GSM operators are GSM - Kazakhstan, Beeline and Neo. CDMA operators are Altel, Mobile Telecom Service and Nursat. However, the market is virtually divided by the three players GSM-Kazakhstan, Beeline and Altel. As mentioned earlier, at the end of 2007 the total number of mobile subscribers reached 12.5 million. The largest number of subscribers uses the services of GSM-Kazakhstan, according to official releases they serve 7 million mobile subscribers. The next largest subscriber base is served by Beeline 4.6 million. The third largest operator is Altel with a 0.8 million subscriber base. There is a need to say that both the companies and the Statistics Agency of Kazakhstan count the number of registered Subscriber Identity Modules (SIM-Cards). In Kazakhstan most of the operators do not have terms for service contract with locked telephone, thus, users can have as many SIM-Cards as they want. In most cases users are billed as they make calls with no monthly fee. It is believed that up to 7-10 % of users have two or three mobile telephones and additional telephones can be either active or not. As a result the number of actual active mobile subscribers is approximately 10% less than the official figures.

According to the research results of ICT-Marketing agency, from the period of 2005-2007 there was a tendency for traffic flow from fixed networks to mobile networks. It can be represented by the growth of income shares in this sector, in 2005 the income increased by 35 % and by 48% in 2006. In 2007 the growth rate slowed down with 38%, which to a certain extent can be explained by market saturation and decrease in SIM-Cards sales.

In order to better understand this market it would be useful to represent some consumer characteristics of the market in Kazakhstan. The three most frequent services used in mobile communications are: outgoing calls within the network; outgoing calls to the network of other mobile operators; and outgoing calls to fixed telephones within the same

city as the caller. According to the results of the survey by ICT-Marketing mobile subscribers rarely make international calls and calls to fixed telephones in other regions of Kazakhstan; although, the tariffs on outgoing calls to the fixed telephone in other regions of Kazakhstan is the same as the calls within the same region as the caller. There are no fees on incoming calls for mobile subscribers in Kazakhstan. Among additional services, the leader is Short Message Service (SMS). According to the survey, 64% of adult respondents use text message services, and only 3% of adult respondents use Multimedia Message Services (MMS). The number of Internet content users is considerably smaller than the number of users of traditional voice services. Main services used in this area are downloads of ringtones and media graphics.

Even though, the mobile market in Kazakhstan is considered as the most competitive, traditional fixed operator Kazakhtelecom has influence in this market as well. The board of directors of Kazakhtelecom is also the major shareholder of the three mobile operators: GSM Kazakhstan with 49% shares; Altel with 50% shares; and Neo with 100% shares. The strongest competitor is Beeline, which is the brand of Vympelcom, one of the largest mobile operators in the Russian Federation.

3. Internet and data communication market

This segment of the telecommunications market is among the three most dynamically developing. The growth of income in this market in 2006 was 50 %, and 52 % in 2007. In 2006 the Internet penetration was 6% among households and 59 % among enterprises and businesses. Despite the small share of Internet income (7%) from total income this market is considered as the most perspective. According to the Statistics Agency of Kazakhstan the

number of actual Internet users is approximately 270 thousands, and the estimated market capacity (the maximum number of Internet users) is 1.6 million users. The development of the Internet services market in Kazakhstan is restrained by lack of Internet content development, high Internet tariffs and high computer prices, which are not affordable for a considerable number of the population.

Currently, there are five primary Internet providers, who have their own access to the global network, thus, they are independent from the other Internet providers: Kazakhtelecom, Nursat, Ducat, GoldenTelecom, and Astel. The largest provider of Internet services is the national company Kazakhtelecom, whose shares in 2006 were 61% from whole Internet services market in Kazakhstan.

The problem of Internet accessibility for the masses is an issue that is given consideration at the national level. In particular, the program of telecommunications sector development for 2006-2008, considers the opportunities for tariffs reduction and increases the Kazakhstan's Internet content attractiveness. Experts in the field say that the development of Kazakhstan's Internet content by the government should urge the content development in the private sector. Electronic Government (e-government) – the latest Government perspective program (2004-2008) not only will facilitate the work of government structures but also make the population get acquainted with new technologies, thus, improve the internet content attractiveness for users.

i. Electronic government program

In the 1990's governments of many nations faced a necessity to revise the management models which appeared inadequate to modern conditions. With the

development of information technologies the opportunity to organize the work of State institutions in more effective ways primarily regarding the services to population and businesses has appeared. Thus, in the middle of 1990s the concept of "the electronic government" (e-government) was born.

Realization of the e-government should lead to positive changes concerning government's relations with three types of users: citizens, state employees and business representatives. Accordingly, these relations are designated as Government-to-Citizen (G2C), Government-Government (G2G) and Government-Businesses (G2B). Thus, e-government should modernize all levels of management: from interdepartmental interaction to interaction of government and population. By means of information technologies and the Internet it should provide organizations and population with appropriate services[29].

Many countries have developed national programs of transition to an information society, through creating and developing electronic government. Different resources specify four basic development models: Continental; Anglo-American, Asian and Russian models[30].

The continental model is characterized by the presence of non-governmental institutions such as (the European Parliament, Eurocommission, the European court), recommendations of which are obligatory for execution by all countries of the European Union (EU); by the high level of integration of European people and the countries; by a rigid legislation system that regulates information streams circulating in the European information space.

The Anglo-American model is developed in the US, Great Britain and Canada. In the US the model emphasizes creation of an information superbackbone, which provides universal services for the population and provides them with the information concerning

problems of the government. For instance, there is an “Ask the White House” Internet-service that allows for submitting a question to the President’s Administration officials[31]. The interaction is in real time so the visitors of the site have the chance to receive the answer immediately.

The Asian model of e-government is based on a specific style of management, on Asian corporate culture and multilayered system of the government organized by a principle of a hierarchical pyramid. The accent is directed on satisfaction of informational needs of the population through development of electronic communications and formation of unified information space.

The basis for the Russian model is the federal program “Electronic Russia 2002-2010” The basic purposes of the program are directed on increase of the functioning of economy, government and local administration, provision of means for the population to receive necessary services concerning activities in an information society.

According to the Isin Nurlan, the president of Kazakhstan’s IT companies association, the architecture of information infrastructure of the electronic government depends on development of telecommunications in the country. The Experience of the countries that have staked on development of the IT-industry, shows, that realization of such major objectives as construction of electronic government can and should become the catalyst of development of the IT-branch of the country.

Today, we can view only some of the functions of the e-government program of Kazakhstan. The most advanced work of the program is the creation of e-gov (http//e-gov.kz) Internet portal, where information services of “electronic government” are realized. All state authorities have started the work in provision of all information resources provided on

Internet Portal[32]. United Nations Organizations (UN) conducts the rankings of the countries on a level of development of electronic government. “Kazakhstan has progressively improved in each of the three annual surveys. To no surprise then, it has markedly enhanced its overall position and solidified its online presence. Notably, its true national website http://government.kz provides extensive information and useful links”[33]. According to the 2005 ranking the leading positions are after US, then Denmark, Great Britain, Sweden, South Korea, etc. Although, Kazakhstan holds first position among South and Central Asian countries it holds only 65th position of the world rankings.

