REGULATION AND COMPETITION ASPECTS OF WiMAX SERVICES IN TURKEY

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ABSTRACT

REGULATION AND COMPETITION ASPECTS OF WiMAX SERVICES IN TURKEY

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In recent years, especially the last decade, Broadband Wireless Access (BWA) Services have been rapidly developed and deployed to the world step by step. Nowadays, this development leads authorities to the field of telecommunication regulation strategies. This thesis study will examine the market share and competition case, test the system performance of WiMAX (Worldwide Interoperability for Microwave Access) services and investigate the required conditions for authorization process in Turkey.

Keywords: WiMAX, regulation, authorization, competition, performance, test, measurement

ÖZ

DÜZENLEME VE REKABET YÖNLERİYLE TÜRKİYE'DE WiMAX HİZMETLERİ

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Son yıllarda, özellikle son on yılda, Genişbant Telsiz Erişim (GTE) Hizmetleri hızlı bir şekilde gelişmiş ve adım adım dünyaya yayılmıştır. Günümüzde, bu gelişme otoritelere telekomünikasyon düzenleme stratejileri alanında öncülük etmektedir. Bu tez çalışmasında; WiMAX (Mikrodalga Erişim için Dünya Çapında Birlikte Çalışabilirlik) hizmetlerinin pazar payı ve rekabet durumu incelenmiş, sistem performans testleri yapılmış ve Türkiye'deki yetkilendirme süreci için gereken koşulların ne olacağı sorusu yanıtlanmaya çalışılmıştır.

Anahtar Kelimeler: WiMAX, düzenleme, yetkilendirme, rekabet, performans, test, ölçüm

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

OVERVIEW OF BROADBAND WIRELESS TECHNOLOGIES

Before delving into broadband wireless, we should review the broadband access over the world today. *Digital subscriber line* (DSL) technology, which delivers broadband over twisted-pair telephone wires, and *cable modem* technology, which delivers over coaxial cable TV plant, are the dominant mass-market broadband access technologies today. Both of these technologies typically provide up to a few megabits per second of data to each user, and continuing advances are making several tens of megabits per second possible. Since their initial deployment in the late 1990s, these services have considerable growth. Turkey has more than 5 million DSL subscribers at the end of year-2008. In Europe, the number of broadband Internet subscribers is 110.5 million by April, 2009.

Broadband access not only provides faster web surfing and quicker file downloads but also enables several multimedia applications, such as real-time audio and video streaming, multimedia conferencing, and interactive gaming. Broadband connections are also being used for voice telephony using voice-over-Internet Protocol (VoIP) technology. More advanced broadband access systems, such as fiber-to-the-home (FTTH) (Figure 1.1) and very high bit rate digital subscriber line (VDSL), enable such applications as entertainment-quality video, including high-definition TV (HDTV) and video on demand (VoD).

As the broadband market continues to grow, several new applications are likely to emerge, and it is difficult to predict which ones will succeed in the future.

Figure 1.1: Türk Telekomünikasyon A.Ş. Fiber-To-The-Home (FTTH) installation

So what is broadband wireless? Broadband wireless is about bringing the broadband experience to a wireless context, which offers users benefits and convenience. The wireless technologies and the broadband connection have their own rapid mass-market today. Many industry observers believe that; combining the convenience of wireless with the performance of broadband will be the next frontier for growth in the industry. Such a combination can be technically and commercially viable. Wireless broadband applications and services take the interest of end-users [1].

1.1. Broadband Wireless Development

The history of broadband wireless is about the desire to find a competitive alternative to traditional wireline technologies. Encouraged by the rapid growth of the Internet, several competitive carriers were motivated to find a wireless solution to bypass incumbent service providers.

Broadband Wireless Technology has developed through four stages:

- Narrowband Wireless Systems
- First-Generation Broadband Systems
- Second-Generation Broadband Systems
- Emergence of 802.16 Standards [1]

1.1.1. Narrowband Wireless Systems

Naturally, the first application for which a wireless alternative was developed was WLL (wireless local loop) voice telephony. These systems were quite successful in developing countries such as China, India, Indonesia, Brazil, and Russia, whose high demand for basic telephone services could not be served using existing infrastructure.

In markets in which strong infrastructure already existed for voice telephony, narrowband systems had to offer additional value to be competitive. Following the commercialization of the Internet in 1993, the demand for Internet-access services began to surge, and many people saw providing high-speed Internet-access as a way for wireless systems to differentiate themselves. For example, in February 1997, AT&T announced that it had developed a wireless access system for the 1900 MHz band that could deliver two voice lines and a 128 Kbps data connection to subscribers. This system, developed under the code name "Project Angel" also had the distinction of being one of the first commercial wireless systems to use adaptive antenna technology. After field trials for a few years and a brief commercial offering, AT&T discontinued the service in December 2001, because of cost run-ups and poor take-rates.

During the same time, several small companies focused on providing Internet-access services using wireless. These wireless Internet service provider (WISP) companies typically deployed systems in the licensed 900 MHz and 2.4 GHz bands. Most of these systems required antennas to be installed at the customer premises, either on rooftops or under the eaves of their buildings. Deployments were limited mostly to select neighborhoods and small towns. These early systems typically offered speeds up to a few hundred kilobits per second [1].

1.1.2. First-Generation Broadband Systems

As DSL and cable modems began to be deployed, wireless systems had to supply much higher speeds to be competitive. Systems began to be developed for higher frequencies, such as the 2.5 GHz and 3.5 GHz bands.

Very high speed systems called LMDS (local multipoint distribution services) supporting up to several hundreds of megabits per second, were also developed in millimeter wave frequency bands, such as the 24 GHz and 39 GHz bands. LMDS based services were targeted at business users and in the late 1990s rapid but short-lived success. Problems obtaining access to rooftops for installing antennas, coupled with its shorter-range capabilities, squashed its growth.

In the late 1990s, one of the more important development of wireless broadband happened and it is called MMDS (multichannel multipoint distribution services) band at 2.5 GHz. The MMDS band was historically used to provide wireless cable broadcast video services, especially in rural areas, where cable TV services were not available. The advent of satellite TV ruined the wireless cable business, and operators were looking for alternative ways to use this spectrum. A few operators began to offer one-way wireless Internet-access service, using telephone line as the return path.

The first generation of the fixed broadband wireless solutions was deployed using towers that served wireless cable subscribers. These towers were typically several hundred meters tall and enabled LOS coverage to distances up to 56 kilometers, using high-power transmitters. First-generation MMDS systems required that subscribers install at their premises outdoor antennas high enough and pointed toward the tower for a clear LOS transmission path. The outdoor antenna and LOS requirements proved to be important difficulties. Since a fairly large area was being served by a single tower, the capacity of these systems was fairly limited [1].

1.1.3. Second-Generation Broadband Systems

Second-generation broadband wireless systems were able to overcome the LOS issue and to provide more capacity. This was done through the use of a cellular architecture and implementation of advanced-signal processing techniques to improve the link and system performance under multipath conditions. Several companies developed advanced solutions that provided significant performance gains over first-generation systems. Most of these new systems could perform well under non-line-of-sight (NLOS) conditions, with customer antennas typically mounted under the eaves or lower. Many of them used techniques *orthogonal frequency division multiplexing* (OFDM) and *code division multiple Access* (CDMA). A few Mbps over cell ranges of a few kilometers had become possible with second generation fixed wireless broadband systems [1].

1.1.4. Emergence of 802.16 Standards

In 1998, the Institute of Electrical and Electronics Engineers (IEEE) formed a group called 802.16 to develop a standard for what was called a *wireless metropolitan area network,* or wireless MAN. Originally, this group focused on developing solutions in the 10 GHz to 66 GHz band, with the primary application being delivering high-speed connections to businesses that could not obtain fiber.

After completing the standard, the group started work on extending and modifying it to work in both licensed and license-exempt frequencies in the 2 GHz to 11 GHz range. This modification, IEEE 802.16a, was completed in 2003, with OFDM (Orthogonal Frequency Division Multiplexing).

Further revisions to 802.16a were made and completed in 2004 and the revised standard, IEEE 802.16-2004 appeared as "Fixed Broadband Wireless". In 2003, the 802.16 group began work on enhancements to the specifications to allow vehicular mobility applications. That revision, 802.16e, was completed in December 2005 and was published formally as IEEE 802.16e-2005 as "Mobile Broadband Wireless" [1].

CHAPTER 2

FOUNDATIONS OF WiMAX

2.1. Fixed WiMAX (IEEE 802.16-2004) and Mobile WiMAX (IEEE 802.16e-2005)

There are two fundamentally different types of broadband wireless services. The first type attempts to provide a set of services similar to that of the traditional fixed-line broadband but using wireless as the medium of transmission. This type, called *fixed wireless broadband,* can be thought of as a competitive alternative to DSL or cable modem. The second type of broadband wireless, called *mobile wireless broadband,* offers the additional functionality of portability, nomadity and mobility. WiMAX technology is designed to accommodate both fixed and mobile broadband applications. Table 2.1 shows the basic fixed and mobile wireless broadband standards and Figure 2.1 shows the worldwide revenue share of Fixed and Mobile WiMAX [1].

Table 2.1: Basic Data on 802.16 Standards

	802.16-2004	**802.16e-2005**
STATUS	Completed June, 2004	Completed December, 2005
FREQUENCY BAND	2 GHz - 11 GHz	2 GHz - 6 GHz
APPLICATION	Fixed LOS, NLOS	Mobile NLOS
MODULATION	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM
DATA RATE	1 Mbps - 75 Mbps	1 Mbps - 75 Mbps

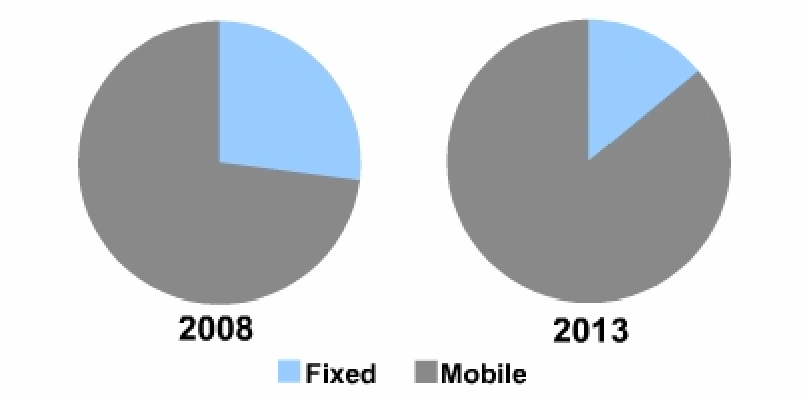

Figure 2.1: Worldwide Revenue Share of Fixed and Mobile WiMAX [14]

2.1.1. Differences of Fixed and Mobile WiMAX

Mobility Management and Hand-over

The simplest explanation for the difference between the fixed and mobile variants of WiMAX boil down to the fact that the mobile variant enables a hand-over from one base station to another as the user, in one session, moves from the coverage zone of one base station to another. This is also known as “mobility management”. To make this happen, vendors must engineer the mobility management technology into their base stations at considerable cost over the fixed WiMAX technology. From a high view, “mobile” means the service functions at 120 km/h while performing competent hand-overs. Service providers should assess what percentage of their subscribers will require that level of service [13].

OFDM vs. OFDMA

Orthogonal Frequency Division Multiplexing (OFDM) breaks the wireless carrier into 256 sub-carriers. Fixed WiMAX uses OFDM. This has two greatest advantages:

a) it reduces inter symbol interference (also known as multipath). It will be mentioned in Part 2.3.

b) improves propagation of the signal, especially in non-line of sight (NLOS) coverage zones.

Orthogonal Frequency Division Multiple Access (OFDMA) breaks the carrier into even more sub carriers (up to 2048 sub carriers). The advantage of this is better propagation and potentially improved building penetration (although other factors such as frequency and power come into play here as well) relative to OFDM. The use of OFDMA should also enable the use of smaller, less costly subscriber devices including PC cards and USB devices. The mobile variant of WiMAX uses OFDMA [13].

Costs

A fixed WiMAX base station might have a street price of $5,000 (depending on volume of purchase) whereas mobile WiMAX base stations start at $50,000. The service provider must weigh cost benefit of the more expensive base station relative to their markets (enterprise E1 substitute, residential "DSL killer", mobile data, etc). A fixed WiMAX subscriber unit is an external device which carries a price tag of about $500. Compare that to mobile WiMAX PC cards that will reportedly retail for $200 [13].

Quality of Service

The fixed variant of WiMAX categorizes traffic. This means traffic such as voice get priority over data. The service provider should weigh this in their infrastructure decision-making as the added category for prioritizing traffic may not prove that valuable in comparison to a fixed environment using external subscriber devices. Data is the first choice for Mobile WiMAX [13].

2.2. Spectrum Options for WiMAX

The availability of frequency spectrum is key to providing broadband wireless services. Several frequency bands can be used for deploying WiMAX. Each band has unique characteristics. The operating frequency band often dictates fundamental bounds on data rates and coverage range.

The 2.3GHz, 2.5GHz, 3.5GHz, and 5.7GHz bands are most likely to see WiMAX deployments. The potential spectrum options for broadband wireless bands shown in Table 2.2.

Table 2.2: Potential Spectrum Options for Broadband Wireless

DESIGNATION	**FREQUENCY ALLOCATION**
Fixed Wireless Access: 3.5GHz	3.4 GHz - 3.6 GHz mostly; 3.3 GHz - 3.4 GHz and 3.6 GHz - 3.8 GHz also available in some countries
Broadband radio services: 2.5GHz	2.495 GHz - 2.690 GHz
Wireless Communications Services: 2.3GHz	2.305 GHz - 2.320 GHz; 2.345 GHz - 2.360 GHz
License exempt: 5GHz	5.250 GHz - 5.350 GHz; 5.725 GHz - 5.825 GHz

Licensed 2.5 GHz: The bands between 2.5 GHz and 2.7 GHz have been allocated in America, and some Asian countries. In many countries, this band is restricted to fixed applications. Among all the available bands, this one offers the most promise for broadband wireless. Regulatory changes may be required in many countries to make this band more available and attractive, particularly for mobile WiMAX [1].

Licensed 2.3 GHz: This band is available in countries such as United States, Australia, South Korea, and New Zealand. In fact, the WiBro services being deployed in South Korea uses this band [1].

Licensed 3.5 GHz: This is the primary band allocated for fixed wireless broadband access in several countries across the globe, with the exception of the United States. Internationally, the allocated band is in the general vicinity of 3.4 GHz to 3.6 GHz, with some newer allocation in 3.3 GHz to 3.4 GHz and 3.6 GHz to 3.8 GHz as well. The available bandwidth varies from country to country, but it is generally around 200 MHz. Spectrum aggregation rules also vary from country to country. In most countries, the current rules in this band do not allow for nomadic and mobile broadband applications. It is hoped that the regulations in this band will, over time, become more flexible [1].

License-exempt 5 GHz: The license-exempt frequency band 5.25 GHz to 5.85 GHz is of interest to WiMAX. This band is generally available worldwide. Being free for anyone to use, this band could enable grassroots deployments of WiMAX, particularly in underserved, low-population-density rural and remote markets [1].

It is possible that WiMAX could be deployed in bands designated for 3G. Particularly in Europe, 3G operators could choose to deploy WiMAX if regulatory relief is obtained. Another interesting possibility is the 1.5 GHz band used by mobile satellite today.

Clearly, WiMAX systems could be deployed in a number of spectrum bands. The challenge is get the allocations and regulations across the globe harmonized in order to gain the advantage of economical scale [1].

2.3. OFDM (Orthogonal Frequency Division Multiplexing)

OFDM is an alternative approach to the design of a bandwidth-efficient communication system in the presence of channel distortion (which causes inter symbol interference). OFDM subdivides the available channel bandwidth into a number of equal-bandwidth subchannels, where the bandwidth of each subchannel is sufficiently narrow so that the frequency response characteristics of the subchannels are nearly ideal, so inter symbol interference is reduced. Such a subdivision of the overall bandwidth into smaller subchannels is illustrated in Figure 2.2. Thus, K=W/Δf subchannels are created, where different information symbols can be transmitted simultaneously in the K subchannels. Consequently, the data is transmitted by frequency-division multiplexing (FDM).

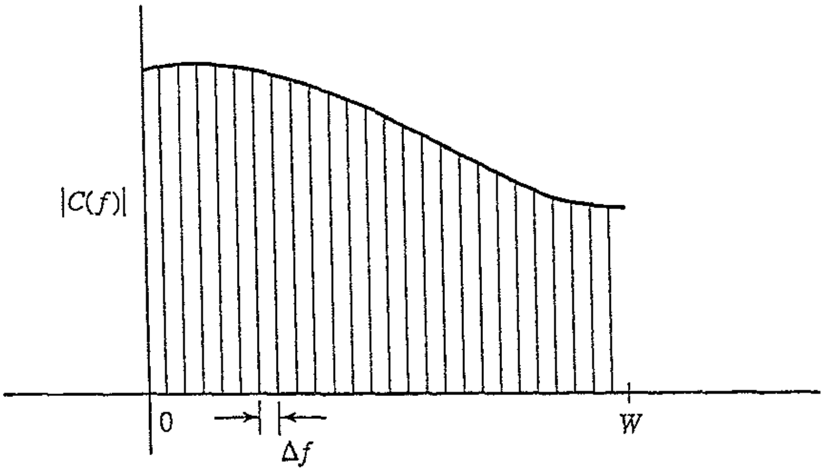

Figure 2.2: Subdivision of the channel bandwidth W into narrowband subchannels of equal width *Δf*.