Table 6 E-Government readiness rankings: South and Central Asia

		Index	Rank in		Rank change
		2005	2005	2004	
1	Kazakhstan	0.4813	65	69	4
2	Kyrgyzstan	0.4417	76	66	-10
3	Maldives	0.4321	77	78	1
4	Uzbekistan	0.4114	79	81	2
5	India	0.4001	87	86	-1
6	Sri Lanka	0.3950	94	96	2
7	Iran (Islamic Republic of)	0.3813	98	115	17
8	Tajikistan	0.3346	117	..	..
9	Nepal	0.3021	126	132	6
10	Bhutan	0.2941	130	165	35
11	Pakistan	0.2836	136	122	-14
12	Bangladesh	0.1762	162	159	-3
13	Afghanistan	0.1490	168	171	3
	Average	0.3448			

Source: United Nations Global E-Government Readiness Report, 2005

ii. Electronic commerce in Kazakhstan

The issue of electronic commerce (e-commerce) in Kazakhstan considerably lags behind the advanced countries. There is no authentic data on the volume of Kazakhstan’s retail Internet-trade market; however it is very likely that the volume of retail Internet-trade

in Kazakhstan is in times less than in neighboring Russia. This has concerns for a smaller share of Internet users and a much smaller quantity of Internet-shops. For example, the total number of Internet shops in Kazakhstan is no more than 50 (in Russia around 4500 Internet shops). For comparison, in 2005 the total volume of income of e-commerce in Russia amounted to 1 billion US dollars, where in US in 172 billion dollars.

In general, the factors that hold up the development of e-commerce in Kazakhstan are similar to those of Russia[34]:

- Small amount of Internet users (favorable conditions for e-commerce in the country starts after overcoming the threshold of 10% internet users from total population)
- Lack of development of Kazakhstani Internet content. Majority of Internet users in Kazakhstan prefer to use pithier Russian web-resources.
- Distrust of Internet users for reliability of communication facilities transferring confidential financial information.
- Low purchasing power of most of the Kazakhstani population, especially in rural regions (37% of families of cities and 42 % of rural regions mark that their income suffices for no more than the purchase of living essentials)
- Imperfection of traditional retail channels (e-commerce introduces progress when these channels are well advanced)
- Relatively low development of electronic payment systems
- Absence of legislation for regulating electronic commerce in Kazakhstan

Thus, in order to develop the electronic commerce market in Kazakhstan the society should overcome many complex issues that concern not only the telecommunications system

and internet technology industry. According to the data of the national internet award agency Award.kz, there are about 50 websites performing electronic commerce services in the country.

C. Wimax Deployment Alternatives in Kazakhstan

In the previous section of this project, the telecommunications system of Kazakhstan was analyzed where some positive and negative aspects were discussed. For the positive, it was mentioned that Kazakhstan and the government looked forward to implementing new technologies in the sector of the telecommunications.

New policies considered to grow this sector are being developed and implemented. On the other hand, there are several negative issues, such as the monopolistic character of the market and lack of development compared to standards and trends of developed countries. In analysis of current fixed operators and internet providers, the data of Statistics Agency of Kazakhstan was used. Accordingly, the telecommunications market was divided into three main sectors based on the income share from the total income of the telecommunications sector. Deeper analysis includes the situation study in the regions, the technologies being used, and the services being provided. The entire analysis was based on currently popular communication services that the Kazakhstan population uses. According to research, the followings assumptions can be considered.

Kazakhstan's fixed communication market is at the stage when growth slows down (68% of households are equipped with fixed telephone lines and on average since 2004 the number of fixed lines have increased for 250-300 thousands annually). The national operator provides the majority of fixed line services. There are several scenarios of Wimax technology application in this field. The most probable scenario is the national operator considers Wimax for fixed Wireless access. It is very unlikely that provided access networks be designated for voice services. In addition, it is clear Wimax is most likely to be implemented in urban areas. Although, Wimax technology could bring great advantages in rural areas, there are several

barriers for Wimax operators to enter rural areas, such as very low demand in broadband services and high costs of network deployment for operators driving to future unprofitableness.

The mobile communications market is the most dynamically developing market in Kazakhstan. The average coverage has reached 65 percent in the country and the number of mobile users has reached the population of the country. Current mobile networks in the country are mainly designated for voice services through CDMA2000 and GSM standards. Cellular service providers can deploy Wimax equipment as an overlay to their current cellular network to offer affordable broadband data services to enterprise customers. For example, after researching and deploying commercial wireless broadband systems, Aircel India, a cellular service provider, has elected Wimax for their network expansion. There are numerous other examples around the world where providers are deploying "Wimax equipment as a complementary technology to cellular and as a means to rolling out broadband services to their subscribers"[35].

Internet and data exchange market has little shares in total income of the telecommunications sector; however, it is considered to have the most promise. The exact number of Internet users in the country is unidentified. According to the estimates of National Statistics Agency, however, there are approximately 250,000 to 300,000 Internet users. Since the total market capacity is estimated as 1.6 million users, this market has promising future growth.

News releases report that there are currently four operators willing to deploy Wimax equipment on their networks for Internet and data exchange. In May 2008, the alternative operator, *Aspan Telecom*, announced the start of commercial operation of the first Wimax

metropolitan area network[36]. They represent their wireless network as a means of overcoming access network and their future perspective transition to mobile Wimax. Aspan Telecom was created by National Innovation Fund (www.nif.kz) with the capital of $655 thousands and currently has three base stations coverage. The other three alternative operators are: *Ducat*; *Black Sea Telecom* (BST), Russian broadband services operator who do not have any network infrastructure in Kazakhstan; and Greenfield operator, *Bitel-Telecom.* All operators consider Wimax deployment for fixed Wireless Access and future transition to Mobile Wimax.

The market analysis and the intentions of the operators in today's situation of Kazakhstan show that service providers are interested in developing Broadband Wireless Access network. Wireless access networks can be deployed faster without any need to dig the ground around customer premises and lay out the cables. In addition, capital expenditures are lower since it is mostly dependent only on installation of base stations or access points. At the same time, single base station can provide enough coverage for a very wide range of customers or businesses. The following section considers some deployment scenarios of Wimax in the access network.

1. Why Choose Wimax

When first emerged, Wimax was implied "the next generation network or Wireless technology connecting you to the Internet at faster speeds and from much longer ranges than current wireless technologies allow"[37]. In a customer's view, the benefits of Wimax are as follows

- It provides additional range of choices from both fixed and wireless broadband operators.
- It provides Digital Subscriber Line services with more portability.
- It provides a lower installation cost at customer premises, causing a rapid decline of fixed broadband prices.
- Wimax-based access does not incur "installation" fees from the incumbent.

From the service provider perspective, the benefits of Wimax include:

- Delivery of high throughput for broadband-based services (VoIP, high-speed Internet and Video).
- Wimax reduces the capital expenditures required for network expansion.
- Wimax provides improved performance and extended range.
- Wimax is an open standard supported by Wimax Forum, which counts for "522 members comprising the majority of operators, component and equipment companies in the communications ecosystem"[38] it helps in facilitation of equipment compatibility and availability[39].

There are different drivers for Wimax adoption that varies from provider to provider. Today, the Wimax Forum members offer numerous scenarios of technology application for a range of companies of different profiles from Greenfield operators to traditional service providers with developed infrastructure. These deployment scenarios are based on crucial

features of Wimax which helped in increase of operability around the world. The followings are some of the Wimax significant features.

i. Range and Coverage

Theoretically under ideal circumstances, Wimax provides connection in a radius of up to 30 miles without line of sight.

> *"The IEEE 802.16 is the air interface for fixed point-to-multipoint Broadband Wireless Access (BWA) standard designed for optimal performance in all types of propagation environments, including line-of-sight (LOS), near LOS and non-line-of-sight (NLOS) environments, and delivers reliable robust performance even in cases where extreme link pathologies have been introduced. The robust Orthogonal Frequency Division Multiplexing (OFDM) waveform supports high spectral efficiency (bits per second per Hertz) over ranges from 2 to 40 kilometers with up to 70 Mbps in a single radio frequency (RF) channel"*[40].