With each subchannel, a carrier is associated,

$$x_k(t) = \sin 2\pi f_k t, \qquad k = 0, 1, \ldots, K-1 \tag{2.1}$$

where f_k is the mid-frequency in the *k*th subchannel. By selecting the symbol rate *1/T* on each of the subchannels to be equal to the separation of *Δf* of adjacent subcarriers, the subcarriers are orthogonal over the symbol interval *T*, independent of the relative phase relationship between subcarriers; i.e.,

$$\int_0^T \sin(2\pi f_k t + \phi_k)\sin(2\pi f_j t + \phi_j)\, dt = 0 \tag{2.2}$$

where $f_k - f_j = n/T$, $n=1, 2, \ldots$, independent of the values of the phases ϕ_k and ϕ_j. In this case, we have orthogonal frequency-division multiplexing (OFDM) [5].

In OFDM systems, data is transmitted by subcarriers. Subcarriers at different frequencies (Figure 2.3) are converted from parallel to serial and summed to generate the output signal at receiver (Figure 2.4).

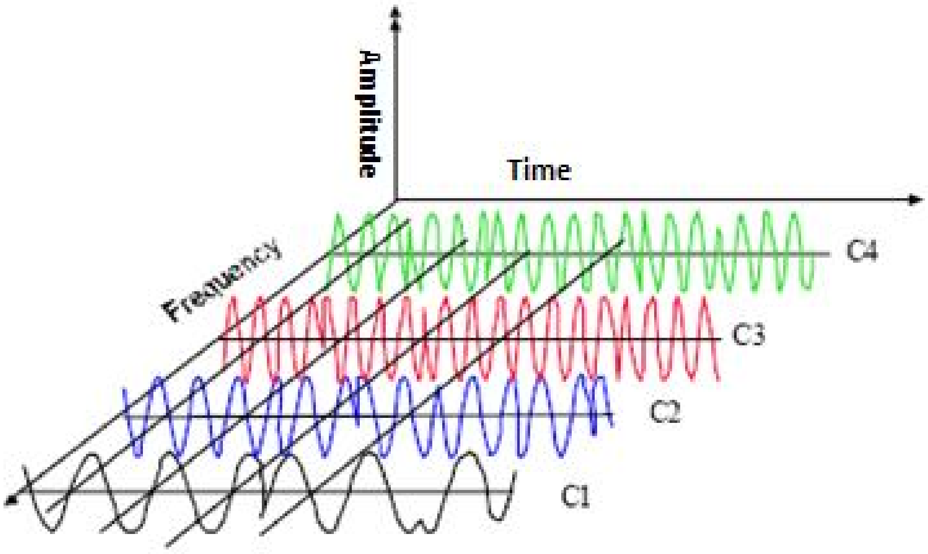

Figure 2.3: 4-subcarrier OFDM

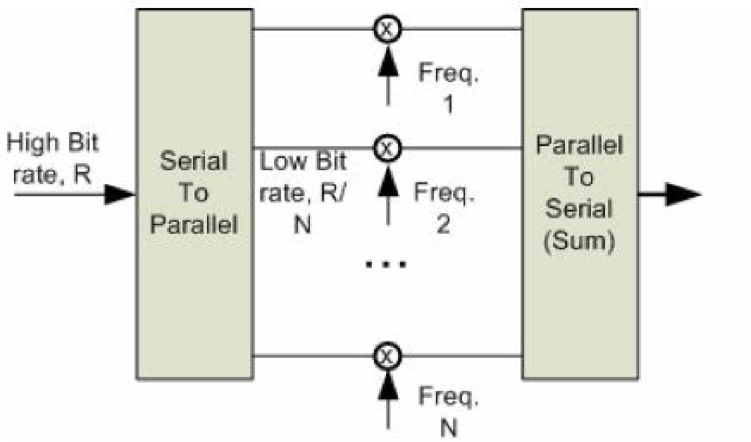

Figure 2.4: Conversion of subcarriers from serial to parallel and vice versa

QAM with different constellation sizes may be used in an OFDM system.

As known, OFDM is a special case of Frequency Division Multiplexing (FDM). For example, an FDM channel is like water flow out of a faucet, in contrast the OFDM signal is like a shower. In a faucet all water comes in one big stream and cannot be sub-divided. OFDM shower is made up a lot of little streams (Figure 2.5).

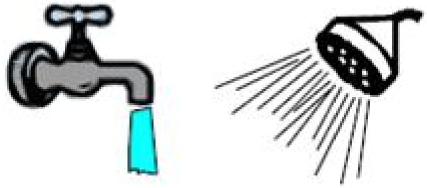

Figure 2.5: A regular FDM and Orthogonal FDM - Example 1

What the advantage might be of one over the other? One obvious one is that if we put our thumb over a faucet hole, we can stop the water flow but we cannot do the same with the shower. So, although both do the same thing, they respond differently to interference.

Another way to see is to use the analogy of making a shipment via a truck. We have two options, one hire a big truck or a bunch of smaller ones. Both methods carry the exact same amount of data. But in case of an accident, only 1/4 of data on the OFDM trucking will suffer (Figure 2.6).

Figure 2.6: A regular FDM and Orthogonal FDM - Example 2: All cargo in one truck versus splitting the shipment into more than one.

These four smaller trucks when seen as signals are called the sub-carriers in an OFDM [12].

Multicarrier OFDM using QAM modulation on each of the subcarriers as described above has been implemented for a variety of applications, including high-speed transmission over telephone lines, such as digital subscriber lines (DSL). This type of multicarrier OFDM modulation has also been called *discrete-multitone (DMT) modulation.* Multicarrier OFDM is also used in digital audio broadcasting in Europe and other parts of the world and in digital cellular communication systems [5].

CHAPTER 3

WiMAX COMPARISONS

WiMAX is not the only solution for delivering broadband wireless services. Several solutions, particularly for fixed applications, are already in the market. There are standards-based alternative solutions that at least partially overlap with WiMAX, particularly for the portable and mobile applications. In the near term, the most significant of these alternatives are third-generation cellular systems and IEEE 802.11-based Wi-Fi systems. Figure 3.1 shows the evolution of MANs (Metropolitan Area Network), Cellular Network, LAN (Local Area Network) and PAN (Personal Area Network) [1].

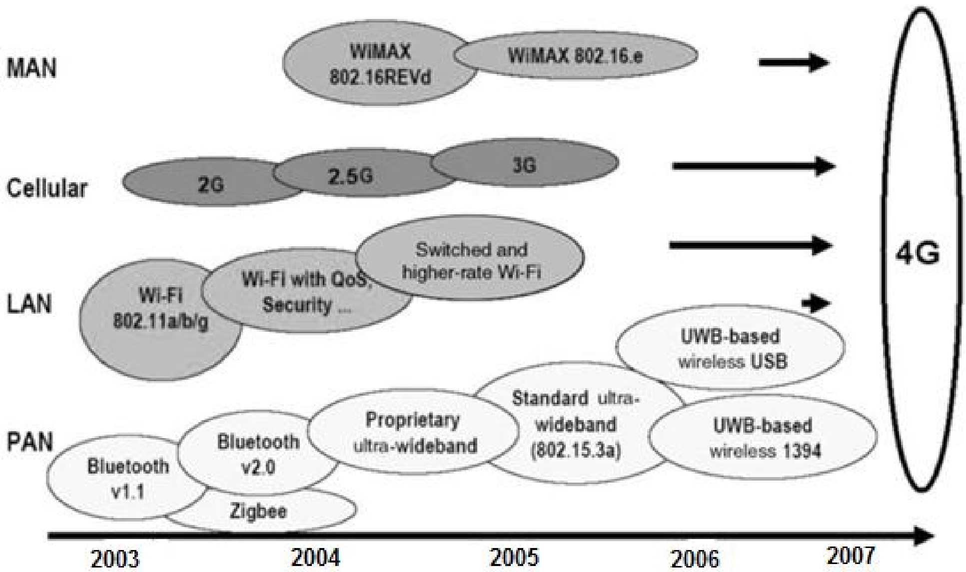

Figure 3.1: Evolution of MAN, Cellular, LAN and PAN [2]

WiMAX, based on the IEEE 802.16 family of standards, is a solution that can offer wireless broadband Internet access to residences and businesses at a relatively low cost. The standard supports shared transfer rates up to 75 Mbps from a single base station, which can offer broadband access without requiring a physical connection from the end-user to a service provider. Service delivery to end clients is likely to be roughly 300 Kbps for residences and 2 Mbps for businesses.

One of the promises of WiMAX is that it could offer the solution to what is sometimes called the 'last-mile' problem, referring to the expense and time of connecting individual homes and offices to trunk lines for communications. WiMAX promises a wireless access range of up to 50 kilometers, compared with 100 meters for Wi-Fi and 15 meters for Bluetooth.

To understand what WiMAX brings to the table we need to understand what additional features it provides over existing technologies. Existing broadband wireless access technologies that are closest to WiMAX with respect to service features are Wi-Fi and third-generation mobile [2].

3.1. 3G Cellular Systems

Around the world, mobile operators are upgrading their networks to 3G technology to deliver broadband applications to their subscribers. Mobile operators using GSM (global system for mobile communications) are deploying UMTS (universal mobile telephone system) and HSDPA (high speed downlink packet access) technologies as part of their 3G evolution.

HSDPA is a downlink-only air interface, capable of providing a peak user data rate of 14.4 Mbps, using a 5 MHz channel.

It should be noted that HSDPA is a downlink-only interface; hence until an uplink complement of this is implemented, the peak data rates achievable on the uplink will be less than 384kbps, in most cases averaging 40 Kbps to 100 Kbps. An uplink version, HSUPA (high-speed uplink packet access), supports peak data rates up to 5.8 Mbps. HSDPA and HSUPA together are referred to as HSPA (high-speed packet access).

1xEV-DO (Evolution Data Optimized) is a high-speed data standard defined as an evolution to 2G systems. Standard supports a peak downlink data rate of 2.4 Mbps in a 1.25 MHz channel. Typical user-experienced data rates are in the order of 100 Kbps to 300 Kbps. It can also support uplink data rates of up to 1.8 Mbps.

In addition to providing high-speed data services, 3G systems are evolving to support multimedia services. 1xEV-DO enables voice and video telephony over IP. Multicast and broadcast services are also supported in 1xEV-DO. Similarly, development efforts are under way to support IP voice, video, and gaming, as well as multicast and broadcast services over UMTS/HSPA networks.

It should also be noted that 3GPP (The 3rd Generation Partnership Project) developed the next major revision to the 3G standards. The objective of this long-term evolution (LTE) is to be able to support a peak data rate of 100 Mbps in the downlink and 50 Mbps in the uplink. In order to achieve these high data rates, the air interface is based on OFDM similar to WiMAX [1].

3.2. Wi-Fi Systems

Wi-Fi has become one of the most popular forms of wireless local area networking, which has high speed. However, the popularity of Wi-Fi has exposed its primary limitation-range. The wireless technology can only serve signals in a ‘hotspot’ with a typical reach of about 300 meters outside or 100 meters indoors.

In addition to 3G, Wi-Fi based-systems may be used to provide broadband wireless. Wi-Fi is based on the IEEE 802.11 family of standards and is primarily a local area networking (LAN) technology designed to provide in-building broadband coverage. Current Wi-Fi systems based on IEEE 802.11 support data rate of 54 Mbps and typically provide indoor coverage over a distance of 100 meters. Wi-Fi has become the great standard for broadband connectivity in homes, offices, and public hotspot locations. In the past couple of years, a number of municipalities and local communities around the world have taken the initiative to get Wi-Fi systems deployed in outdoor settings to provide broadband access to city centers and metrozones as well as to rural and underserved areas. It is this application of Wi-Fi that overlaps with the fixed and nomadic application space of WiMAX.

Metro-area Wi-Fi deployments rely on higher power transmitters that are deployed on lampposts or building tops and radiating at or close to the maximum power limits for operating in the license-exempt band. With high power transmitters, Wi-Fi systems can typically provide a coverage range of only about 1600 meters from the access point. They could be deployed to provide broadband access to hotzones within a city or community. Wi-Fi offers remarkably higher peak data rates than 3G systems, primarily since it operates over a larger 20MHz bandwidth. Further, Wi-Fi systems are not designed to support high speed mobility. One advantage of Wi-Fi over WiMAX and 3G is the wide availability of terminal devices. A vast majority of laptops shipped today have a built-in Wi-Fi interface. Wi-Fi interfaces are now also being built into a variety of devices, including personal data assistants (PDAs), cordless phones, cellular phones, cameras, and media players. The large embedded base of terminals makes it easy for consumers to use the services of broadband networks built using Wi-Fi. As with 3G, the capabilities of Wi-Fi are being enhanced to support even higher data rates and to provide better QoS support [1].

3.3. WiMAX versus 3G and Wi-Fi

How does WiMAX compare with the existing and emerging capabilities of 3G and Wi-Fi? The capabilities of WiMAX depend on the channel bandwidth used. Unlike 3G systems, which have a fixed channel bandwidth, WiMAX defines a selectable channel bandwidth from 1.25 MHz to 20 MHz, which allows for a very flexible deployment. The reliance of WiMAX on OFDM modulation, as opposed to CDMA as in 3G, allows them to support very high peak rates (Table 3.1). The need for spreading makes very high data rates more difficult in CDMA systems.
Another advantage of WiMAX is its ability to efficiently support more symmetric links useful for fixed applications, such as E1 replacement and support for flexible and dynamic adjustment of the downlink-to-uplink data rate ratios. Typically, 3G systems have a fixed asymmetric data rate ratio between downlink and uplink.

What about in terms of supporting advanced IP applications, such as voice, video, and multimedia? How do the technologies compare in terms of traffic and controlling quality? WiMAX is built to support a variety of traffic mixes, including real-time and non-real-time constant bit rate and variable bit rate traffic, prioritized data, and best-effort data. Such 3G solutions as HSDPA and 1xEV-DO were also designed for a variety of QoS levels.

Perhaps the most important advantage for WiMAX may be the potential for lower cost owing to its IP architecture. Using IP architecture simplifies the core network 3G has a complex and separate core network for voice and data and reduces the capital and operating expenses. IP gives WiMAX a performance/price advantage. IP also allows for easier integration with third-party application developers and makes convergence with other networks and applications easier.

In terms of supporting roaming and high-speed vehicular mobility, WiMAX capabilities are somewhat unproven when compared to those of 3G. In 3G, mobility was an integral part of the design; WiMAX was designed as a fixed system, with mobility capabilities developed later.

In summary, WiMAX occupies a somewhat middle ground between Wi-Fi and 3G technologies when compared in the key dimensions of data rate, coverage, QoS, mobility, and price. Table 3.1 provides a summary comparison of WiMAX with 3G and Wi-Fi technologies [1].

Table 3.1: Summary Comparison of WiMAX with 3G and Wi-Fi Technologies

PARAMETER	**FIXED WiMAX**	**MOBILE WiMAX**	**HSPA**	**1x EV-DO**	**Wi-Fi**
Standards	IEEE 802.16-2004	IEEE 802.16e-2005	3GPP	3GPP	IEEE 802.11
Peak downlink data rate	75 Mbps	75 Mbps	14.4 Mbps	3.1 Mbps	54 Mbps
Peak uplink data rate	75 Mbps	75 Mbps	5.8 Mbps	1.8 Mbps	54 Mbps
Bandwidth	Up to 20 MHz	Up to 20 MHz	5 MHz	1.25 MHz	20/40 MHz
Modulation	QPSK 16 QAM 64 QAM	QPSK 16 QAM 64 QAM	QPSK 16 QAM	QPSK 8 PSK 16 QAM	BPSK QPSK 16 QAM 64 QAM
Multiplexing	TDM/OFDM	TDM/OFDMA	TDM/CDMA	TDM/ CDMA	CSMA
Frequency	3.5 GHz and 5.8 GHz	2.3 GHz, 2.5 GHz, and 3.5 GHz	800/900/1,800/ 1,900/2,100 MHz	800/900/ 1,800/ 1,900 MHz	2.4 GHz, 5 GHz
Coverage	50 km	50 km	4 km	4 km	100 m
Mobility	Not Applicable	High	High	High	Low

3.4. Other Comparable Systems

Two other standards based-technology will be seen in the future with some overlap with WiMAX: the IEEE 802.20 and IEEE 802.22 standards under development. The IEEE 802.20 standard is aimed at broadband solutions specifically for vehicular mobility up to 250 km/h speed. This standard is likely to be defined for operation below 3.5 GHz to deliver peak user data rates in excess of 4 Mbps and 1.2 Mbps in the downlink and uplink, respectively. This standards development effort began a few years ago. The IEEE 802.22 standard is aimed specifically at bringing broadband access to rural and remote areas through wireless regional area networks (WRAN). The basic goal of 802.22 can take advantage of unused TV channels that exist in these populated areas. Operating in the VHF (30 MHz to 300 MHz) and low UHF (300 MHZ to 3 GHz) bands provides good propagation conditions that can lead to greater range. IEEE 802.22 is in early stages of development and is expected to provide fixed broadband applications over larger coverage areas with low user densities [1].