The coverage basically depends on tower height, antenna gain, and transmission power. In real world conditions, the coverage reduces due to interference, typical in urban, high-dense areas. According to the survey among 24 leading Wimax operators around the world, in general operators are satisfied with outdoor coverage, which they provide with the average cell radius of 1-1.5 km (pure outdoor coverage). The small cell radius is explained by the high density of users within the area and limited to the bandwidth capacity within the cell. The number of base stations needed depends on throughput demand, rather than range. Furthermore, the majority (86 percent) of the operators surveyed consider that indoor coverage is also very important because most of their customers connect to Wimax network from indoor locations. For the provision of indoor coverage mentioned, cell radius shrinks to 400-500 meters due to a loss of 15-16 dB for first wall building penetration[41]. As a solution to expanding indoor coverage, operators indicate their readiness to move further than

macrocell topology and focus on deployment of microcells and picocells in urban, high density areas.

ii. Scalability

As the network expands and there is a demand to serve larger amount of users, the cell capacity can be increased because the standard supports flexible radio frequency channel bandwidth and frequency reuse. The spectrum re-allocation through cell splitting and sectorization allows dealing with subscriber growth. The additional tool for the efficient spectrum use and cell deployment is achieved since the standard supports automatic transmit power control and provides measurements for channel quality. The regulations for spectrum allocation are different from country to country, but Wimax supports several channel sizes ranging from 1.25 MHz to 28 MHz with many options in between[31]. This is very handy for operators since there is more chance for better spectrum use. For example, an operator who has the license for 30 MHz of spectrum and pays for each MHz has many options for channel allocation without wasting the spectrum.

iii. Quality of Service

The performance of wireless network is extremely dependant on QoS ensured by radio resource management. Compared to Wi-Fi, which offers poor quality for real-time applications, Wimax presents good QoS setting a priority to the time sensitive traffic such as VoIP or video streaming. 802.16d (or fixed Wimax) standard provides four categories of traffic prioritization required for different types of traffic from VoIP and video to web surfing. Mobile Wimax offers five such categories of prioritization[42].

Table 7 Prioritization of Traffic in Wimax

Service Class	Applications	QOS Specification
Unsolicited Grant Service (UGS)	VoIP	• Jitter tolerance • Maximum latency tolerance • Maximum sustained rate
Real-Time Packet Service (rtPS)	Streaming audio or video	• Traffic priority • Maximum latency tolerance • Maximum reserved rate • Maximum sustained rate
Extended Real Time Packet Service (ERTPS)	VoIP (Voice with activity detection)	• Traffic priority • Maximum latency tolerance • Jitter tolerance • Maximum reserved rate • Maximum sustained rate
Non-Real Time Packet Service (nrtPS)	FTP	• Traffic priority • Maximum reserved rate • Maximum sustained rate
Best Effort	Data transfer, Web surfing etc.	• Traffic priority • Maximum sustained rate

Source: WiMAX Forum and IEEE (www.wimaxforum.org)

In addition, 802.16e introduces Extended Real-Time Polling Service (ERTPS), which allows controlling traffic rates and transmission policies as well as improving latency and jitter[43].

It is necessary to mention that when considering QoS for real-time data, ensure end-to-end QoS for better performance. Thus, all segments of a network (access - IP transport - backhaul) are important. QoS implementation in a single segment may not bring the required performance for real-time applications.

2. Wimax Specifications

In 2001, the Wimax Forum introduced the term, Wimax (Worldwide Interoperability for Microwave Access) to promote the Institute of Electrical Engineers (IEEE) 802.16, a family standard for broadband wireless access systems. Initially, it originated with 802.16a standard, which addressed the Wimax in the spectrum of 10-66 GHz and focused on Line-of-Sight (LOS) applications. In 2004, the IEEE 802.16d (or IEEE 802.16-2004) was published, introducing some improvements to the specifications. It addressed frequencies between 2 to 11 GHz and supported Non-Line-of-Sight applications. In 2004, a few providers implemented Wimax (the 802.16d standard) on their networks. The 802.16d is also referred as a fixed Wimax. In 2005, with the corrections to the fixed Wimax the mobile Wimax or 802.16e standard evolved[44]. The mobile Wimax introduced support for portable, mobile, nomadic and also fixed solutions.

Table 8 Progression of the 802.16 Standard

Reference #	Description
802.16	• Addresses spectrum range of 10 to 66GHz • Requires Line-of-Sight (LOS) • Addresses multipath with OFDM
802.16a	• Added spectrum range 2 to 11 GHz • Incorporated Non-line-of-sight (NLOS) • Enhanced MAC layer capabilities • Improved quality of service (QoS) • Supports both Time Division Duplexing (TDD) and frequency division duplexing (FDD)
802.16c	• Represents updates in the 10 to 66 GHz spectrum range
802.16-2004(d)	• Incorporates 802.16, 802.16a and 802.16c standards • Uses OFDM-256 subcarriers • Up to 75 Mbps at 20 MHz channelization
802.16e	• Adds support for mobile broadband • Scalable OFDMA • Enables high-speed handoffs • Up to 15 Mbps at 5 MHz channelization

Many of the standards purposes are technical; however, standard bodies also pursue economical purposes. The ultimate effect expected from the standards, if broadly accepted, is to reduce costs and speed up expansion of broadband wireless.

i. OFDM, OFDMA, and SOFDMA

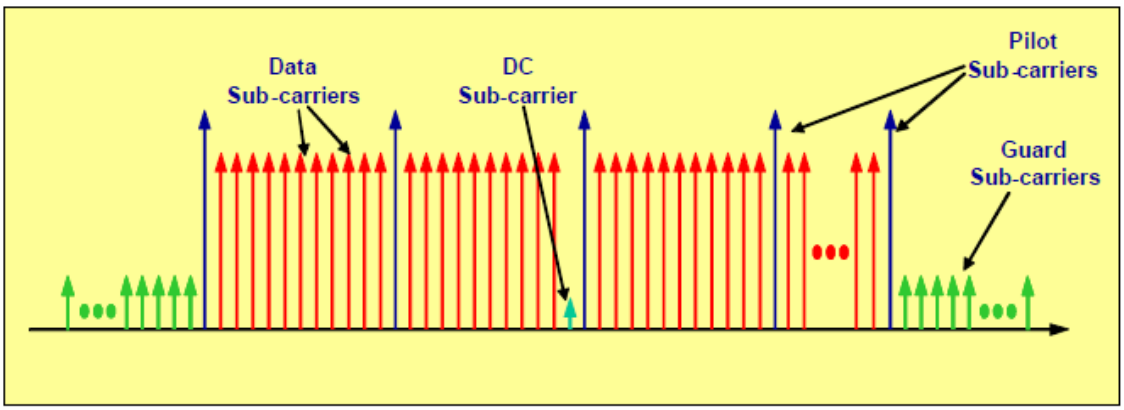
Orthogonal Frequency Division Multiplexing (OFDM) is a digital modulation scheme using multiple orthogonal frequency sub-carriers. Each subcarrier is modulated by a conventional modulation scheme (e.g., quadrature amplitude modulation QAM) with reduced data rates (thus, providing increased symbol duration), keeping the overall data transfer rate the same as in the conventional modulation schemes in the same bandwidth. OFDM signals are obtained by using Fast Fourier Transform (FFT).

The main advantage of OFDM compared to a single carrier scheme is its feature to resist difficult conditions in the channel. For example, without the use of sophisticated filters or equalizers the channel is sustainable to the narrowband interference and frequency-selective damping caused by the multipath propagation. Channel equalization is easier since the OFDM signal can be viewed as a lot of slow modulated narrowband signals, rather than as a fast-modulated broadband signal. Reduced data rate makes it possible to use protective interval between characters, which allows coping with time diversity and eliminating intersymbol interference[45].

Orthogonal Frequency Division Multiplexing Access (OFDMA) is not just about the modulation technique, but also a separation of channels. In OFDMA, there are more carriers than in OFDM: 2048 instead of 256 and the number of sub-channels is sufficient for the organization of the network: in different modes there are from 32 to 70 sub-channels, with 24 or 48 information carriers in each. Not all of the 2048 carriers are used; there are guard bands

on the sides and pilot sub-carriers in between. Based on a channel condition the coding, modulation, and amplitude are set separately in each sub-channel to optimize the use of network resources[46].