3.5. Why WiMAX?

WiMAX can satisfy different access needs. Potential applications include extending broadband capabilities to bring them closer to subscribers, filling gaps in cable, DSL and E1 services, Wi-Fi and cellular backhaul, providing last-100 m access from fiber to the curb and giving service providers another cost-effective option for supporting broadband services (Figure 3.2).

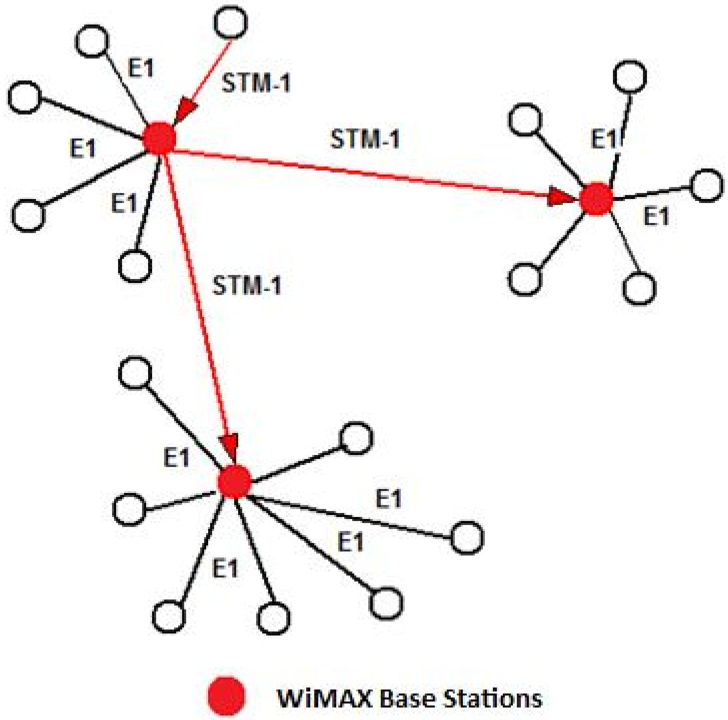

Figure 3.2: Using WiMAX base station as a “hub”

As WiMAX can support very high bandwidth solutions where large spectrum deployments (i.e. >10 MHz) are desired, it can empower existing infrastructure, keeping costs down while delivering the bandwidth needed to support a full range of high-value, multimedia services. Further, WiMAX can help service providers meet many of the challenges they face due to increasing customer demands without discarding their existing infrastructure investments because it has the ability to interoperate across different network types.

WiMAX can provide wide area coverage and quality of service capabilities for applications ranging from real-time delay-sensitive voice-over-IP (VoIP) to real-time streaming video and non-real-time downloads, ensuring that subscribers obtain the performance they expect for all types of communications.

WiMAX, which is an IP-based wireless broadband technology, can be integrated into both wide-area third-generation (3G) mobile and wireless and wireline networks, allowing it to become part of a seamless anytime, anywhere broadband access solution [2].

WiMAX is served as the next step in the evolution of 3G mobile phones, via a potential combination of WiMAX and CDMA standards called 4G.

Despite all the excitement over WiMAX, the ultimate role of WiMAX in the wireless market is uncertain. Large supporters have a vision that WiMAX will change the way we all access the Internet in a matter of years [3].

Users of mobile services projected to grow from 181 million in 2008 to over 2 billion by 2014-a 1024% growth. The number of users accessing mobile broadband through laptops will grow 1022% to 258 million in 2014. Operators worldwide added a combined 1.45 million WiMAX subscribers in 2008. As of December, there were around 3.16 million WiMAX subscribers, up 87% year on year. Nearly 450 operators are deploying or trailing WiMAX, the researchers said. Over 138.000 base stations were deployed in 2008 [6].

3.6. Power Comparisons

Devices using WiMAX technology are in safety standards endorsed by the WHO (World Health Organization) and other health agencies. Those standards take the safety of everyone, including children, into account by providing substantial safety margins. Table 3.2 shows the comparison of WiMAX with other wireless technologies like 2G, 3G and Bluetooth in scope of transmission powers.

Table 3.2: Transmission Power Values of Wireless Equipments

dBm LEVEL	**POWER**	**APPLICATION**
43 dBm	20 W	Typical WiMAX base station transmitter power
43 dBm	20 W	Typical GSM base station transmitter power
23 dBm	200 mW	WiMAX CPEs
33 dBm	2 W	Maximum output from a 3G mobile phone
		Maximum output from a GSM 850/900 mobile phone
30 dBm	1 W	Maximum output from a GSM 1800/1900 mobile phone
21 dBm	125 mW	Maximum output from a 3G mobile phone
20 dBm	100 mW	Bluetooth 100 m
		Typical wireless router transmission power.
15 dBm	32 mW	Typical Wi-Fi transmission power in laptops.
4 dBm	2.5 mW	Bluetooth 10 m range
−10 dBm	100 μW	Typical maximum received signal power (−10 to −30 dBm) of wireless network
−70 dBm	100 pW	Typical range (−60 to −80 dBm) of wireless (802.11) received signal power over a network

To achieve the long ranges it requires, a WiMAX network must have an optimized power profile from the base station to the components in the mobile device. High transmit power is important for long range, but how high can WiMAX go? Designers must find the optimal balance between high transmit power and low power consumption to ensure robust links, high data rates and good range for WiMAX services.

Mobile WiMAX networks will achieve coverage of ~1km per base station, and providers will deploy numerous techniques to achieve this long range, including high transmit power, subchannelization and adaptive modulation.

A typical WiMAX base station transmits at power levels of approximately +43 dBm (20 W), and the mobile station typically transmits at +23 dBm (200 mW). There is a large difference between downlink power and uplink power, so while a mobile can easily receive transmissions from a base station, the mobile's relatively low transmit power makes it difficult for the base station to hear it.

One way to combat this mismatch is with a technique called subchannelization. In effect, each mobile concentrates its power over a subset of all available subchannels, and the other subcarriers are simultaneously made available to other users.

Another technique to address the link imbalance is adaptive modulation. In this case, the mobile transmits using a lower order modulation compared with the base station. For example, the mobile could transmit QPSK or 16 QAM signals, while the base station transmits using 64 QAM. Because the SNR required to receive QPSK or 16 QAM is lower than 64 QAM, using a lower order modulation allows the mobile station to communicate with the base station using less transmit power. The SNR required for QPSK is 5 dB, for instance, compared with 10.5 dB for 16 QAM and 20 dB for 64 QAM modulation. If the mobile station transmits with QPSK, the base station can tolerate 5.5 dB more link loss than with 16 QAM.

When subchannelization and adaptive modulation are combined, a network operator can effectively balance the uplink and downlink budgets, and the network will operate bidirectionally [17].

CHAPTER 4

MARKET ANALYSIS

Although broadband wireless is not an entirely new technology, WiMAX gives the capability needed to drive the deployment. WiMAX holds the promise of delivering broadband services to the underserved markets, which can be a rural landscape in advanced and developed countries.

4.1. Market Dynamics

In emerging markets, operators are interested in using WiMAX for low-cost voice transport and delivery. In developed markets, WiMAX is all about broadband Internet access.

Overall, the markets without any fixed infrastructure stands for the greatest opportunities. WiMAX will become the means of delivering high-speed data. As the difference between fixed and mobile services, a mix of large, fixed and wireless providers will follow WiMAX deployments.

The local and regional wireless ISPs are likely to be gain as large carriers, particularly fixed carriers, turn their attention to rural areas and investments.

The reasons behind wireless deployments are various as the wireless technologies being offered today. Each wireless technology is designed to serve a specific usage segment:

- Personal Area Networks (PAN);
- Local Area Networks (LAN);

- Metropolitan Area Networks (MAN);
- Wide Area Networks (WAN).

The requirements for each usage segment are based on a variety of variables, including:

- bandwidth needs
- distance needs
- power
- user location
- services offered
- network ownership

4.2. Market Types

Nearly 2/3 of the world people are in the underdeveloped world. Most companies are serving at best 1/3 of the world population and competing over satisfied markets. Many companies realize that stepping up their company's presence in developing countries will be important to their long-term competitiveness and success.

For a large number of countries and for a large percentage of the world population, the telecommunication infrastructure is undeveloped;

- low-income economies in the world have an average of 1.97 main lines per 100 people
- the lower-middle-income economies 9.17 main lines per 100 people
- 47 main lines per 100 people in the developed world.

Economic development and growth requires a level of infrastructure which many countries in the world do not have. A certain level of economic advancement and industrial progress is generally required to lighten poor social conditions the modern life. Where some basic infrastructure does exist and certain services do operate, the operation of such infrastructure is sometimes below the level necessary to enable socioeconomic development. So what developed and underdeveloped markets mean?

4.2.1. Developed Markets

The term 'development' is used in an economic sense. The justification being that the economy is itself an index of other social features. A society develops economically as its members increase their capacity for dealing with the environment. Taking a long-term view, it can be said that there has been constant economic development within human society since the origins of man because man has increased his capacity to win a living from nature.

Developed economies have certain characteristics. They are all industrialized. The greater part of their working population is engaged in industry rather than agriculture, and most of their wealth comes out of mines, factories, etc. They have a high output of labour per person in industry because of their advanced technology and skills.

4.2.2. Underdeveloped Markets

Underdevelopment is not absence of development because every population has developed in one way or another and to a greater or lesser extent. Underdevelopment makes sense only as means of comparing levels of development.

The Business Opportunity in Underdevelopeds: Many companies are already targeting new customers and suppliers. So, they are trying to gain a first-mover advantage. Companies operate in new markets and improve their reputations. It will be a competitive advantage in the countries which have richer and more business opportunities emerge.

The business, not government, develops a nation economically. Governments create the frameworks that encourage that development; but it is the private sector that generates enterprises, creates employment and builds wealth.

Companies will develop new markets for their businesses. Business creates value by:

- increasing revenues
- lowering operational costs
- improving productivity

4.2.3. Answering the Demands

In developing markets, high-speed and low-cost bandwidth, which the developed world has, still does not exist. DSL, fiber, fixed wireless and cable solutions are promising a broadband access, but the impact of these initiatives, including wireless broadband access, is not as well-known as desired.

With the WiMAX standard, these technical limitations will end. WiMAX will help BWA (Broadband Wireless Access) to become more mature, robust solution for a broader customer base. WiMAX is intended to improve BWA capabilities so that it can provide reliable voice, data and video services across wider operating environments.

WiMAX has been billed as an affordable way to bring the high-speed Internet to poorer and rural regions around the world and cover entire countries with seamless high-speed Internet access for viewing video, making phone calls and completing other data-intensive tasks.

4.3. Market Structure

Demographics play a key role in determining the business viability of any telecommunications network. Traditionally, demographic regions are divided into urban, suburban and rural areas.

Urban

Urban areas are considered to be the main market, rightly so, as urban markets provide the majority of business to most telecom operators. Broadband access is widely available; wireless broadband is also available but is costly. The situation varies widely depending upon status of development. Generally cable or DSL are available universally. Other characteristics of an urban market are:

- centrally located;
- high residential population density with more spending power than the national average and the highest spending power in comparison to other markets in the country.
- well spread infrastructure with the highest quality available in the country.
- highest density of business establishments and the centre of the majority of business activities.

Suburban

Suburban areas are considered an add-on to urban markets, as suburban markets are often seen as an extension of cities and are served by the infrastructure available in the city, with little modification by most telecom operators. Broadband access is available but not reliable and lacks quality; cable and DSL are not available universally. Other characteristics of a suburban market are:

- the distance from major metro areas is not very substantial;
- low-to-moderate residential population density with more spending power than the national average, but lower in comparison to the urban population;

- substantial infrastructure in comparison to rural communities but lacks quality and reliability, especially the telecom infrastructure;
- quite a few business establishments but mostly residential.

Rural

Rural areas are considered the final frontier of the telecom universe as rural markets are complex and often mysterious to telecom operators.

Broadband access is not common, if any; cable or only serves rural. Other characteristics of a rural market are:

- the distance from major metro areas is quite substantial;
- low residential population density with substantially lower spending power than the national average and in comparison to the urban population;
- very little or non-existent infrastructure, especially telecom infrastructure, which is at minimal levels.
- little business establishment, agriculture and related activities being the main activities in most rural communities [2].

4.4. Market Supply and Demand Analysis

When market fails to produce a competition or a monopoly exists in telecommunications sector, it will directly affect the subscribers, equipment suppliers etc. The efficient market for competition has a relationship with market supply, market demand, service costs etc. Figure 4.1 shows the market equilibrium for supplier companies and customers.

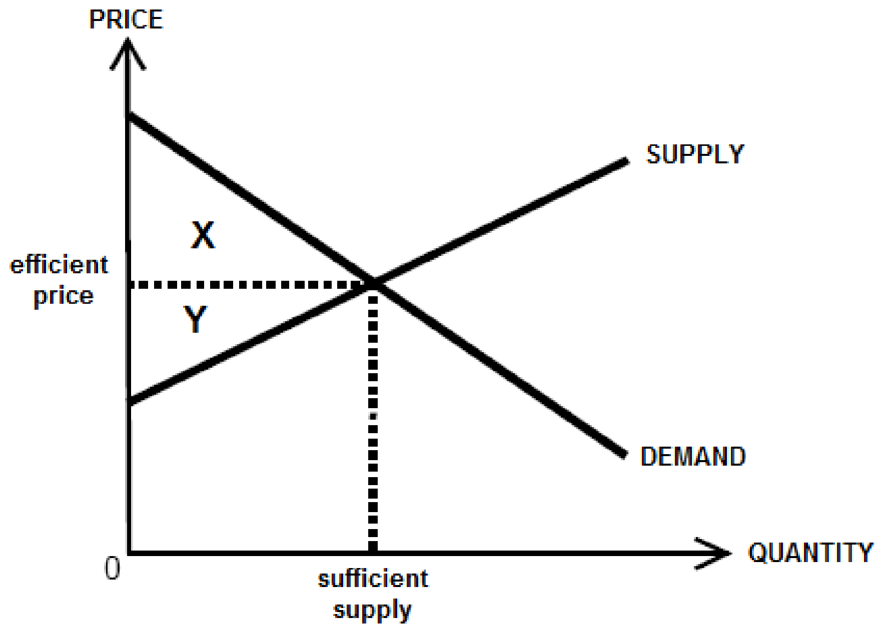

Figure 4.1: Market Supply and Demand (Area X refers to “Consumer Surplus” and Area Y refers to “Supplier Surplus”)

As a result, we can say that, the market has to reach the efficient price level to avoid consumer surplus and has to reach the sufficient supply level to avoid supplier surplus [4].

CHAPTER 5

WiMAX APPLICATIONS AND PRODUCTS

5.1. Applications

The 802.16 standard will help the industry provide solutions across multiple broadband segments. WiMAX was developed to become a last-mile access technology comparable to DSL, cable and E1 technologies. It is a rapidly growing technology that is most viable for backhauling the rapidly increasing volumes of traffic being generated by Wi-Fi hotspots.

WiMAX is billed to support many types of wireless broadband connections including: high-bandwidth MANs, cellular backhaul, clustered Wi-Fi hotspot backhaul, last-mile broadband, cell phone replacements and other applications such as automatic teller machines (ATMs), vehicular data and voice, security applications and wireless VoIP (Figure 5.1).

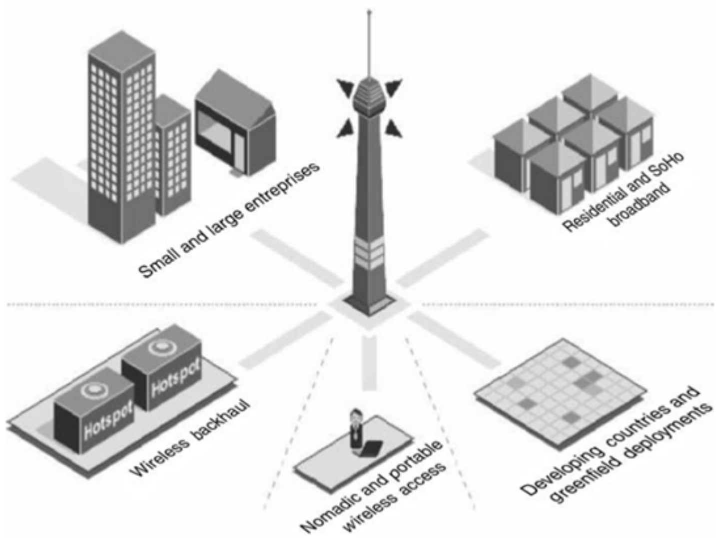

Figure 5.1: WiMAX Applications

WiMAX was developed to provide low-cost, high-quality, flexible, BWA (Broadband Wireless Access) using certified, compatible and interoperable equipments from multiple vendors. As WiMAX is based on interoperability-tested systems that were built using the IEEE 802.16 standard-based solutions, WiMAX will reduce costs. WiMAX is well placed to address challenges associated with traditional wired access deployment types such as:

- *large area coverage access:* covering a large area (also referred to as hot zones) around the base station and providing access to 802.16e clients using point-to-multipoint topology;
- *last-mile access:* connecting residential or business subscribers to the base station using point-to multipoint topology;
- *backhaul:* connecting aggregate subscriber sites to each other and to base stations across long distances using point-to-point topology [2].