Figure 5 OFDMA Sub-Carrier Structure



Courtesy of Wimax Forum, 2006 (www.wimaxforum.org)

Scalable OFDMA (SOFDMA) - the difference between this modulation method and OFDMA is in adaptive change of the width of the radio channel from 1.25 to 20 MHz. This makes it possible to support a large number of simultaneous users, while improving the efficiency of the spectrum use.

ii. "Mobile" or "Fixed" Wimax?

Today both fixed and mobile Wimax coexist because fixed and mobile Wimax deployments have very unlike requirements and target essentially different markets. The distinct demand of the two markets and varying requirements of different applications are the reason for defining two varieties of Wimax.

In a fixed deployment, both the 802.16d and 802.16e present similar performance. For both versions the maximum throughput in a single spectrum is about 15 Mbps for 5 MHz

channel, or 35 Mbps for a 10 MHz channel[36]. Although both are referred as Wimax there is a need to put difference between them.

The multi-carrier modulation technique Scalable Orthogonal Frequency Division Multiplexing Access (SOFDMA) with sub-channeling adds a support for mobile applications and enables handoffs in introduced 802.16e standard. Fixed Wimax (802.16d) uses less complex modulation techniques OFDM and OFDMA. Consequently, due to less complexity, the fixed Wimax base station equipment costs less than that of mobile Wimax[47]. On the other hand, main trends in the telecommunications industry are diverted to broadband mobile market and experts in the field say that the deployment of mobile Wimax is more cost effective by volume and economies of scale. Some say several migration scenarios from fixed to mobile Wimax exist. However, most of the options introduce additional difficulties. In particular, operators would add overlay network for the locations where they want to provide mobile and portable access. Since the spectrum allocation for mobile and fixed Wimax is different from country to country, operators might need to acquire additional licenses for the required spectrum. Furthermore, operators would deploy dual-mode Customer Premises Equipment (CPE) operable in both standards and perform an upgrade of base station software[36]. Additionally, there is a problem of backward compatibility between the standards. For instance, the CPE designated for fixed Wimax cannot operate on mobile Wimax network.

Fixed Wimax (802.16d) standard was first commercially available and operators who deployed their networks basing on the fixed Wimax might have taken share ahead of competitors and migration scenarios could be their best choice to compete in provision of services in broadband mobile market. End-user device manufacturers and hardware vendors,

Motorola and Alcatel-Lucent (also the members of Wimax Forum), suggest the promotion of the 802.16e standard since it has several improvements over 802.16d in addition to mobility, such as backward compatibility and higher performance in capacity, coverage and quality of service[40].

For a provider who has not yet started the deployment of Wimax, probably the best choice is the 802.16e. Mobile Wimax supports both fixed and mobile applications. In addition to handoffs (both soft and hard) required for mobile implementation, it supports power saving modes for extension of battery life of mobile devices. It allows better indoor coverage realized by sub-channelization and the Adaptive Antenna Systems (AAS). Nevertheless, fixed Wimax can find application by a Wireless Internet Service provider intended to provide a wireless access in a rural areas due to less complexity of OFDM based, 802.16d products.

Table 9 Comparison of 802.16d and 802.16e

	802.16-2004 (d)	802.16e
Multiple Access Method	OFDM / OFDMA[1]	S-OFDMA
Bandwidth supported (MHz)	1.75/3/3.5/5.5/7 (OFDM)[1] 1.25/3.5/7/14/28 (OFDMA)	1.25/2.5/5/10/20 1.75/3/3.5/5.5/7
FFT Size	256(OFDM) / 2048 (OFDMA)[1]	128/256/512/1024/2048
Sub-carrier spacing (kHz)	22.5 (OFDM @ 5 MHz)[1] 2.8 (OFDMA @ 5MHz)	11.2 for all BW modes
Duplexing	FDD/TDD/Half Duplex FDD[2]	FDD/TDD/Half Duplex FDD
Frame Duration (ms)	2/2.5/4/5/8/10/12.5/20	2/2.5/4/5/8/10/12.5/20
Channel coder	Concatenated Convolutional RS code, Block TC, CTC[3]	Concatenated Convolutional RS code, Block TC, CTC, LDPC
Sub-channelization (DL)	FUSC/PUSC/Band AMC	FUSC/PUSC/Band AMC
Sub-channelization (UL)	PUSC/Optional PUSC	PUSC/Optional PUSC
Frequency reuse	1 cell reuse not supported	1 cell reuse can be supported
Mobility / Handoff Support	No	Yes
Sleep Modes	No	Yes
Sounding Channel	No	Yes
Multicast / Broadcast Support	No	Yes

Courtesy of Motorola, Inc. (Wimax E vs D)

3. Mobile Wimax Deployment Alternatives

The following section discusses general basics requiring consideration before mobile Wimax network deployment. Based on the coverage requirements, the approach for calculation network capacity is discussed. The performance of the mobile access network depends on a core network element as Base Station. Some of the features of the Base Stations are covered, including antenna configuration, frequency reuse, and channel bandwidth.

i. Metropolitan Area Considerations

There are about twenty five middle sized metropolitan areas in Kazakhstan, where the population ranges from 300,000 to 2 million. Practically, metropolitan areas are composed of compactly populated city center encircled by the areas with the less density of population. For the purposes of this project, I consider a metropolitan area with the population of 500,000 spread on an area of 300 km^2, since this represents the most common middle sized metropolitan area come across in the Kazakhstan. A hypothetical metropolitan area looks similar to that being presented in table 10.

Table 10 Hypothetical Metropolitan Area

Region	Area	Year 1 Population	Population Density
Dense Urban	20 km^2	225,000	11,250/km^2
Urban	40 km^2	140,000	3,500/km^2
Suburban	90 km^2	110,000	1,222/km^2
Rural & Open Space	150 km^2	25,000	166/km^2
Metro Area	**300 km^2**	**500,000**	**1,666/km^2**

For a Wireless operator, the key goal is to provide universal coverage in the entire metropolitan area. This assumes considerations of the building density, terrain, building heights, and anything that may affect propagation of the wireless signal. Additionally, for mobile users, it is necessary to assure robust coverage regardless their location both indoor and outdoor, or even in the movement.

Wimax operators are intended to provide wide range of broadband services supported with good Quality of Service. Thus, to guarantee these services, it is very important to determine capacity requirements at the planning stage of network deployment. The deployment of the network should account future growth of the customer base and the quality the user experiences at the busiest periods. This is remarkable in dense areas since network deployment in these regions is driven by the capacity requirements and not the range.

For determination of user capacity requirements, there is an approach proposed by the Wimax Forum. The metric used for determining the capacity requirements is Mbps per km^2. The calculation of the capacity requirements is a multi-step process, which is described in the following section.

The census data, such as population and population growth, can be obtained for metropolitan areas from authoritative bodies. The addressable market for mobile users is assumed to be anyone in a certain age group. The targeted age group can be different from operator to operator based on the services provided. For ease of calculation during the course of this project, it is considered to be everyone between 15 and 75 years old.

The mature market implies the penetration of 10 to 12 % for the total metropolitan area by the tenth year of operation. Usually, operators provide several service plans according to the needs of some user groups identified by the operator. For calculations of the capacity requirements users will be grouped into the following categories.

- **Professional User:** The individual who usually uses Broadband Access Services for business purposes and for personal use. Key application types are video conferencing, e-mail, VoIP, and file downloads. Most of the time, use stationary access is required, but nomadic and portable access are also required.
- **High-End User:** The individual with high traffic demands primarily for personal rather than business needs. The prevailing applications are gaming, Web browsing, music downloads, etc.
- **Casual User:** Individuals who need active access to the broadband services only a few hours a day basically for web browsing and data oriented services.

Table 11 Calculating the Required Capacity

Step	Description	Comments and Assumptions for Analysis
1	Population Density	500 thousand people over 300 km^2
2	Addressable market	Ages 15 to 75, typically 70 to 75 percent of population
3	Mature market penetration	10-12 % in year 10 (averages to 10.4% over the metro area)
4	Mature customer mix	• 50% Professional User • 35 % High-end user • 15 % Casual user
5	Peak busy hour (PBH) activity	Varies with customer type
6	Effect of mobility and roaming	Must estimate customer distribution during high traffic periods (Peak Busy Hour)
7	Desired performance during PBH	Determined by applications, services level agreement (SLA), QoS.
8	Required data density	A simple calculation

Source: Wimax Forum, 2007 (www.wimaxforum.org)

Another important factor while calculating required capacity is the impact of mobility and roaming in the metropolitan area. This is the most significant where the businesses are located since the traffic in this locations is the most dense. The inflow of the users from suburban and rural areas to these areas could be expected in the morning hours and create additional traffic on a network during the working hours. This inflow might vary from city to city but for our hypothetical example we will consider the increase by 15%, a number typical for many metropolitan areas[48].

The most difficult to determine while calculating capacity requirements is the peak busy hour activity level. The activity of users during the peak busy hour depends on customer mix, application type, etc. However, based on the characteristics of the applications most probably the downlink traffic will dominate the uplink traffic. Thus, in consideration of capacity planning, the downlink traffic is accounted. Additionally, the period of time dedicated to downlink activity versus uplink activity is necessary for estimating the amount of active subscribers on the network. Furthermore, some users are in idle mode, for instance, when reviewing what has just been downloaded, while others idle very little time when using traditional voice services. The Wimax Forum provides some estimated data on the activity of subscribers during PBH, which is provided in Table 12.

The minimal performance level can be defined in the Service level Agreement between end-user and operator. Also, minimal performance during PBH depends on the quality level operators wish to provide to their customers.

Table 12 Estimated Peak Busy Hour Data Rate Requirements

Customer type	**Mature Customer Mix**	**Peak busy hour activity: 1 of "N" active**	**DL duty cycle**	**Minimal per End-user DL rate during PBH**
Professional	50 %	N = 5	25 %	75 kB/sec (600 kbps)
High-end user	35 %	N = 7	25 %	60 kB/sec (480 kbps)
Casual user	15%	N = 20	25 %	30 kB/sec (240 kbps)
Overall customer average over Metro Area		**N = 7.9**	**25 %**	**63 kB/sec (504 kbps)**

Source: Wimax Forum, 2007 (www.wimaxforum.org)

The final downlink capacity requirements for the tenth year of operation results from the combination of PBH assumptions provided in Table 13, customer mobility during PBH and estimated 2% increase per year in activity levels. The total coverage of suburban and rural areas undoubtedly meets the capacity requirements for the region, whereas network deployment of urban areas is performed in phases, adding capacity over time to comply with growing traffic.

Table 13 Metro Area Capacity Requirements

Metro Region	**Number Of Customers**	**Adjustments to Account for Mobility During PBH**	**Downlink Data Density Requirements in 10^{th} Year**
Dense urban	19,300	+ 15%	23 Mbps/km^2 over 20 km^2 area
Urban	12,000	+15%	7.5 Mbps/km^2 Over 40 km^2 area
Suburban	9,400	0	1.8 Mbps/km^2 over 90 km^2 area
Rural & Open Space	2,100	0	0.26 Mbps/km^2 over 150 km^2 area

The required data density calculated in this section is reasonable for this hypothetical metro area, but is not applied without additional reasons to other metropolitan areas. For instance, in cities such as Tokyo or New York, the population density is much higher than in this example and capacity requirements differ significantly too.

ii. Antenna Configuration

Today, a lot of vendors produce Wimax equipment and operators have a lot of options to choose from. All the equipment meets the compatibility and interoperability requirements and it is offered in many different configurations. Wimax equipment is provided with wide variety of features and there is a wide range of spectrum where equipment can operate. The availability of spectrum is the determining factor when considering whether it is necessary to implement frequency reuse or choose appropriate channel bandwidth.

According to the Agency of Kazakhstan for Informatization and Communication, the frequency allocation for Wimax in Kazakhstan is as follows:

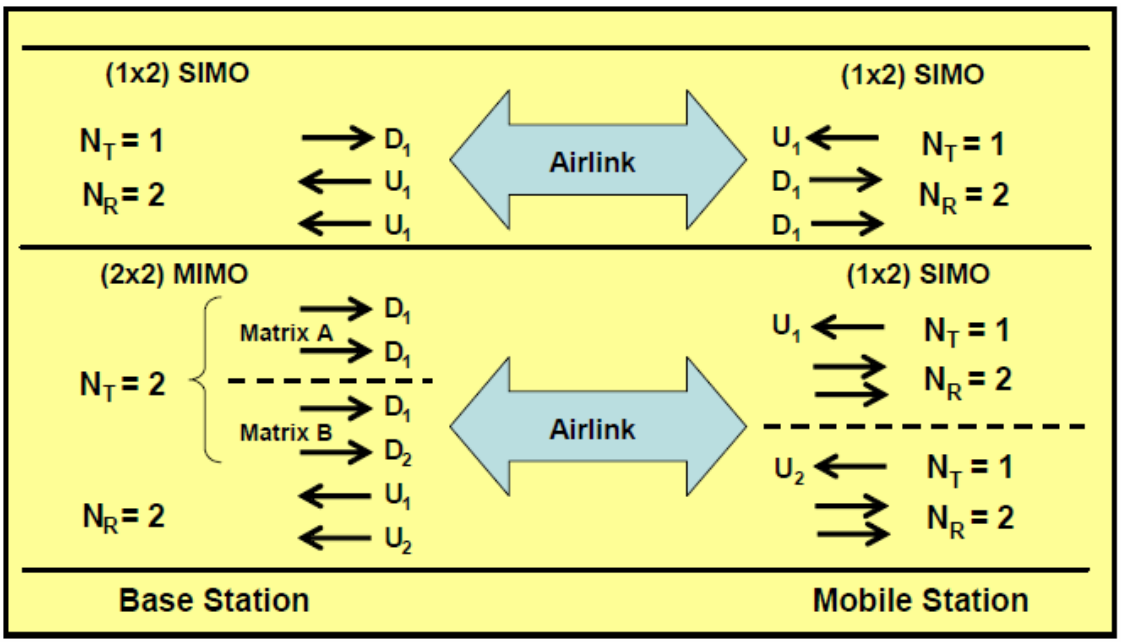
- For fixed Wimax 3.5 GHz and 5 GHz band
- For mobile Wimax 2.5 GHz and 3.5 GHz band

Mobile Wimax technology supports several antenna configurations; namely, Single Input Multiple Output (SIMO), Multiple Input Multiple Output (MIMO), and Smart Antenna technologies to increase system performance. Smart antenna technologies support advanced features such as adaptive Beamforming, Space Time Code (STC) and Spatial Multiplexing (SM), which are concerned with complex matrix and vector operations on signals from multiple antennas[49].

- **Spatial Multiplexing:** allows increment in throughput through transmitting multiple streams over multiple antennas.
- **Space Time Code:** reduces fade margin and allows spatial diversity.
- **Beamforming:** reduces outage probability and improves capacity and coverage of the system.

While these options can be optional for a Base Station, the Mobile Station should support all of these features of Base Stations provided from different vendors to ensure interoperability.