5.1.1. MANs (Metropolitan Area Networks)

What makes WiMAX so attractive is its potential to provide broadband wireless access to entire sections of metropolitan areas as well as small and remote locales throughout the world (Figure 5.2).

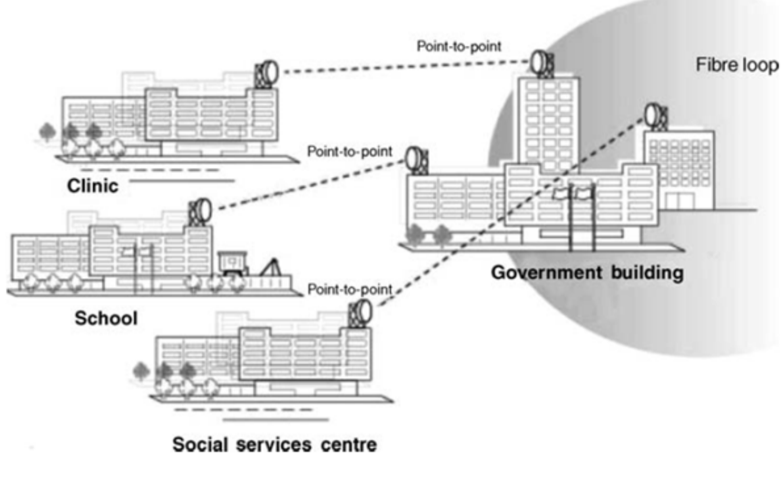

Figure 5.2: Metropolitan Area Networks

Broadband wireless access provides more capacity at lower cost than DSL or cable for extending the fiber networks and supporting multimedia and fast Internet applications in the enterprise or home, but it has been held back by the lack of a standard, so that solutions have been based on proprietary, single-vendor efforts. Standardization through the IEEE 802.16 specification raises the potential to:

- make wireless the key platform of the future by providing more value than wired broadband;
- extend the range of Wi-Fi so that the dream of ubiquitous wireless can become a reality and provide an alternative or complement to 3G;
- provide an economically viable communications infrastructure for developing countries and mobile black spot regions in developed nations.

IEEE 802.16-based networks address the last mile of the communications infrastructure between a service provider's point of presence (POP) and business or residential customer locations.

A wireless MAN based on the WiMAX air interface standard is configured in much the same way as a traditional cellular network with strategically located base stations using a point-to-multipoint architecture to deliver services over a radius up to several kilometers depending on frequency, transmit power and receiver sensitivity. The base stations are typically backhauled to the core network by means of fiber or point-to-point microwave links to available fiber nodes or via leased lines from an incumbent wireline operator (Türk Telekomünikasyon A.Ş. in Turkey) [2].

5.1.2. Last-Mile High Speed Internet Access

DSL operators, who focused their deployments in populated urban and metropolitan areas, are now faced with the challenge to provide broadband services in suburban and rural areas where new markets are quickly taking root (Figure 5.3).

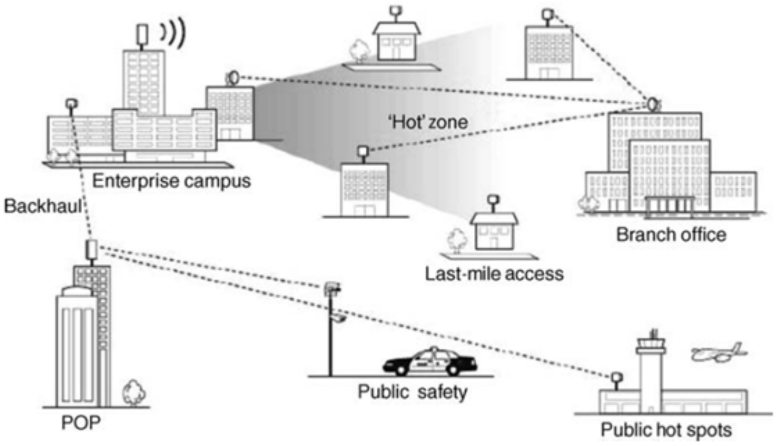

Figure 5.3: Last-mile

The WiMAX technology can also meet the requirements of large and medium-sized enterprises, small and medium-sized businesses, residentials and SoHos (Small Office-Home Offices) (Figure 5.4) [2].

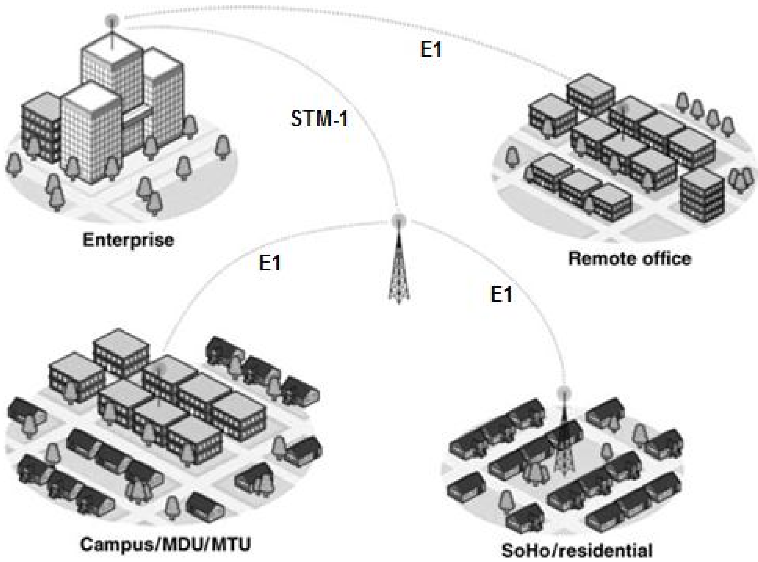

Figure 5.4: Enterprise Connectivity

5.2. Products

CPEs (Customer Premises Equipments)

Figure 5.5: PCMCIA card

Figure 5.6: Indoor Wired CPE

Figure 5.7:
Outdoor NLOS (Non-Line-of-Sight) CPE

Figure 5.8: Indoor Wireless CPE

Figure 5.9: A WiMAX Handset

CHAPTER 6

WiMAX PERFORMANCE TESTS

6.1. Download/Upload Tests Results in 3.4-3.6 GHz Frequency Band and 14 MHz Bandwidth

WiMAX Base Station was mounted on 60 meters lattice tower. There are 4 sector antennas with 90° angle (Figure 6.1).

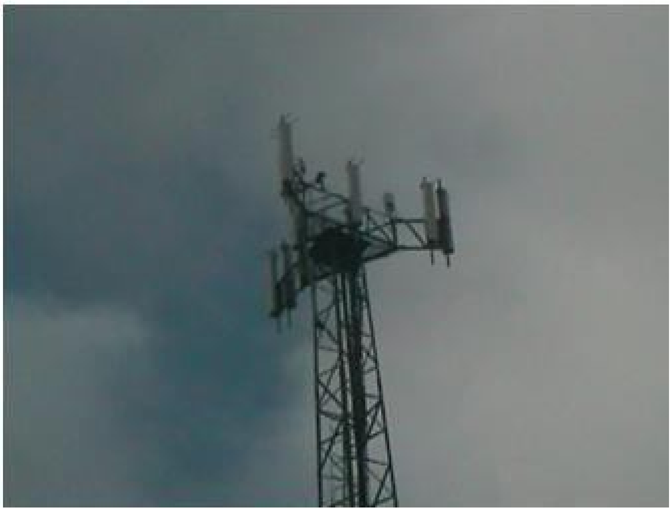

Figure 6.1: Mounted WiMAX Base Station: Base Station had mounted on 60 meters lattice tower.

Transmit Frequency: 3410-3424 MHz
Transmit Bandwidth: 14 MHz
Receive Frequency: 3510-3524 MHz
Receive Bandwidth: 14 MHz

For different LOS (Line of Sight) and NLOS (Non-Line of Sight) locations, Distance/Speed tests for Internet Connection were done. Download and upload speeds were measured in both TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). Also different modulation types were used.

TCP and UDP

TCP is the most commonly used protocol on the Internet. The reason for this is because TCP offers error correction. When the TCP protocol is used there is a "guaranteed delivery." This is due largely in part to a method called "flow control." Flow control determines when data needs to be re-sent, and stops the flow of data until previous packets are successfully transferred. This works because if a packet of data is sent, a collision may occur. When this happens, the client re-requests the packet from the server until the whole packet is complete and is identical to its original. UDP is another commonly used protocol on the Internet. However, UDP is never used to send important data such as web pages, database information, etc; UDP is commonly used for streaming audio and video. Streaming media such as Windows Media audio files (.wma), Real Player (.rm), and others use UDP because it offers speed. The reason UDP is faster than TCP is because there is no form of flow control or error correction. The data sent over the Internet is affected by collisions, and errors will be present. Remember that UDP is only concerned with speed. This is the main reason why streaming media is not high quality [15].

Location 1

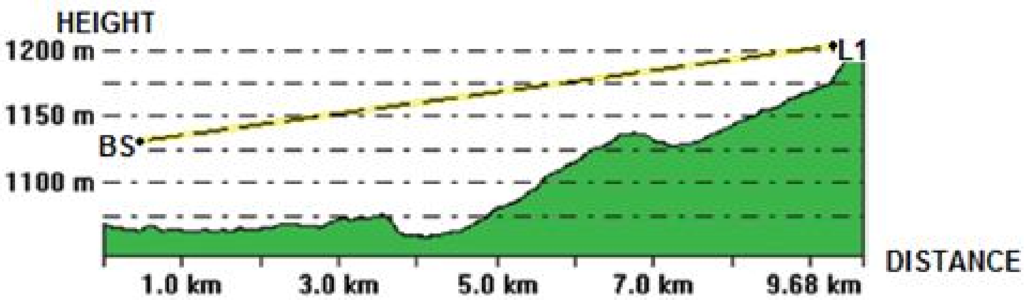

Figure 6.2: Signal path from BS (Base Station) to L1 (Location 1).

Link Status	: LOS
Distance to Base Station	: 9.65 km
Uplink Modulation	: 64 QAM
Downlink Modulation	: 64 QAM
Uplink TCP transfer speed	: 7.64 Mbps
Downlink TCP transfer speed	: 8.13 Mbps
Uplink UDP transfer speed	: 8.30 Mbps
Downlink UDP transfer speed	: 10.0 Mbps

Location 2

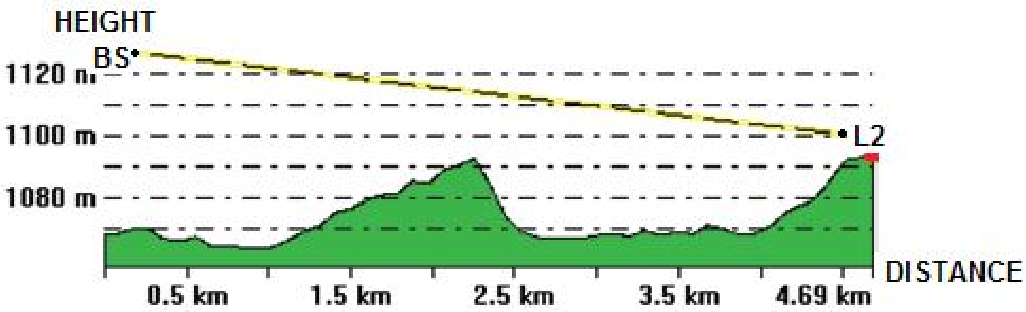

Figure 6.3: Signal path from BS (Base Station) to L2 (Location 2).

Link Status	: LOS
Distance to Base Station	: 4.69 km
Uplink Modulation	: 64 QAM
Downlink Modulation	: 64 QAM
Uplink TCP transfer speed	: 7.71 Mbps
Downlink TCP transfer speed	: 8.0 Mbps
Uplink UDP transfer speed	: 8.29 Mbps
Downlink UDP transfer speed	: 9.87 Mbps

Location 3

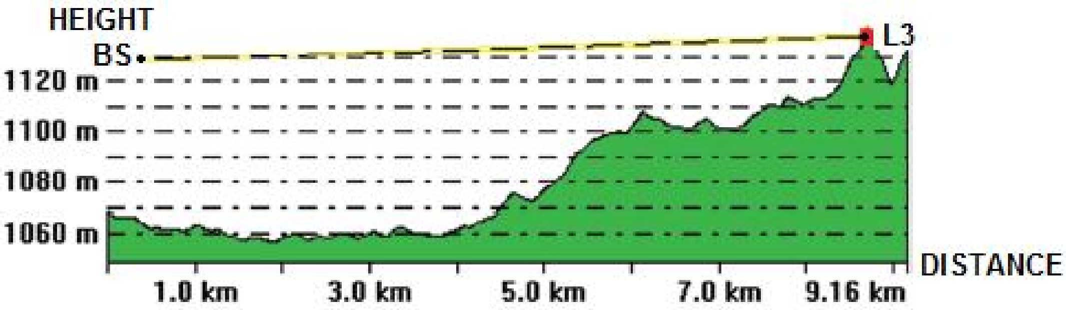

Figure 6.4: Signal path from BS (Base Station) to L3 (Location 3).

Link Status	: LOS
Distance to Base Station	: 9.16 km
Uplink Modulation	: 64 QAM
Downlink Modulation	: 64 QAM
Uplink TCP transfer speed	: 8.22 Mbps
Downlink TCP transfer speed	: 9.15 Mbps
Uplink UDP transfer speed	: 8.54 Mbps
Downlink UDP transfer speed	: 10.3 Mbps

Location 4

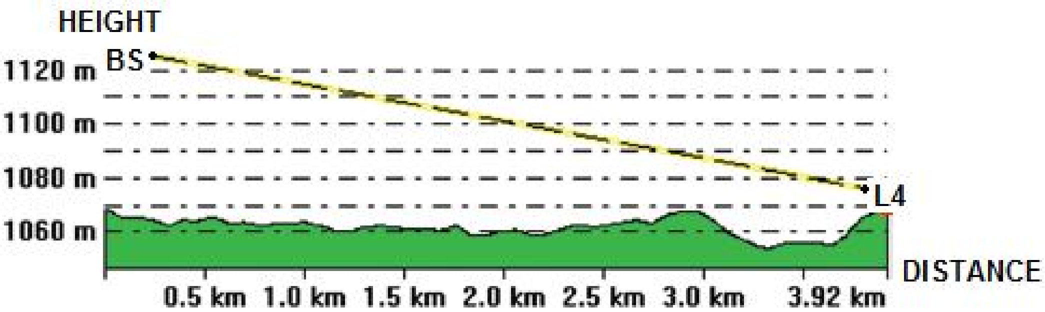

Figure 6.5: Signal path from BS (Base Station) to L4 (Location 4).

Link Status	: LOS
Distance to Base Station	: 3.92 km
Uplink Modulation	: 64 QAM
Downlink Modulation	: 64 QAM
Uplink TCP transfer speed	: 7.71 Mbps
Downlink TCP transfer speed	: 8.0 Mbps
Uplink UDP transfer speed	: 8.29 Mbps
Downlink UDP transfer speed	: 9.87 Mbps

Location 5

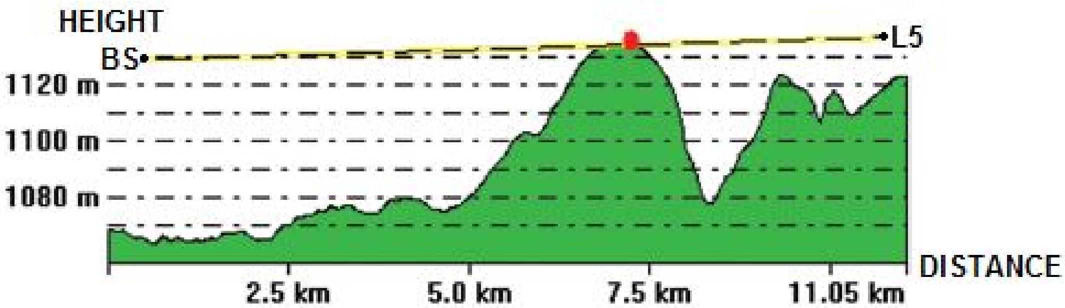

Figure 6.6: Signal path from BS (Base Station) to L5 (Location 5).

Link Status	: NLOS
Distance to Base Station	: 11.05 km
Uplink Modulation	: 16 QAM
Downlink Modulation	: 64 QAM
Uplink TCP transfer speed	: 5.33 Mbps
Downlink TCP transfer speed	: 7.84 Mbps
Uplink UDP transfer speed	: 5.51 Mbps
Downlink UDP transfer speed	: 10.4 Mbps

Location 6

Figure 6.7: Signal path from BS (Base Station) to L6 (Location 6).

Link Status	: NLOS
Distance to Base Station	: 6.11 km
Uplink Modulation	: 64 QAM
Downlink Modulation	: 64 QAM
Uplink TCP transfer speed	: 7.18 Mbps
Downlink TCP transfer speed	: 9.30 Mbps
Uplink UDP transfer speed	: 7.68 Mbps
Downlink UDP transfer speed	: 9.97 Mbps

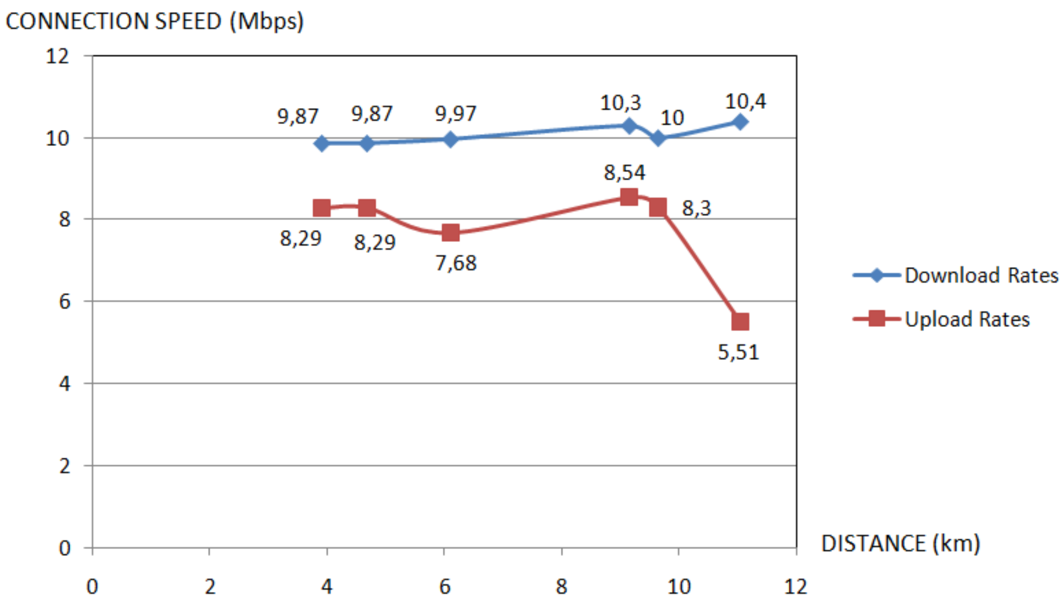

Figure 6.8: Download/Upload Rates in 14 MHz Bandwidth

Figure 6.8 shows the download and upload rates in 14 MHz Bandwidth. Up to 11 kilometers, the download rate is nearly 10 Mbps and the upload rate is nearly 8 Mbps. From 11.05 kilometers distance, upload speed is measured 5.51 Mbps because of the change of uplink modulation type from 64 QAM to 16 QAM.

6.2. Download/Upload Test Results in 3.4-3.6 GHz Frequency Band and in 5 MHz and 10 MHz Bandwidths

The performance results are measured from many different places of Ankara. Three base stations are mounted to Ulus, Etlik and Sincan. Each base station has a 100 Mbps transmission line to Ulus with F/O or R/L SDH systems and connected to a Switch. In some infrastructure cases, IP/MPLS backbone is used for transmission. Router-Switch configuration is used to connect the WiMAX network to IP/MPLS Internet backbone. Figure 6.8, 6.9 and 6.10 show the different basic WiMAX infrastructures.

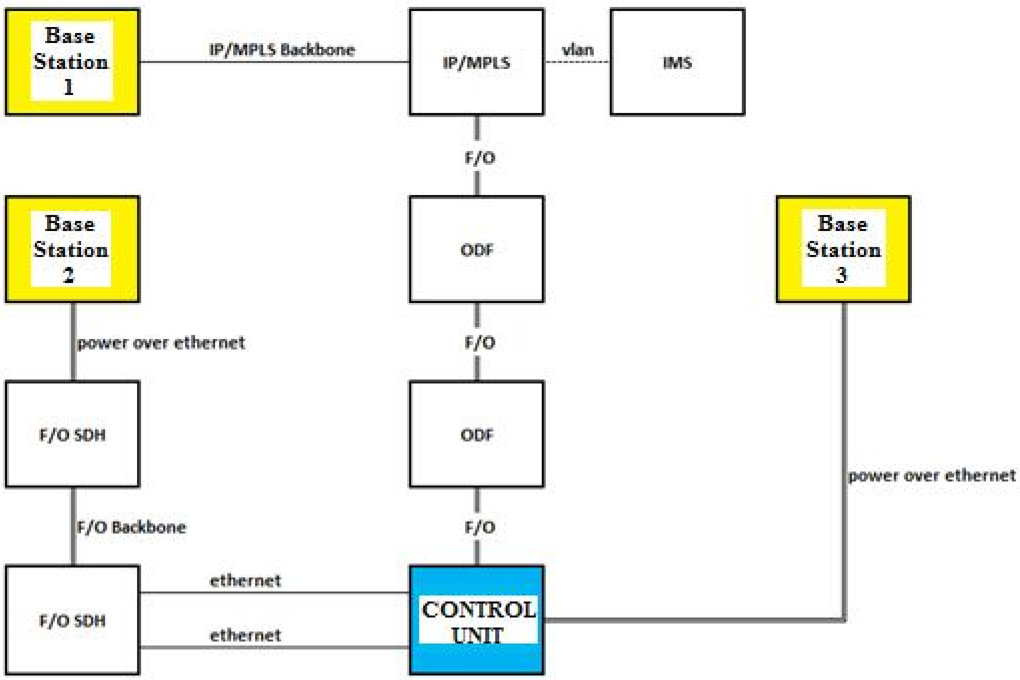

Figure 6.9: WiMAX basic infrastructure 1

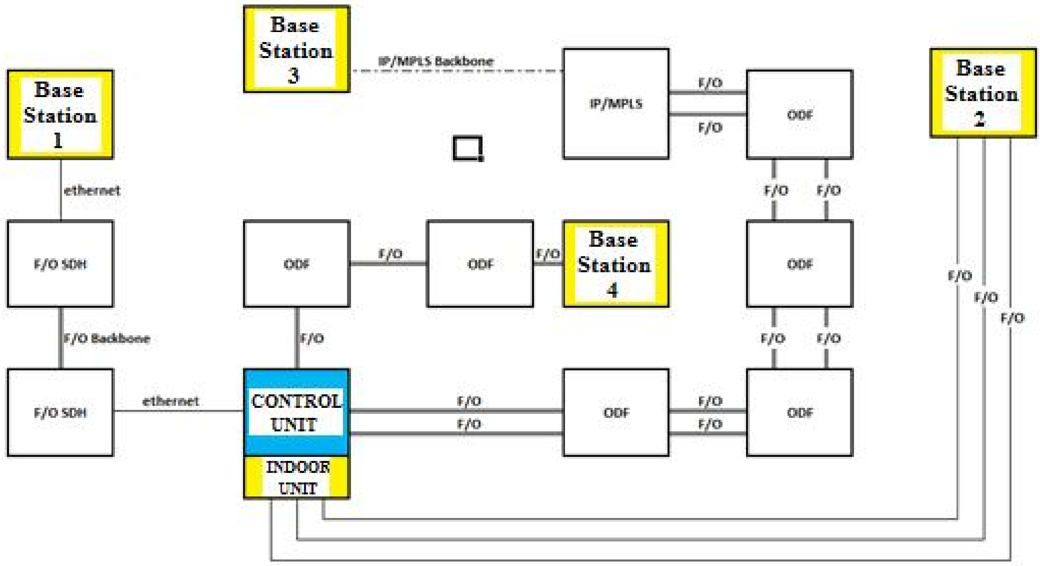

Figure 6.10: WiMAX basic infrastructure 2

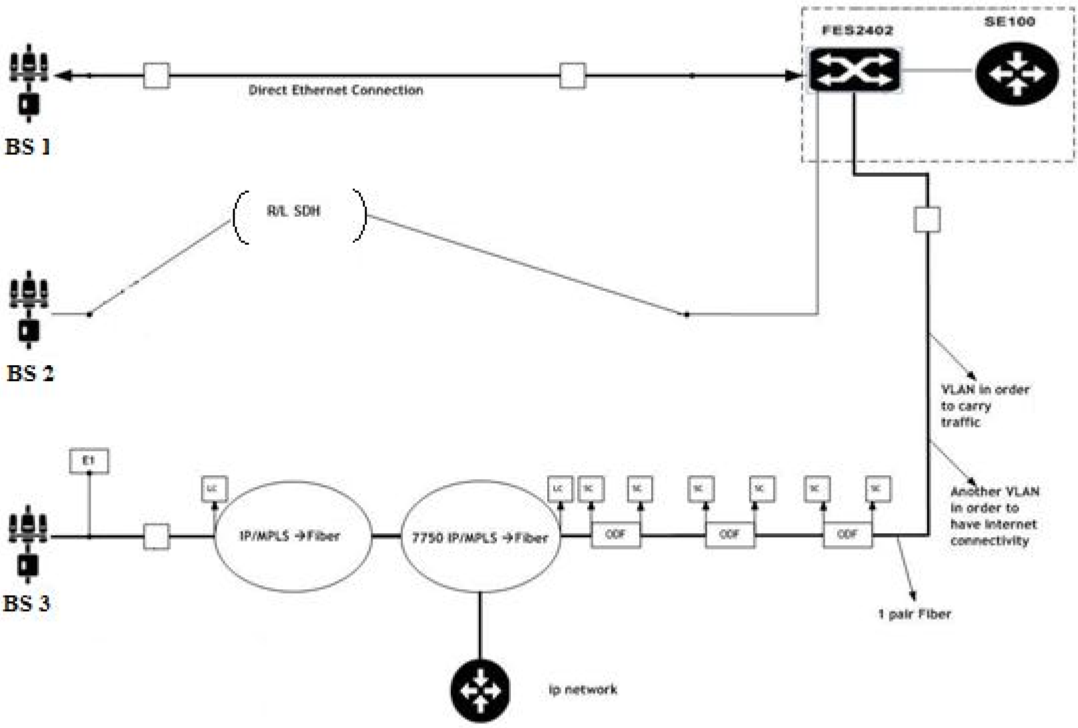

Figure 6.11: WiMAX basic infrastructure 3

The basic infrastructures in Figure 6.9, 6.10 and 6.11 show the connections of base stations (Figure 6.12, Figure 6.13) to the control units with R/L (Radio link) and F/O (Fiber Optic). Control units contain router and switch configurations and VLAN (Virtual Local Area Network) definitions. VLANs are defined to carry the two-way traffic from a single F/O cable. IMS (IP Multimedia Subsystem) shown in Figure 6.9 is an architectural framework for delivering Internet Protocol (IP) multimedia services. FES2402 in Figure 6.11 is a type of switch and SE100 is a type of router. ODFs (Optical Distribution Frames) (Figure 6.14) are used for fiber optic cable connections to each other. The terms "LC" and "SC" in Figure 6.11 are short-names of "Lucent Connector" and "Siemon Connector" type F/O cable connectors. "Lucent" and "Siemon" are the names of manufacturer companies.

Figure 6.12: WiMAX Base Station 1

Figure 6.13: WiMAX Base Station 2

Figure 6.14: Optical Distribution Frame (ODF)

6.2.1. Test Results in 5 MHz Bandwidth

Location 1:

Distance:	30 km
Link Status:	LOS
Downlink Modulation:	64 QAM
Uplink Modulation:	16 QAM
Average Download Speed:	8.3 Mbps (Figure 6.15)
Average Upload Speed:	1.6 Mbps (Figure 6.16)

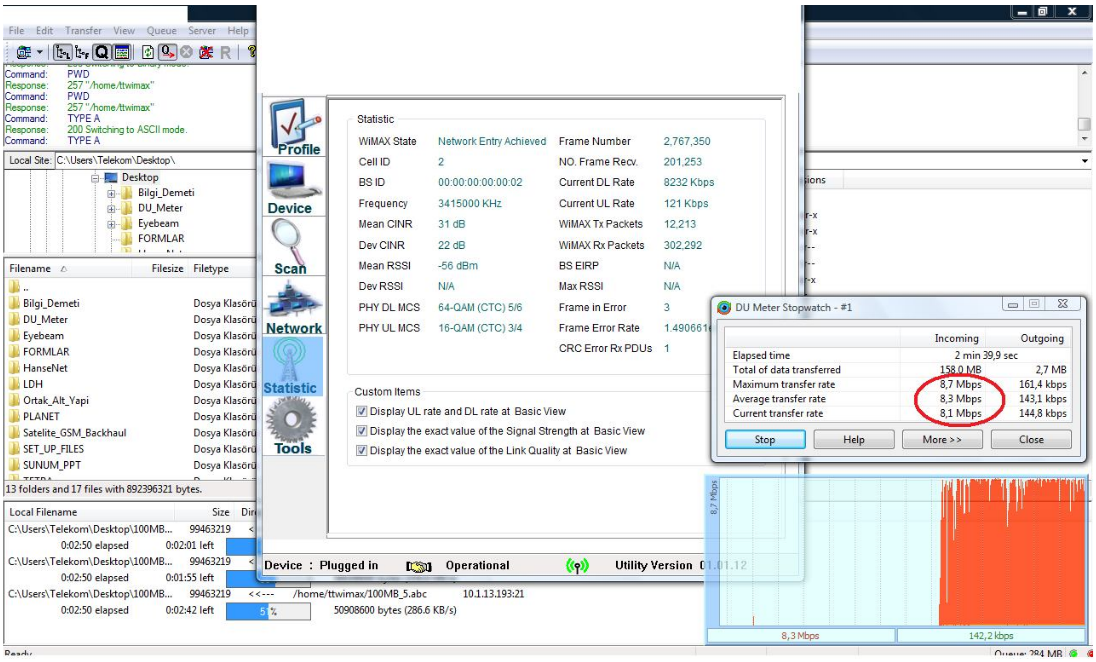

Figure 6.15: Location 1 Download Rates in 5 MHz Bandwidth from 30 km

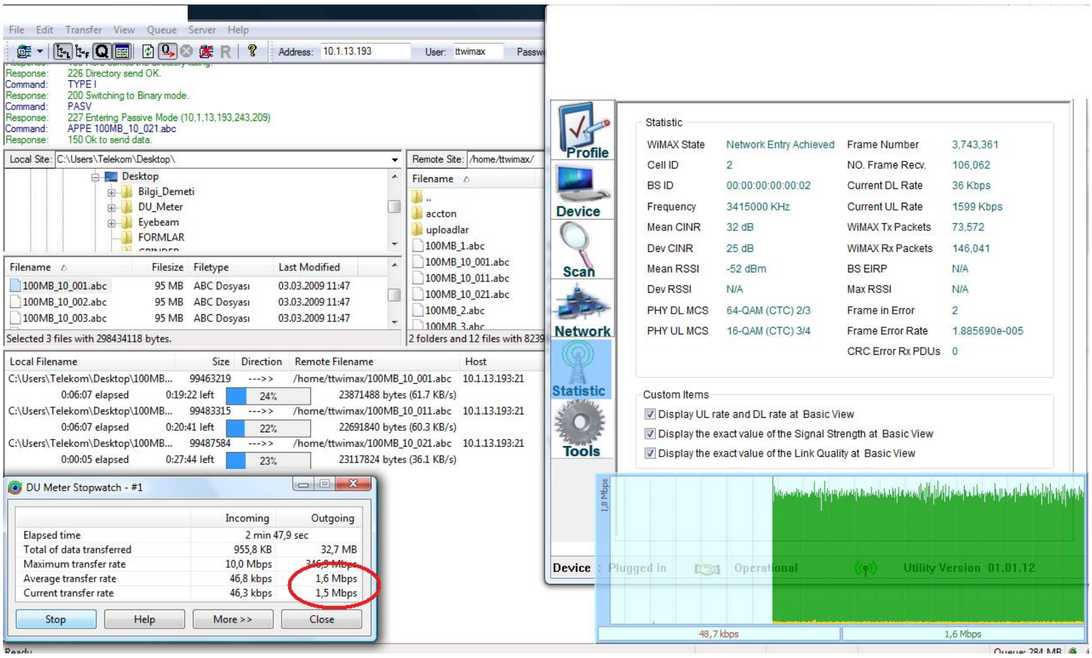

Figure 6.16: Location 1 Upload Rates in 5 MHz Bandwidth from 30 km

Location 2

Distance: 30 km

Link Status: LOS

Downlink Modulation: 16 QAM

Uplink Modulation: 16 QAM

Average Download Speed: 5.1 Mbps (Figure 6.17)

Average Upload Speed: 1.6 Mbps (Figure 6.18)