Figure 6 SIMO/MIMO Base Station and Mobile Station Options



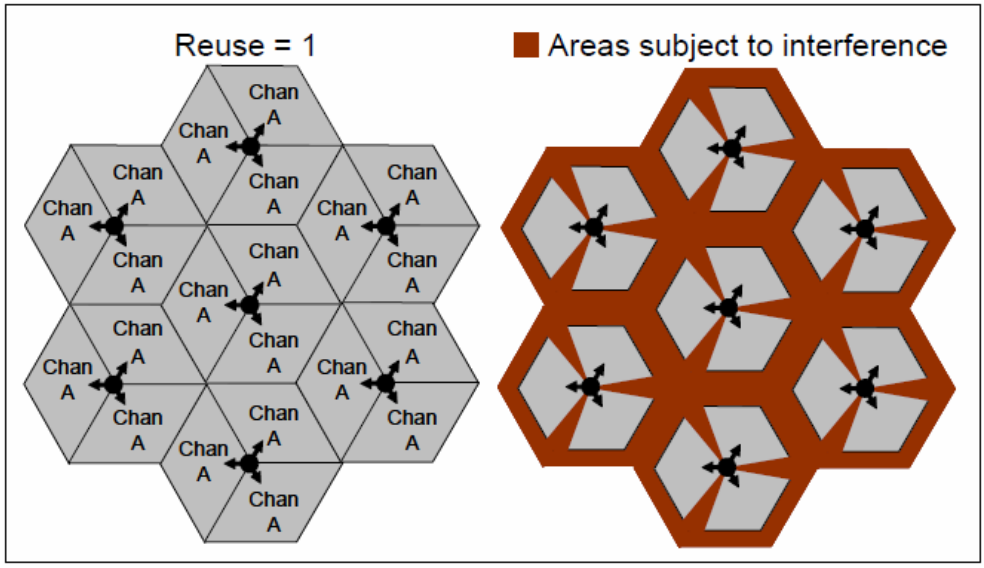
Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

iii. Frequency Reuse

Frequency reuse techniques are used to lessen intercellular and intersectoral co-channel interference (CCI). Traditional cellular systems use different frequency reuse factors depending on the range of available spectrum. Using a frequency reuse factor of 5 requires five times as much spectrum as would be used with reuse factor of 1. Traditionally, cellular networks use two common frequency reuse factors of 3 and 1 (*Comparative analysis*).

In the implementation of frequency reuse factor of 1 (c, 1, 3)[i], (also universal frequency reuse), the same channel is used in all the sectors of the same base station. The advantage of this approach is that it requires least amount of frequency range, and for some operators could be the only implementation alternative due to limited spectrum availability. In traditional cellular networks such as GSM, the usage of the same frequency causes interference at the boundaries of the cell and between sectors. The Wimax technology supports pseudorandom subcarrier permutation scheme with channel segmentation, which allows mitigating the CCI at the cell and sector edges[37]. Since some subcarriers are not utilized fully, implementation with frequency reuse factor of 1 has smaller downlink channel capacity.

Figure 7 Three Sector Base Station with Frequency Reuse Factor Of 1

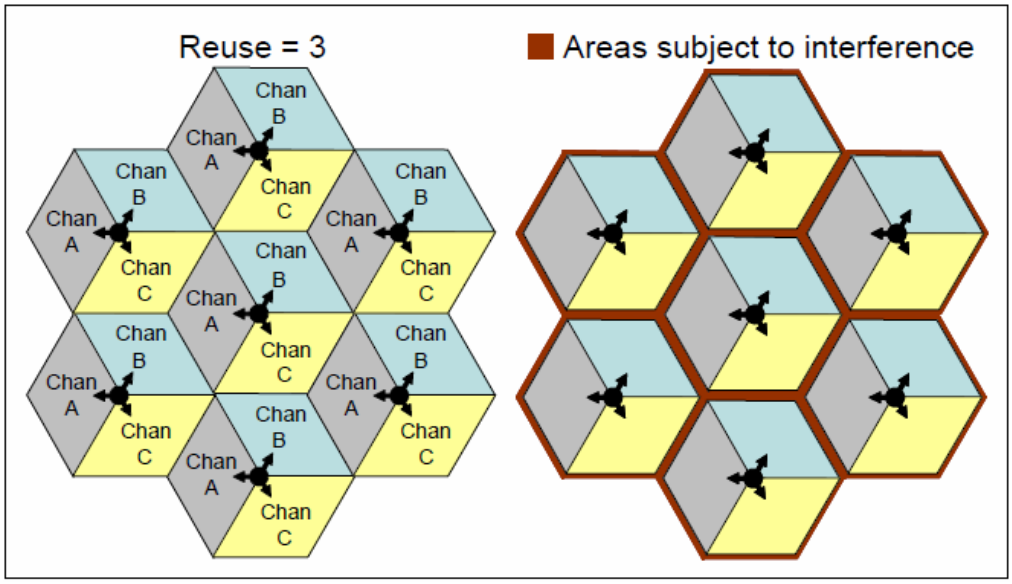


Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

[i] "Nomenclature for describing the frequency reuse pattern is (c, n, s); where c is the number of base station sites in a cluster, n is the number of unique frequency channels required, and s is the number of sectors per base station site" (*Wimax Forum*)

With frequency reuse factor of 3 (c, 3, 3), each sector of a base station is set a different frequency. This alternative requires three times as much spectrum as it is used in implementation of frequency reuse factor of 1. With frequency reuse 3, there is no CCI interference between sectors and significantly less CCI interference between cells due to the enlarged space between channels with the same frequency. There is improved use of subcarriers and better spectrum efficiency. However, when taking into account additional required spectrum, overall spectrum efficiency in a reuse-3 scenario is lower[37].

Figure 8 Three Sector Base Station with Frequency Reuse Factor of 3



Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

iv. Frequency Bands

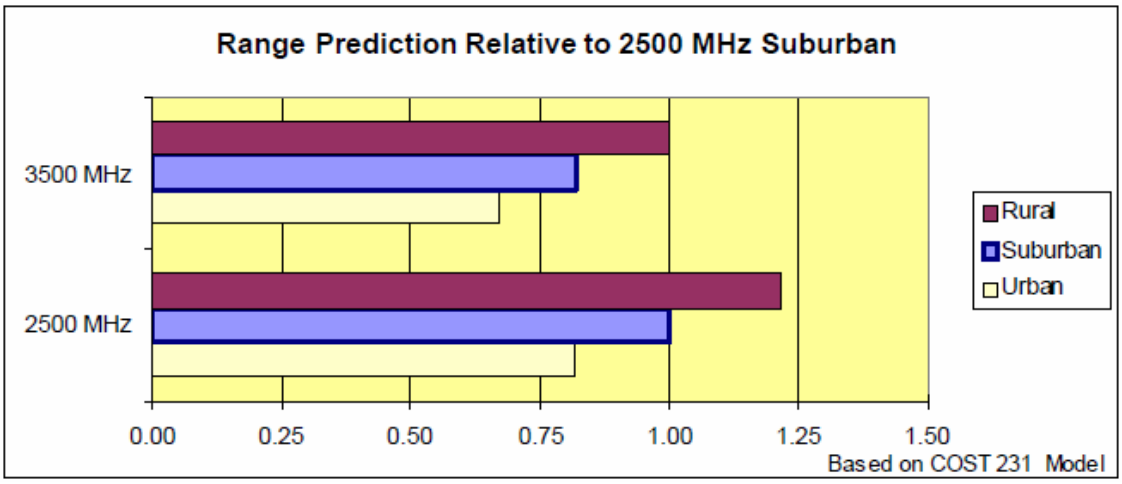
Mobile Wimax profile supports frequency ranges from 2300 MHz to 2690 MHz, and 3300 MHz to 3800 MHz[38]. Both of the frequency bands are available for implementation of

mobile Wimax technology in Kazakhstan. For an operator willing to provide mobile Wimax, it is necessary to view some frequency related considerations.