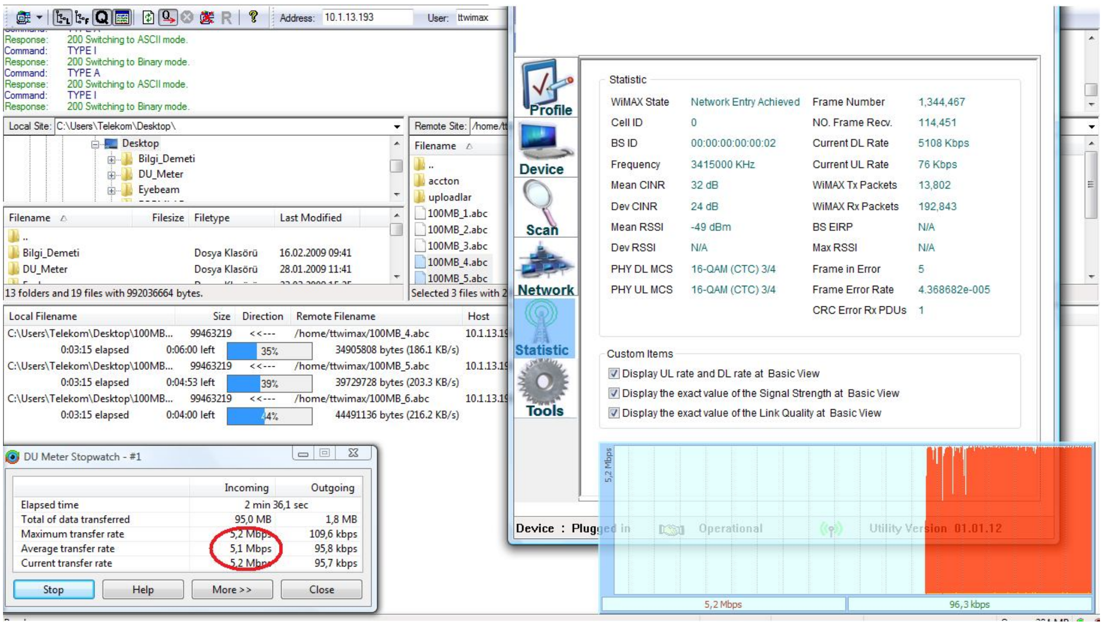

Figure 6.17: Location 2 Download Rates in 5 MHz Bandwidth from 30 km

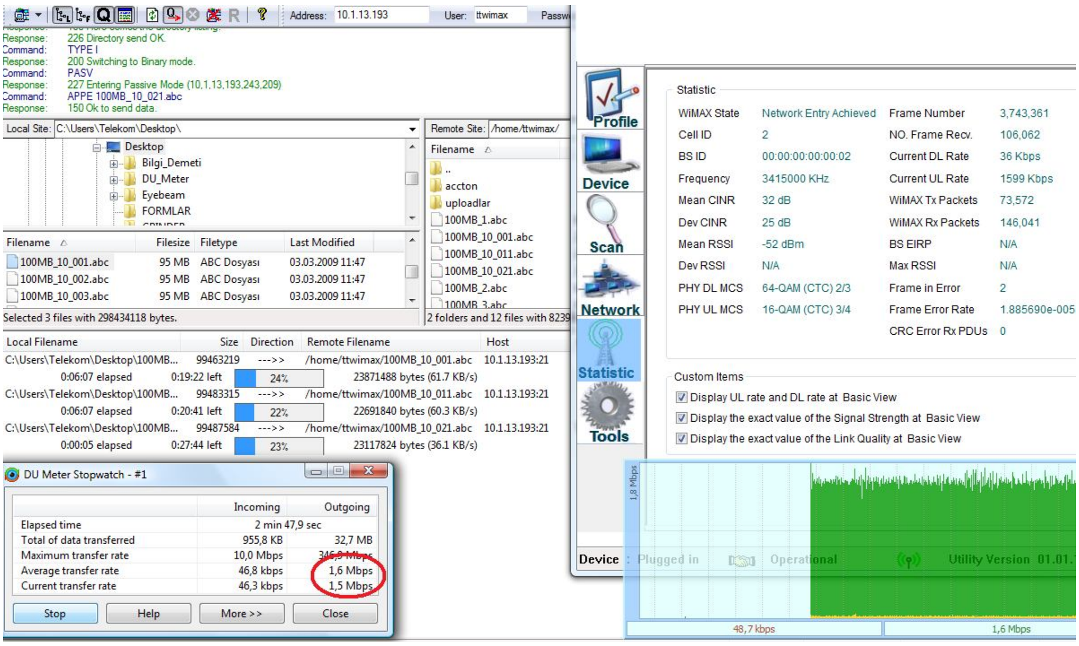

Figure 6.18: Location 2 Upload Rates in 5 MHz Bandwidth from 30 km

6.2.2. Test Results in 10 MHz Bandwidth

Location 3

Distance:	45 km
Link Status:	LOS
Downlink Modulation:	64 QAM
Uplink Modulation:	16 QAM
Average Download Speed:	11.6 Mbps (Figure 6.19)
Average Upload Speed:	2.3 Mbps (Figure 6.20)

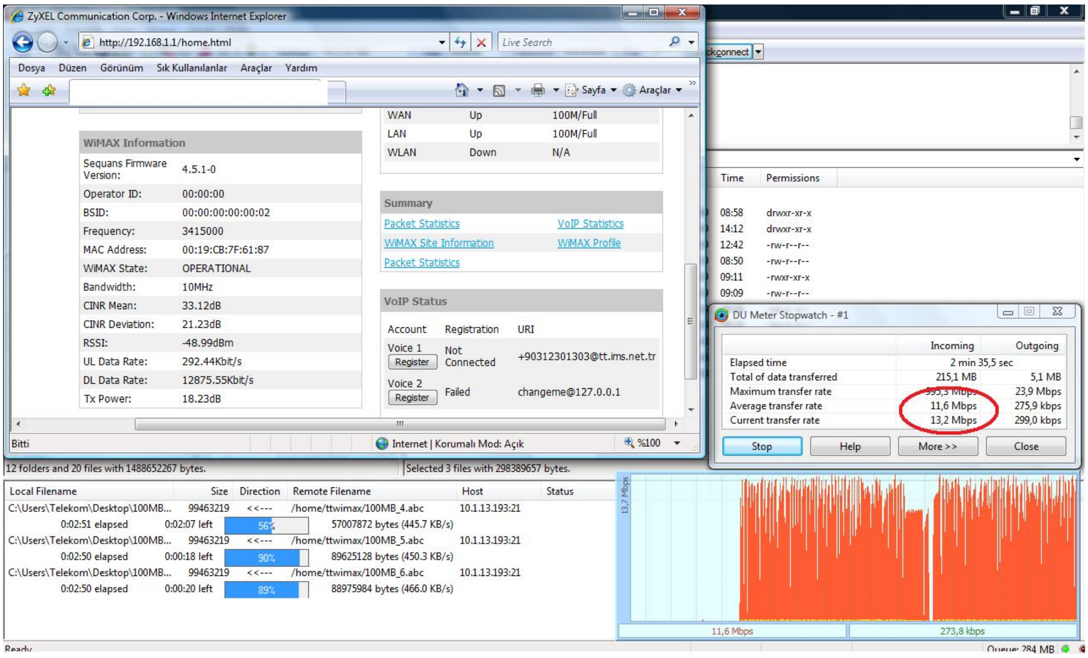

Figure 6.19: Location 3 Download Rates in 10 MHz Bandwidth from 45 km

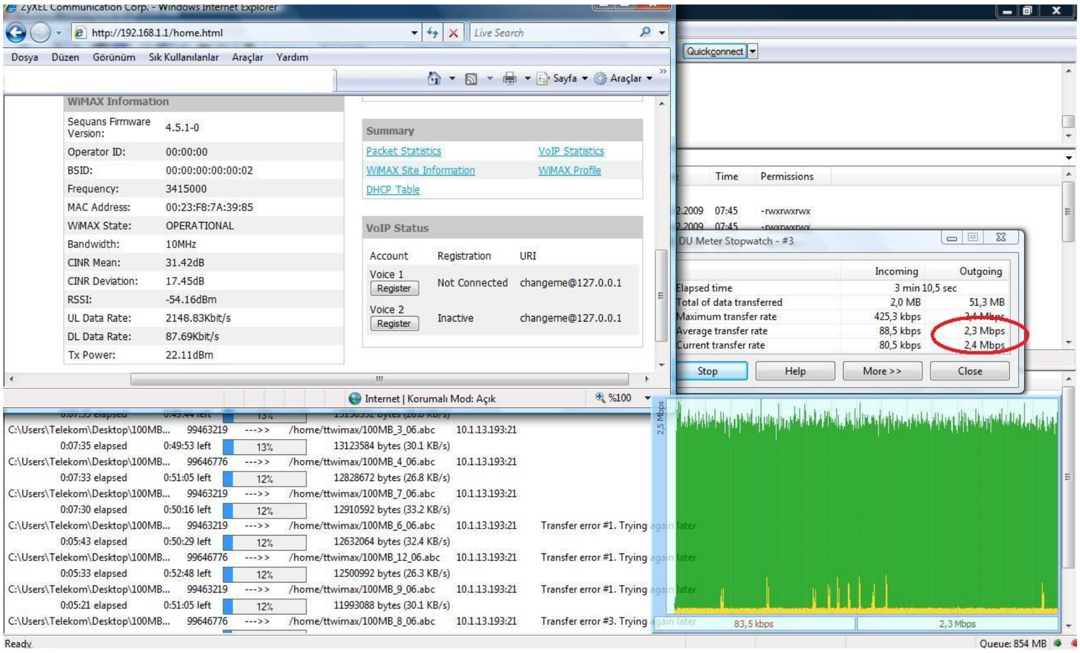

Figure 6.20: Location 3 Upload Rates in 10 MHz Bandwidth from 45 km

Location 4

Distance:	30 km
Link Status:	LOS
Downlink Modulation:	16 QAM
Uplink Modulation:	16 QAM
Average Download Speed:	9.9 Mbps (Figure 6.21)
Average Upload Speed:	2.8 Mbps (Figure 6.22)

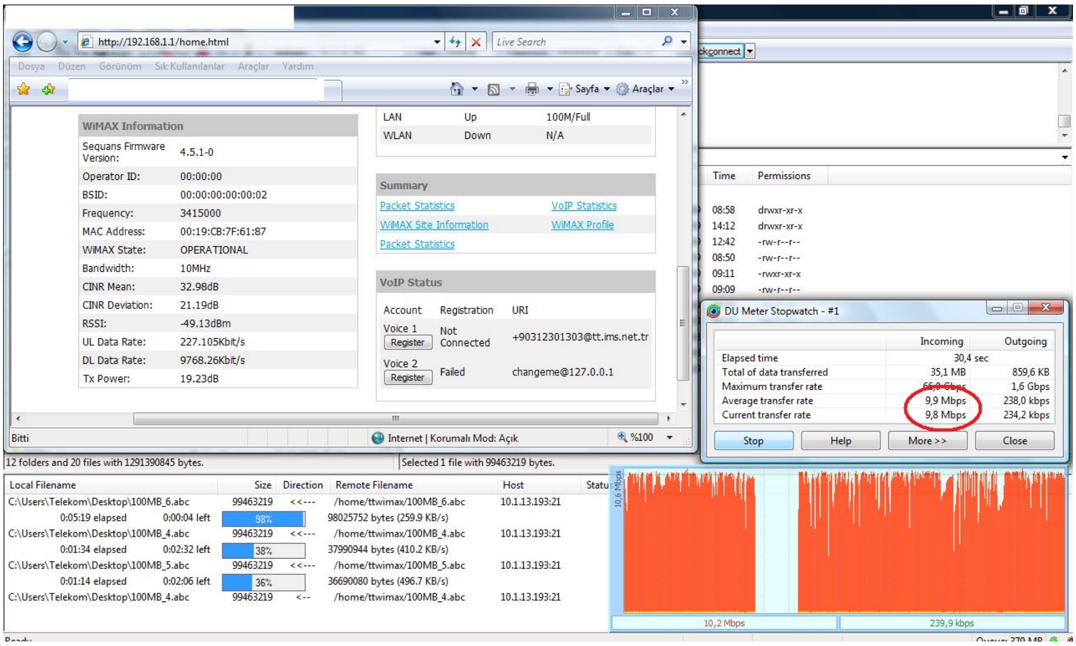

Figure 6.21: Location 4 Download Rates in 10 MHz Bandwidth from 30 km

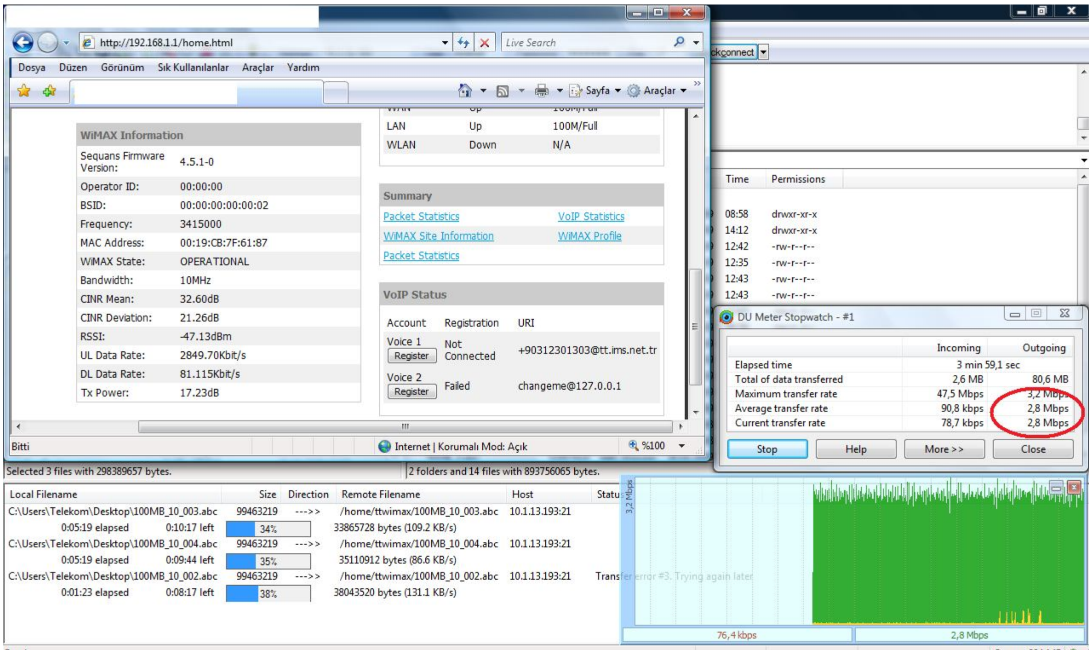

Figure 6.22: Location 4 Upload Rates in 10 MHz Bandwidth from 30 km

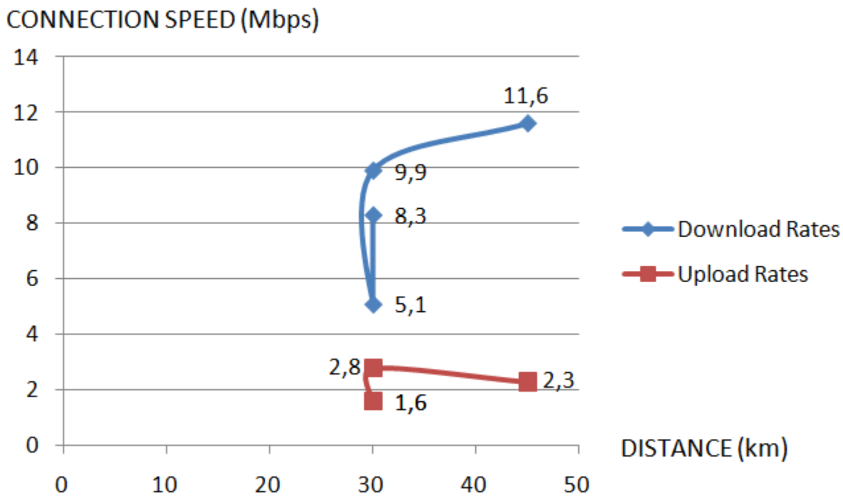

Figure 6.23: Download/Upload Rates in 5 MHz and 10 MHz Bandwidths

Figure 6.23 shows the Download/Upload rates in 5 MHz and 10 MHz Bandwidths. Changes in modulation type, bandwidth and distance affect the download and upload speeds (Table 6.1).

Table 6.1: Download/Upload Rates in 5 MHz and 10 MHz Bandwidths

	BANDWIDTH	**MODULATION**	**DISTANCE**	**SPEED**
DOWNLOAD	5 MHz	64 QAM	30 km	8.3 Mbps
	5 MHz	16 QAM	30 km	5.1 Mbps
	10 MHz	16 QAM	30 km	9.9 Mbps
	10 MHz	64 QAM	45 km	11.6 Mbps
UPLOAD	5 MHz	16 QAM	30 km	1.6 Mbps
	5 MHz	16 QAM	30 km	1.6 Mbps
	10 MHz	16 QAM	30 km	2.8 Mbps
	10 MHz	16 QAM	45 km	2.3 Mbps

CHAPTER 7

WiMAX STUDIES IN OTHER COUNTRIES

Australia

The Australian wireless broadband market is characterized by growing competition between WiMAX and competitive technology providers. Unwired Australia Pty Limited operates a WiMAX network in Sydney that the company has 70 sites, 3.000 kilometers square and covers a population of 3.5 million people. The service is advertised to reach 10 kilometers from base stations. (Figure 7.1) [3].

Figure 7.1: WiMAX in Australia (red points: 802.16d, yellow points: 802.16e) [10]

Austria

Austria auctioned wireless local loop (WLL) licences in October 2004 and several companies won licences to provide services in the 3.5 GHz frequency range. The licences do not give permission to the use of a specific air interface but WiMAX is the technology planned for at least one of the networks. WiMAX Telecom took 3.5 GHz licence in Austria to provide future WiMAX services [3]. Today's deployment of WiMAX Telecom includes a total of 140 WiMAX base stations, covering population of about 500,000 in Austria [16]. Other licenses were awarded to Telekom Austria, Telekabel and Teleport. WLL frequencies have also been made available between 24-26 GHz (Figure 7.2) [3].

Denmark

Danske Telecom has its headquarters in Copenhagen. With its considerable nationwide spectrum holdings in the 3.5 GHz band, Danske Telecom has deployed a WiMAX network comprising 72 base station sites in 7 cities. Broadband services were launched in Denmark's three largest cities, Copenhagen, Aarhus, and Odense in October of 2005. By mid February 2008 Danske Telecom had extended coverage to 7 cities covering more than 550,000 Danish households and about 40% of the population [16].

Switzerland

Switzerland had opened a public consultation on the licensing of broadband wireless technologies in an effort to determine the demand for licences in the market and the most effective way to allocate them. ComCom decided the number of licences and usage. BWA Technologies were limited to licensed usage in the 3.4 to 3.6 GHz frequency bands. Licence-exempt usage is possible in the 5.7 GHz frequency bands with restrictions on power levels [3].

Figure 7.2: WiMAX in Europe (red points: 802.16d, yellow points: 802.16e) [10]

France

Companies have deployed pre-WiMAX trials based on the 802.16-2004 standards in the towns. WiMAX backhaul connections were used for one part of the trial to deliver connectivity to Wi-Fi hotspots. The France Telecom trials were allowed to take place in the 3.5 GHz range in the trial areas (Figure 7.2) [3].

Germany

The German regulator, RegTP is in the process of recycling WLL frequencies to be used by newer technologies such as WiMAX. Frequencies for WiMAX are available in the 3.5 GHz range. Deutsche Telekom will deploy pre-WiMAX technologies in a pilot project. The German national regulatory authority had assigned limited test frequencies for trials (Figure 7.2) [3].

Japan

The communication operator Yozan has started WiMAX trials in Tokyo by mid-year 2005 and started to build fixed WiMAX network. Tokyo is already wired for DSL and fiber and broadband prices are among the cheapest in the world so Yozan will try to compete on price and mobility (Figure 7.3) [3].

Korea

The Korean government allocated three WiBro licenses based on the IEEE 802.16e standard in the 2.3GHz range for wireless/mobile Internet services. Korea’s WiBro rollout is the first high-speed mobile broadband service of its kind in the world. Korea’s leading operators KT (fixed) and SKT (mobile) launched WiBro services in 2006 (Figure 7.3) [3].

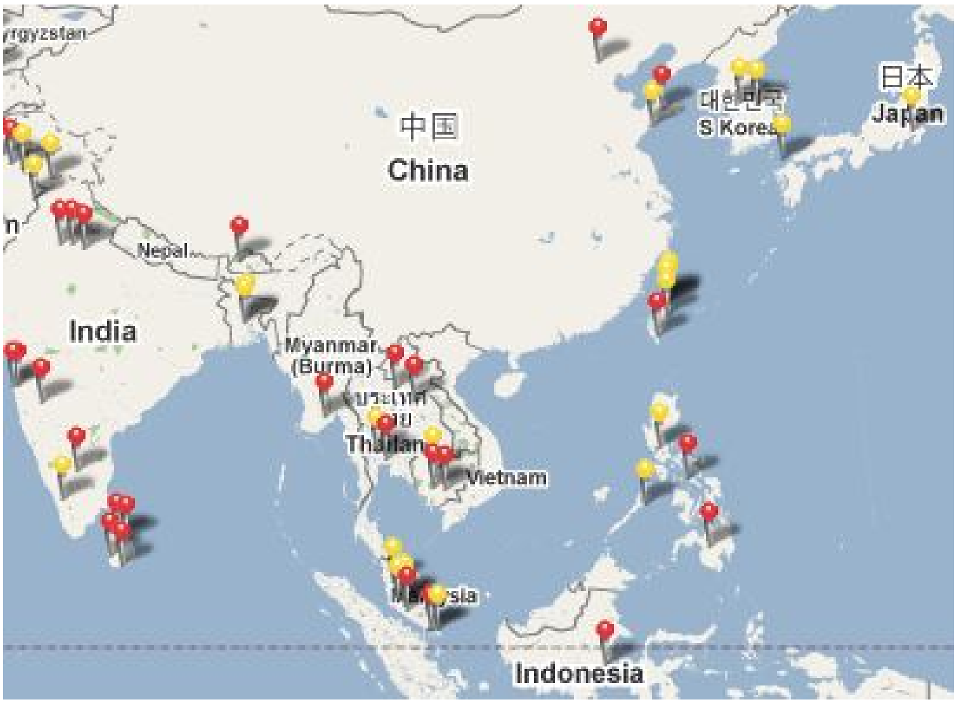

Figure 7.3: WiMAX in Asia (red points: 802.16d, yellow points: 802.16e) [10]

Singapore

Broadband infrastructure market is duopoly: SingTel ADSL and StarHub cable modem. Increased choice in the market and bring about cheaper Internet Access. 3.5 GHz 'WiMAX priority' frequency used by space-to-earth satellite services. Service rollout was in 2006 as license stipulates 2.5 GHz holders must start service within 18 months and 2.3 GHz holders within 36 months [3].

United States

Potential WiMAX providers in the United States have focused on the 2.5 GHz and 5 GHz bands. The 3.400-3.650 MHz range is allocated for radars on a primary basis and does not contain provisions for use of fixed or mobile systems.

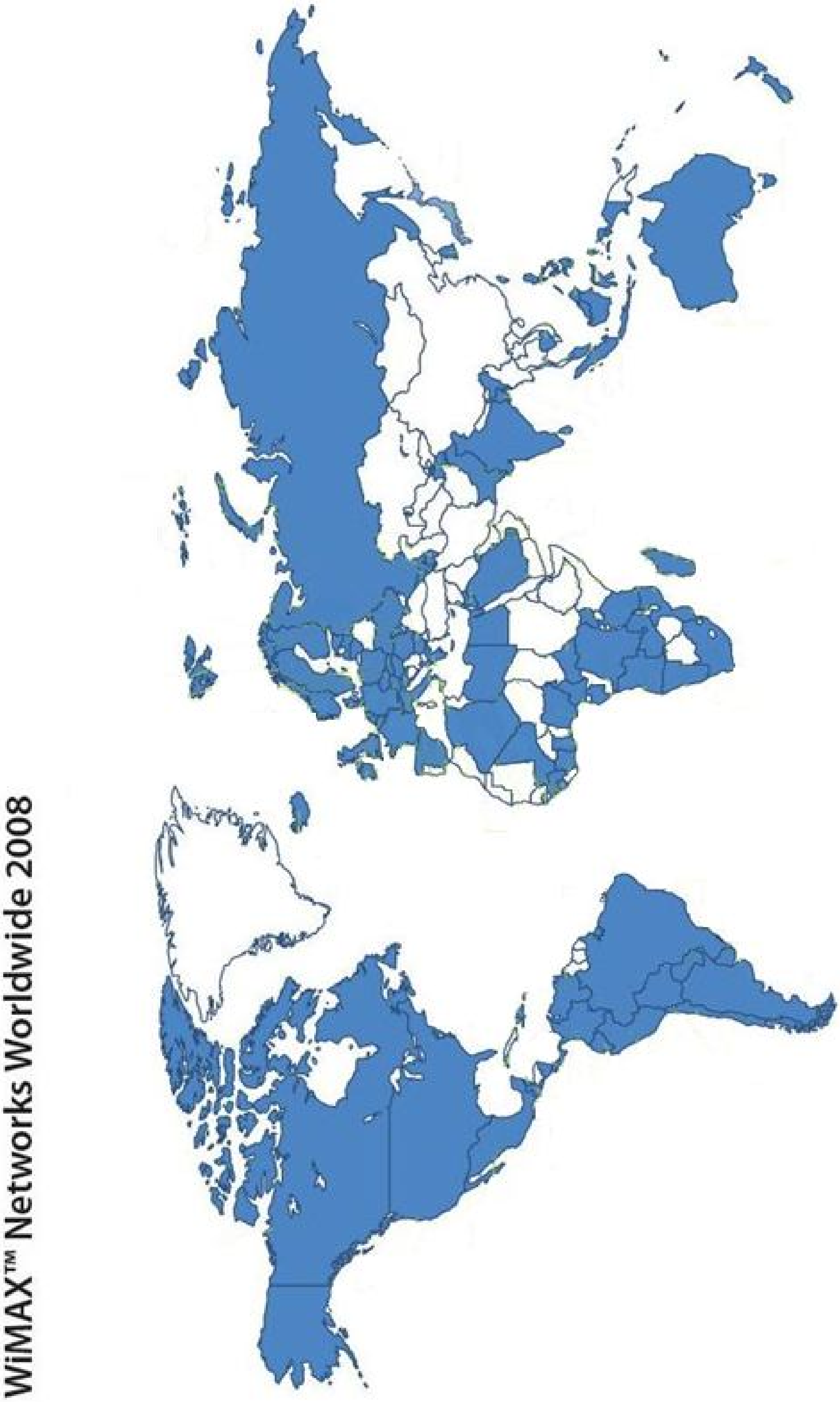

Figure 7.4: WiMAX Networks Worldwide (Blue regions show the WiMAX usage) [8]

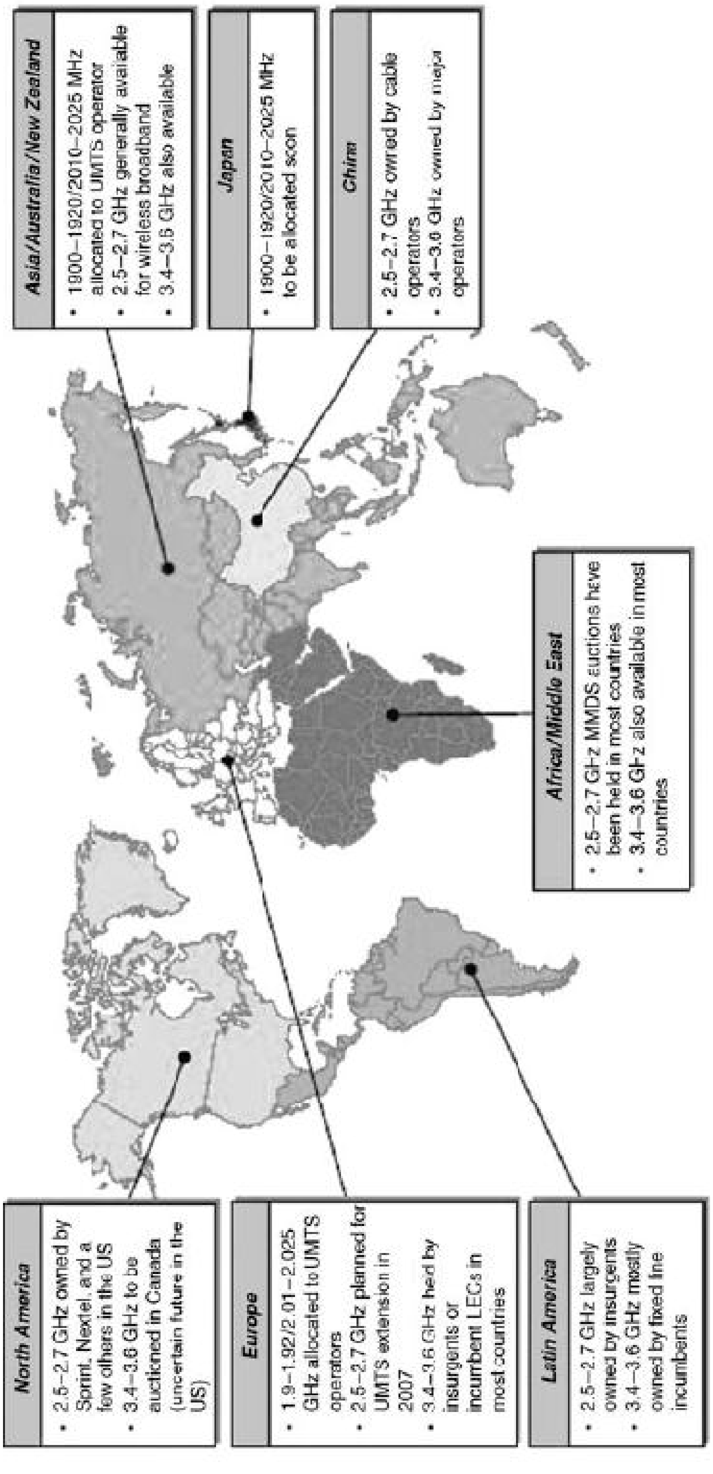

Figure 7.5: WiMAX Frequency Bands Worldwide [2]

CHAPTER 8

REGULATORY AND COMPETITIVE ISSUES OF WiMAX IN TURKEY

8.1. Authority of Broadband Wireless Access Services

As the result of technological developments in the world, as well as stationary applications, working on different frequency bands for wireless broadband technologies, because of the necessity of nomadic and mobile applications, various wireless broadband technologies and services appears. In this context, the BWA services, which work on different frequency bands, have to be regulated.

The following services will be offered in the scope of BWA Services in Turkey:

- Installation and operation of Private BWA Network,
- Telephony Services,
- Internet Access Services.

We should examine the European countries within the scope of BWA to understand which type of service is authorized, banned or not used; Fixed Broadband Wireless Access (FBWA) or Mobile/Nomadic Broadband Wireless Access (MBWA).

In 3.5 GHz Frequency Band;

- Mobile Broadband Wireless Access authorized countries: Austria, Belgium, Germany, Sweden, Switzerland, Latvia, Lithuania, Macedonia, Malta, Poland, Romania, Slovakia and Slovenia,
- Mobil Mobile Broadband Wireless Access banned countries: Denmark, Finland, Luxembourg, Norway, Spain and Estonia,

- The future of Mobile Broadband Wireless Services is not clear in Italy and Hungary. Regulatory studies still continue.
- There are no limitations for WiMAX licences in USA for the frequency bands: 2.3 GHz, 2.5 GHz and 5 GHz.
- A lot of MBWA licences are given in Canada for the frequency bands 2.3 GHz, 2.5 GHz and 3.5 GHz. There are no limitations for WiMAX services.

Information and Communication Technologies Authority of Turkey should consider four main titles in the scope of BWA Services Authorization Strategy in Turkey:

- Regional or National Authorization of WiMAX Licences
- Assigning the Frequency Bands of WiMAX Licences
- The Price of WiMAX Licences
- Time Duration of WiMAX Licences

8.1.1. Regional or National Authorization of WiMAX Licences

It is useful to see the other countries' regional or national licencing types. Figure 8.1 shows the regional/national licences in some continents.

According to Figure 8.1, it can be said that, in Turkey the authorization of the WiMAX services should be regional (WiMAX licences should be given for 7 geographic parts of Turkey).

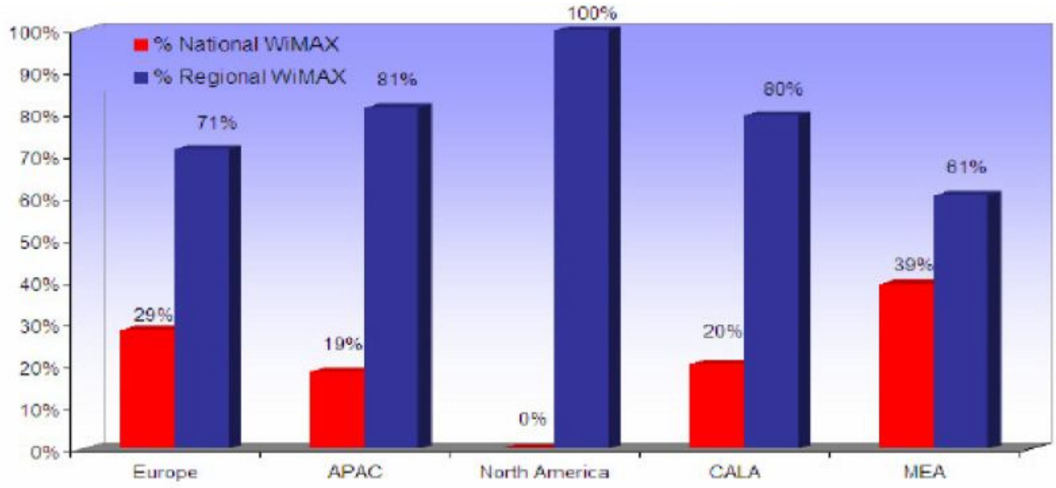

Figure 8.1: Percentages of Licence Types in Continents.