The decision to choose between either of the frequencies is generally based on the range parameter. It is significant to understand the difference in the “link budget characteristics” between these two frequencies. It is worth mentioning that generally, the range parameter is limited by the uplink signal (from MS to BS). Compared to Base Station, the Mobile Station has limited battery life, which results in a weaker signal power. The antenna size is also small. Portable devices, such as laptops, generally have access to AC power; hence, they have higher transmit power. Thus, the coverage area of a base station is mostly limited to the uplink budget.

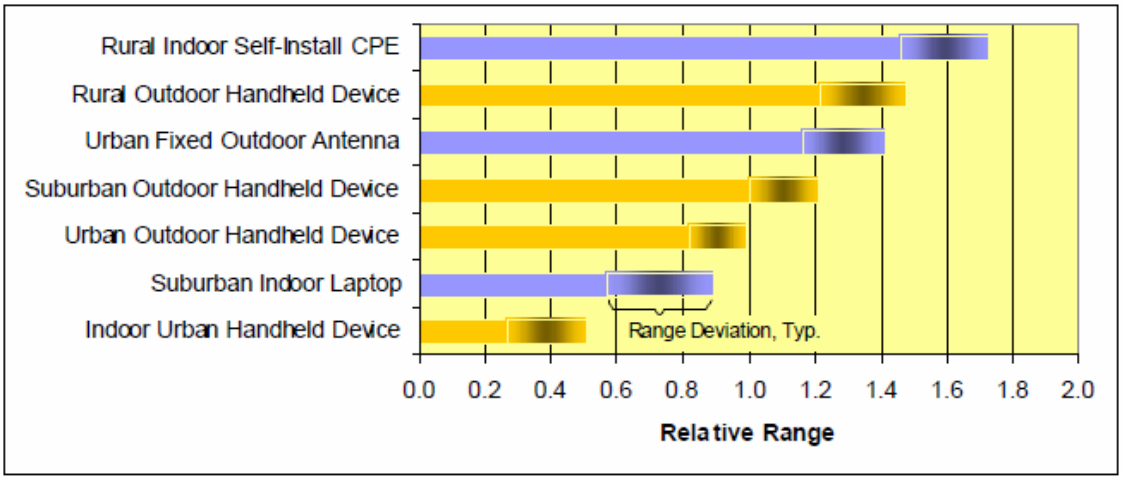
The location of portable users also affects their ability to communicate the network. To provide mobile applications, the network provides a signal strong enough to address users located deeply in buildings or in a movement. Multiple walls penetration loss is also taken into account. Figures 9 and 10 provide some empirical data on range of 2500 MHZ versus 3500 MHz, and range relative to subscriber location. Operators who intend to address fixed applications do with less number of base stations rather than operators with intentions to address mobile applications.

Figure 9 Relative Range, 2500 MHz and 3500 MHz[ii]



Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Figure 10 Range Relative to Subscriber Location



Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

[ii] "The COST 231 model predicts a path loss at both 2500 MHz and 3500 MHz than either the ITU M.2225 Vehicular model or the Standard Pedestrian model. It predicts a a lower path than the M.2225 Pedestrian Model".

v. Channel Bandwidth

The Wimax Forum profile supports the channel bandwidths of 5, 7, 8.75, and 10 MHz. The 802.16e standard supports even more channel bandwidths in between 1.25 and 20 MHz. The key issue in channel consideration is to have larger channel sizes since it provides better system performance. This allows effective frequencies reuse and minimal guard bands resulting in more effective spectrum use. The larger channel sizes allow the more sub-channels and higher throughput.

vi. Comparative Analysis of Different Scenarios

Wimax Forum provides a comparative analysis of different Base Station structure and features implementation in the mobile Wimax access network. The results of this analysis are provided in Appendix A. Base Station number is taken as a unit of measurement. The analysis considers different Base Station deployments with adaptive antenna techniques such as Space Time Coding, Beamforming and Spatial Multiplexing. Further, the comparison in implementing 2500 MHz and 3500 MHz frequency bands is provided.

Conclusion

Third generation (3G) networks allow great opportunities for network operators to provision a wider range of services with improved capacity and more efficient usage of spectrum. Today many operators worldwide provide broadband wireless data services in a mobile environment. Germany and Japan started first 3G networks in 2001 and up to December 2007 there were 190 3G networks worldwide[50]. Users demand for broadband services grows in geometrical progression and many of the 2G operators had implemented migration to 3G. Implementation of a wireless network based on Wimax allows the operator cost effective path towards efficient business model.

Current mobile telecommunications operators in Kazakhstan are categorized as 2G and 2.5G operators and mainly provide voice services. Some mobile operators have undertaken steps for migration to 3G, while others delay transformation claiming the market is not ready yet for the 3G services. However, the analysis provided by the National Statistics Agency shows that from 2006 to 2008, the customer demand for Digital Subscriber Line (DSL) ports surpasses the actual available ports by 150%, 57% and 33% respectively, resulting in 1.2 million households connected to DSL by 2009[51]. Wimax operators experience tough competition from the DSL services provider, the national incumbent operator, *Kazakhtelecom*. There is a continuously growing demand for broadband access services for fixed applications. Currently, in the majority of cases, the national operator meets these needs.

Today, Internet users of Kazakhstan can acquire broadband access services from different providers. Generally, Competitive Local Exchange Carriers (CLEC) provide broadband access services for businesses and enterprises as their tariffs are too high for

individual users. For instance, the tariffs for a 512Mbit/s DSL services of Competitive operators (Ducat, GoldenTelecom) varies from $91 to $108[52]. The most affordable and the most popular broadband access is a DSL service provided by a national operator. A user can connect to DSL service of 512Mbit/s at a price of $49; however the service is not provided everywhere because of technical reasons such as poor “last mile” or archaic switching equipment.

The development of a Wimax is going to take place in a few stages. First, the Wimax operators in Kazakhstan plan to cover urban areas and mainly for fixed data exchange applications. At this stage, to collect robust customer base for profitability, operators must develop the tariff model that is competitive with DSL operators. As soon as demand for mobile broadband wireless services grows, operators increase the network capacity to allow more users. Since operators implement the *mobile* Wimax, the expenses for expansion are not going to be as high as they could be if *fixed* Wimax was deployed. Growth of subscriber base defines the network capacity and base station quantity. Geographical characteristics, low population density, and the absence of user needs in broadband results in the delay of Wimax rollout to rural areas to at least 6-8 years.

Household computer penetration also affects the user requirements in data access services. With predicted 5-7 years of computer market saturation[53], the Internet data access services experience their peak not earlier than this projected period. Currently, users have no or very little demand in mobile wireless broadband services due to poor local content development for mobile and portable devices. Thus, for mobile broadband to be widely used, there are issues to overcome such as content development and user devices availability, which by rough estimates are not to occur earlier than 4-5 years.

The issue of spectrum availability, which is of current importance in many other countries, seems to be insignificant for Kazakhstan since both spectrum bands approved by Wimax Forum (2.5 GHz and 3.5 GHz) are granted licenses for *mobile* Wimax use. The official data regarding which operators granted licenses on which spectrum bands are not available. It is clear acquisition of larger spectrum bands by any of the operators are to bring competitive advantage and are essential for network expansion since it allows more capacity and scalability.

The outcomes provided by the Wimax Forum on comparison of different implementation scenarios shows that advanced antenna techniques can considerably improve the performance of the capacity limited networks with high density and without unreasonable increase of the base station count. Also in the coming years, it is adequate to implement lower complexity base stations configuration with future migration to advanced antenna base station systems as number of customer grows.