According to the studies in 2000s about WiMAX regulations all over the world shows that; licences were mostly national for different frequency bands. But in last decade, especially for 3.5 GHz frequency band, licences have gradually become regional. On the other hand, it is seen that; in developing countries WiMAX licences are national but developed countries have regional licences.

To decide the licence type to be regional or national in Turkey, the following issues should be taken into account:

- Most of the licences over the world are national (100% of licences in America and 71% of licences in Europe are regional).
- In 3.5 GHz frequency band, regional licences are given in Austria, Belgium, Germany, Finland, Ireland, Italy and Norway. Denmark, France and Sweden have both national and regional licences.
- In 24-29 GHz frequency band, France, Italy and Poland have regional licences.
- In general, after 2000, the licences were given as regional especially in 3.5 GHz and 24-29 GHz frequency bands.

Besides, if the authorization of WiMAX services in Turkey will be national, the licenced operators will have to pay the price of geographical regions where they do not want to offer WiMAX services. Afterwards, this condition will affect the subscriber fees and the wide spreading of the WiMAX. It will also affect the national profit and public advantages. On the other hand, lower subscription fees and monthly costs will yield to increase the number of subscribers.

National authorization has coverage obligations and some other commitments. If a national authorization will be decided to use in Turkey, it will reduce the operator numbers to enter to authorization of WiMAX. Only big operators will be ready to get the licence. If Information and Communication Technologies Authority of Turkey will decide to give regional licences, small operators will also have a chance to be in auction. Especially, regional authorization will affect the competitiveness in Turkey and the service quality of WiMAX services.

8.1.2. Assigning the Frequency Bands of WiMAX Licences

When the frequency plans of world nations are carefully studied, we can see that, 3.5 GHz, 10 GHz, 24 GHz, 28 GHz, 32 GHz and 40 GHz frequency band will be allowed for BWA services in general. In European countries, generally 3.5 GHz, 10 GHz and 24-29 GHz frequency bands are used for BWA services.

If we examine the applications of given services in the world in the scope of BWA, we can see; WiMAX mostly uses 3.3-3.8 GHz frequency band (Figure 8.2).

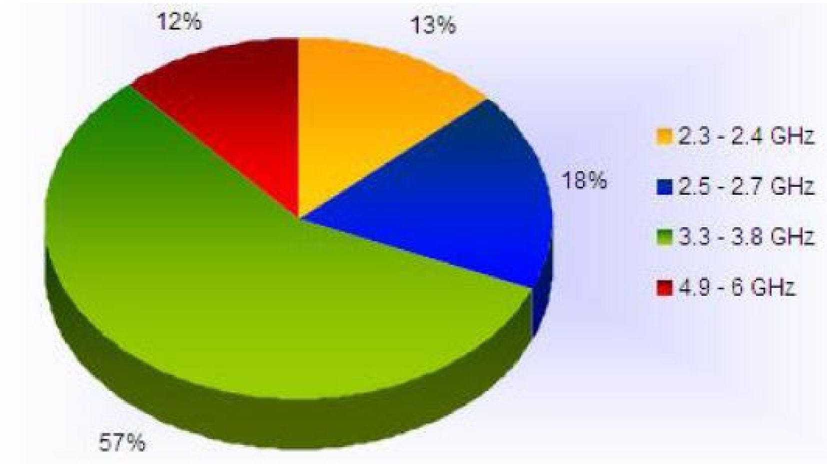

Figure 8.2: Percentages of WiMAX Frequency Bands over the world.

If we look at the WiMAX bandwidths which are used in European countries, we'll see following results:

In 3.5 GHz frequency band;

- Austria, Germany, Italy, Switzerland, Luxembourg, Bulgaria, Croatia and Slovenia: 2x21 MHz,
- Spain and England: 2x20 MHz,
- Belgium and Ireland: 2x25 MHz,
- Switzerland, Sweden, Portugal and Lithuania: 2x28 MHz,
- France: 2x15 MHz,
- Croatia, Estonia, Slovakia, Hungary and Macedonia: 2x14 MHz

In Turkey, the WiMAX bandwidth assignments should be nearly same with European countries. In some European countries, 10 GHz frequency band is assigned to WiMAX. But in Turkey, 10 GHz frequency band has been still in use by other systems (radio-link systems). So it is not possible to use this frequency band.

The frequency plan of Turkey shows, the following frequency bands and bandwidths can be assigned for WiMAX applications:

40.5-42.5 GHz:

Generally 2x250 MHz or more times of 250 MHz bandwidth will be assigned to operators. (as given in England: 2x250 MHz). But operator demands will not expected in this frequency band,

24.5-26.5 GHz:

2x56 MHz or more times of 56 MHz bandwidth will be given to operators. Operator demands for this frequency band will also not be expected. Bu we can say that operators will decide to use this band more than 40.5-42.5 GHz frequency band.

3.4-3.6 GHz:

In Turkey, 3.4-3.6 GHz frequency band is assigned Türk Telekomünikasyon A.Ş. (TTAŞ) for the "Wireless Local Loop" (in Turkish; KTS: Kablosuz Telefon Sistemi) which is used in rural areas to offer telephony services generally to villages. But, official studies had finished by Information and Communication Technologies Authority of Turkey and TTAŞ, and TTAŞ is going to recant this frequency band until 2010.

TTAŞ is going to recant the following frequency bands:

3435-3475 (40 MHz)
3485-3500 (15 MHz)
3500-3510 (10 MHz)
3535-3600 (65 MHz)
TOTAL (130 MHz)

Four big telecommunications operators exist in Turkey today. So it is possible to say that, four WiMAX licences will be given to these four operators.

Operator 1: 3435-3455 (20 MHz) and 3535-3555 (20 MHz): total 2x20 MHz
Operator 2: 3455-3475 (20 MHz) and 3555-3575 (20 MHz): total 2x20 MHz
Operator 3: 3485-3500 (15 MHz) and 3585-3600 (15 MHz): total 2x15 MHz
Operator 4: 3500-3510 (10 MHz) and 3575-3585 (10 MHz): total 2x10 MHz

If Information and Communication Technologies Authority of Turkey make some other bandwidths available in 3.4-3.6 frequency band, it will possible to authorize more operators for WiMAX services.

Information and Communication Technologies Authority of Turkey has planned 3.6-3.8 GHz frequency band for WiMAX services to be assigned after January, 2012.

Operators are excited to get 3.5 GHz licence in Turkey now. So certainly, they will show their interests when the authorization studies begin. As matters of fact, since 2005, a lot of small and big operators have taken the testing licence of WiMAX (29 companies have taken 37 WiMAX test licence).

8.1.3. The Price of WiMAX Licences

In other countries, different WiMAX licences have given with different prices. Mostly, the prices of the licences have appeared after the authorization studies. In Turkey, the prices of the WiMAX licence will be decided in a similar manner.

Before the authorization study, Information and Communication Technologies Authority of Turkey has to decide on the minimum price of WiMAX licences. To do that, the following topics should be investigated:

- The licence prices in other countries should be examined.
- The licence prices of existing services in Turkey should be examined.
- The factors to estimate the price should be examined. These factors are:

- Frequency
- Bandwidth
- Geographic Development
- Type of service

Information and Communication Technologies Authority of Turkey should also think about authorization fees in other countries to decide the price of WiMAX licences in Turkey. Table 8.1 shows the authorization fees in European countries.

Table 8.1: Authorization Fees in European Countries

COUNTRY	GIVEN LICENCE	LICENCE FEE
England	3.4 GHz Fixed Wireless Access	**TOTAL: 7 million £** for 15 regional licences
Italy	3.4-3.6 GHz Auction	**TOTAL: 136.3 million €** for 3 licences
Greece	3.4-3.6 GHz 4 licences	The maximum offer for 2x14 MHz licence is: **20,475 million €**
Austria	Between 2x21 MHz and 2x42 MHz Fixed and Mobile Wireless Access	17 spectrums in 6 regions **TOTAL: 464.000 €**
France	2 licences for every 22 metropolitan areas. Total: 44 licences.	**TOTAL: Nearly 126 million €**
Germany	4 licences Fixed and Mobile Wireless Access	**TOTAL: Nearly 56 million €**

In other European countries, the authorization fees are less than 5 million €

8.1.4. Time Duration of WiMAX Licences

To decide on the time duration of WiMAX licences, the following issues should be taken into account:

- Licence durations in other countries
- Licence durations of existing services in Turkey
- Public opinions and expert reports

If we examine the licence durations in other countries in 3.5 GHz frequency band, we can see that, WiMAX licences have mostly assigned between 10 and 20 years. We give the following examples:

- Austria, France, Germany, Italy, Poland, Portugal, Sweden, Latvia, Lithuania, Hungary and Malta: 15 years.
- Denmark, Ireland, Luxembourg, Sweden, Switzerland, Bulgaria, Macedonia, Romania, Slovakia and Slovenia: 10 years.
- Sweden and Greece: 10 and 15 years.
- England: 5 years
- Spain and Czech Republic: 20 years.
- France: 15 and 20 years.
- Netherlands: 12 years.
- Norway: 18 years
- Finland: 4 years.

The licence durations of the existing licences are also an important reference. The auction of 3G services is done in 28 November, 2008 in Turkey by Information and Communication Technologies Authority of Turkey and the licence durations are decided as 20 years.

To understand why 3G licences are given for 20 years in Turkey, we can simply analyze income and expenditures of GSM operators. For example Turkcell:

- paid 358 million Euros for 3G licence
- has the infrastructure which will not be ready for 3G services about 1 year
- has to modify its 2G network for 3G capabilities.
- has to advertise its 3G services, etc…

	2005	2006	2007e	2008f	2009f	2010f	2011f	2012f
No. of Mobile Phone Subscribers ('000)	45,700	52,548	62,103	69,552	75,812	81,877	88,105	92,510
No. of Mobile Phone Subscribers/100 Inhabitants	63.4	70.9	82.6	91.4	98.3	104.8	111.5	115.8
No. of Mobile Phone Subscribers/100 Fixed Line Subscribers	233.9	279.1	339.9	390.5	433.5	477.7	521.9	556.3
No. of 3G Phone Subscribers ('000)	0	0	0	500	1,150	1,950	2,850	5,273
3G Market As % Of Entire Mobile Market	0.0	0	0	0.9	1.9	3.2	4.6	5.7

Figure 8.3: Turkey Cellular Sector Historical Data and Forecasts [9]

According to Figure 8.3, Turkcell;

- will has about 40 million cellular subscribers and 1 million subscribers will use 3G services at the end of 2009.
- has a tariff about 15 Euros/month for 1 Mbps Internet Connection over 3G.
- will get about 90 million Euros income at the end of 2009 (for last 6 months of 2009 after authorization) from 3G services.

If we compare the incomes and expenditures Turkcell will amortize the licence fee in 2 years. Renting fees, operation and maintenance expenditures, network installations, advertisements etc. will increase the amortizing time of Turkcell 3G services.

Expert reports and public opinions by Information and Communication Technologies Authority of Turkey say: “The WiMAX operators need 6-7 years to amortize their expenditures.

As a result, the possible WiMAX licence duration in Turkey should be in range of 15 and 20 years [11].

8.2. Company Rights and Obligations

Authorization of WiMAX in Turkey should have some company rights and obligations. It should be done by Information and Communication Technologies Authority of Turkey.

The Company Rights and Obligations should be as follows:

- Operator should be allowed to offer voice, data and video services to its subscribers containing telephony service and internet access.
- Operator should be allowed to set up/use/rent/ its BWA infrastructure.
- Operator should not be allowed to get all regional licences (7 geographic regions for Turkey).
- Operator should be allowed to connect its regional networks to each other.
- Operator should be allowed to billing by itself.
- Operator should not be allowed to get more than one frequency band licence in one region.
- Operator should be forced to prevent service interruptions.
- Operator should be forced to take every security options and precautions for its infrastructure.
- Operator should be forced to be ready for detailed billing.
- Operator should be forced to save its traffic and subscriber informations.

8.3. Competitive Analysis

The scope of the WiMAX standard and the ambitions of its supporters have expanded considerably in the past few years, moving beyond the traditional broadband wireless access (BWA) functions of fixed access and last or middle mile, to offer a platform for key trends among major service providers, notably personal broadband and fixed-mobile convergence.

Large carrier demands on their technologies and suppliers are complex and stringent, and the WiMAX bodies were forced to add significantly to their technical platform and the testing and certification processes to satisfy the new requirements, as well as look towards building a full ecosystem of software, services and devices around the networks.

By 2008, fixed proprietary BWA will have shrunk to 10% of the total, WiMAX in both 802.16-2004 and 802.16e forms will take 55% and Wi-Fi plus portable proprietary systems will account for a further 35%. By the end of 2009, WiMAX will be the largest player with 63% share and will cross the three-quarters mark by the end of the decade. Spending on WiMAX in the 2007-10 period will see the figure weighted to the last years as the impact of large scale 802.16e personal broadband rollouts start to be felt.

The rapid development of WiMAX will affect the vendor companies. The key changes in vendor line-up will be:

- The suppliers will get increasingly serious about WiMAX. GSM extension will increasingly become a key driver of growth and favor suppliers with entry to this base, especially those without a strong commitment to W-CDMA.

- WiMAX and Wi-Fi will become increasingly integrated, bringing some key outdoor Wi-Fi and WLan device vendors into the space.
- WiMAX will start to develop a carrier-class ecosystem, which will also involve a new and more complex set of software, integration and channel partners.
- The license-exempt 5 GHz variant of the WiMAX standard will be sidelined, leaving this market to be served by Wi-Fi or proprietary technologies
- Certain key applications will become very important as revenue generators, favoring suppliers with expertise in these areas. Public safety is an important example.
- With multimode devices and base stations, and integration technologies like IP Multimedia Subsystem (IMS), it will be increasingly important for WiMAX to coexist and integrate with other wireless and wireline technologies, especially as the world moves towards a multi-platform 4G, and this trend will also favor a particular class of supplier.
- The traditional BWA market, concentrated on fixed access in rural or underdeveloped regions, will still continue to grow at a steady rate well after 2010, driven by new spectrum allocations and the rising demand for broadband in new economies. This market will remain partly the preserve of traditional players those that are not snapped up by majors in 2006-8 but will also increasingly attract vendors, especially in large economies, and where initial fixed access deployments could prove a stepping stone to true mobile broadband.
- The CPE suppliers will increasingly be separated from the base station makers and at the low end; there will be significant commoditization by 2009, especially where there is integration with Wi-Fi. This will also apply to some WiMAX chipsets. However, the greater complexity and scale of demands on 802.16 compared to 802.11 will confine this commodity range to a small section of the total market up to 2010 [7].

CHAPTER 9

CONCLUSION

With the mobility's gained importance, the interest in broadband wireless access technology is increased worldwide. In this context, with interest to the WiMAX technology, the arrangements have been made to provide broadband services.

In Turkey, especially in the field of telecommunications, important steps have been taken in recent years. Telecommunications sector policy development phase is closely following the developments in the world that occur in developing countries and are trying to adopt common strategic objectives. Turkey's increasing competitiveness in world markets is connected to technology and telecommunications sector to be monitored closely to build on the solid ground.

The results of the performance tests show that; to offer broadband data services over existing technologies, WiMAX is seen as the most appropriate choice. In addition, after the production of 802.16e standard compatible base stations and user devices, large audience for WiMAX technology is expected.

Broadband Wireless Access Services will be a good choice in our country, because;

- It will be an important factor in the transition to information society
- The rural areas where cannot reach DSL opportunities will be presented with broadband services
- It will increase competition in the Internet sector in our country
- It will increase in the number of subscribers and the users
- It will create cheaper Internet service
- It will provide significant contributions to the development of the sector

- e-medicine, e-learning, e-agriculture and other applications will spread, will provide significant opportunities to domestic companies especially in the field of software
- It will allow easy integration into social life with e-applications.

New technologies and services to enter the market are closely related with the implementation of information society and globalization processes in the great importance and authority of the new regulations. As organized sector in our country, Information and Communication Technologies Authority of Turkey, is in the field of regulation and authorization to conduct the necessary studies about WiMAX.

In parallel with these developments, the regulation studies should be taken into account in details about Broadband Wireless Access Services including voice and data services to be offered by WiMAX by Information and Communication Technologies Authority of Turkey.

While authorization studies of Broadband Wireless Access Systems in Turkey, including WiMAX Services; licence types, possible frequency band, the prices of licences, duration of licences and company rights and obligations have to be carefully examined.

Regional licence in 3.5 GHz Frequency Band should be possible to assign to operators in Turkey. Prices of the licences are affected by many different issues like: frequency, bandwidth, geographical developments in different regions of Turkey and type of services. The duration of WiMAX licences should be about 15-20 years in Turkey like the given 3G licences before [11]. Also, the service prices have to be compared with other broadband services, like DSL technology, and carefully decided to compete in Broadband market Turkey.

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