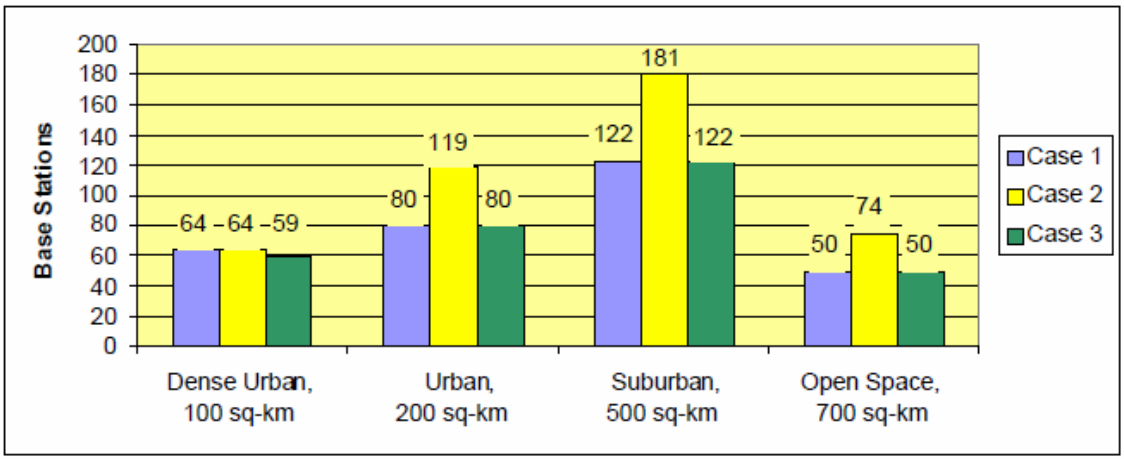
Appendix A

Table A.1 Deployment Options for Frequency Band Comparison

	Case 1	Case 2	Case 3
Frequency Band	2500 MHz	3500 MHz	
BS Antenna Gain	15 dBi	17 dBi	
Available Spectrum	30 MHz		
Channel Bandwidth	10 MHz		
Dense Urban	(2x2) MIMO	(2x2) MIMO	Beamforming
Urban	(1x2) SIMO	(1x2) SIMO	Beamforming
Suburban	(1x2) SIMO	(1x2) SIMO	Beamforming
Rural/Open Space	(1x2) SIMO	(1x2) SIMO	Beamforming
Total BS Required	316	438	311

Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Figure A.1 2500 MHz to 3500 MHz Comparison



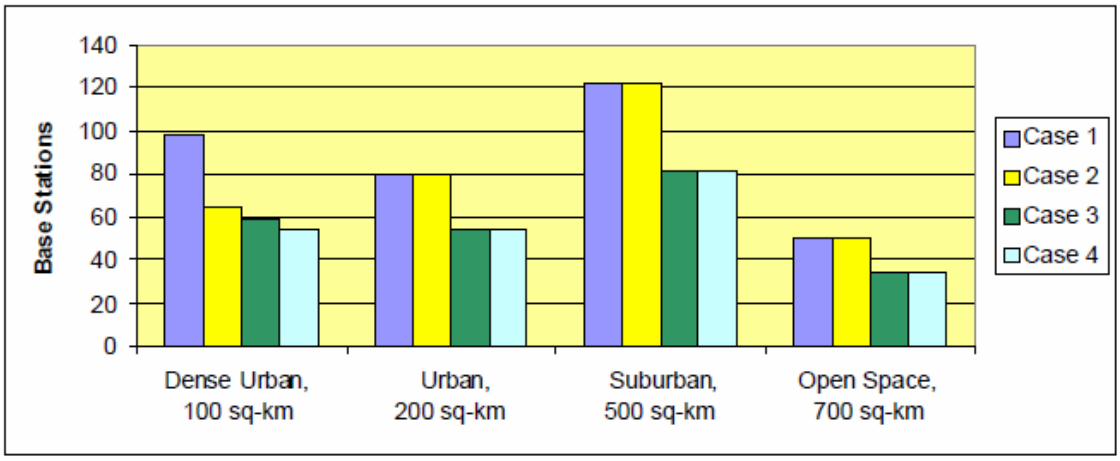
Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Table A.2 Scenarios with Varied BS Antenna Configurations

	Case 1	Case 2	Case 3	Case 4
Frequency Band	2500 MHz			
Available Spectrum	30 MHz			
Channel Bandwidth	10 MHz			
Dense Urban	(1x2) SIMO	(2x2) MIMO	Beamforming	BF + MIMO
Urban	(1x2) SIMO	(1x2) SIMO	Beamforming	Beamforming
Suburban	(1x2) SIMO	(1x2) SIMO	Beamforming	Beamforming
Rural/Open Space	(1x2) SIMO	(1x2) SIMO	Beamforming	Beamforming
Total BS Required	350	316	229	224

Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Figure A.2 Base Station Count for Alternative BS Configurations



Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Table A.3 Channel Bandwidth Comparisons

	Case 1		Case 2		Case 3		Case 4	
Band	2500 MHz							
Base Station	(1x2) SIMO							
Avail. Spectrum	21 MHz				28 MHz		30 MHz	
Channel BW	7 MHz		10 MHz		7 MHz		10 MHz	
	BS	Chan	BS	Chan	BS	Chan	BS	Chan
Dense Urban	140	9	147	6	105	12	98	9
Urban	81	9	85	6	80	12	80	9
Suburban	122	6	122	6	122	6	122	6
Rural/Open Space	50	3	50	3	50	3	50	3
Totals	393	7.3 Avg.	404	5.6 Avg.	357	8.7 Avg.	350	7.1 Avg.

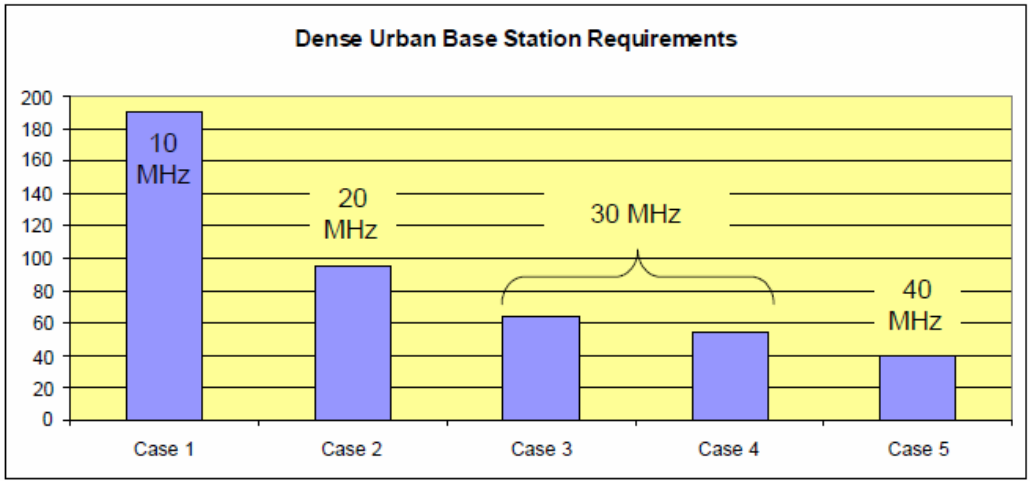
Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Table A.4 Scenarios for Analysis of Spectrum Availability

	Case 1	Case 2	Case 3	Case 4	Case 5
Total Coverage Area	100 km^2				
Req. DL Data Density	20 mbps/ km^2				
Available Spectrum	10 MHz	20 MHz	30 MHz	30 MHz	40 MHz
Channel BW	10 MHz				
BS Antenna	(2x2) MIMO	(2x2) MIMO	(2x2) MIMO	MIMO+ BF	MIMO+ BF
BS to BS Spacing	0.78 km	1.10 km	1.34 km	1.46 km	1.70 km
Area per BS	0.53 km^2	1.05 km^2	1.56 km^2	1.85 km^2	2.50 km^2

Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

Figure A.3 Base Station Requirements for Varied Spectrum Allocations



Courtesy of Wimax Forum, 2007 (www.wimaxforum.org)

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